The 15th International Logistics and Supply Chain Congress

"Big Data Analytics in Logistics and Supply Chain"

October 19-20, 2017 | Istanbul

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Previous Congresses

Date	Name	Conference theme	Local University	Foreign University(ies)
June 30-July 1, 2003	I. International Logistics Congress	–	BAU	RMU ROBERT MORRIS
November 2-3, 2004	II. International Logistics Congress	Developing Value Networks through Logistics and Transport	Dokuz Eylül Üniversitesi	CITY
October 23-24, 2005	III. International Logistics and Supply Chain Congress	Logistics and Supply Chain Management in a Globalizing World	Galatasaray Üniversitesi	PANTHÉON SORBONNE
November 29-30, 2006	IV. International Logistics and Supply Chain Congress	The Era of Collaboration Through Supply Chain Networks	İzmir University of Economics	
November 8-9, 2007	V. International Logistics and Supply Chain Congress	Logistics Bridges on Supply Chain	OKAN ÜNİVERSİTESİ	berlin
November 6-7, 2008	VI. International Logistics and Supply Chain Congress	High-Speed Flow of Money Material and Information	İstanbul Bilgi Üniversitesi	HNU
November 5-6, 2009	VII. International Logistics and Supply Chain Congress	Creating Difference in Information Era via Value Chains	Yıldız Teknik Üniversitesi	
November 4-5, 2010	VIII. International Logistics and Supply Chain Congress	Trade and Freight: From Soil To Consumer		ZLC
October 27-29, 2011	IX. International Logistics and Supply Chain Congress	International Retail Logistics in the Value Era	YAŞAR UNIVERSITY	MICHIGAN STATE UNIVERSITY

November 8-9, 2012	X. International Logistics and Supply Chain Congress	Sustainability of International Logistics Systems and Supply Chain in an era of Global Crisis		
November 7-9, 2013	XI. International Logistics and Supply Chain Congress	Managing Opportunities and Threats in Supply Chain	-	
October 30-31, 2014	XII. International Logistics and Supply Chain Congress	Supply Chain of the Future		
October 22-23, 2015	XIII. International Logistics and Supply Chain Congress	Maritime Logistics: The New Ports of Turkey	-	
December 1-2, 2016	XIV. International Logistics and Supply Chain Congress	Green Logistics and Supply Chains		
October 20-21, 2017	**XIV. International Logistics and Supply Chain Congress**	**Big Data Analytics in Logistics and Supply Chain**		

Plenary Speakers

Surendra M. GUPTA

Surendra M. Gupta, Ph.D., P.E. is a Professor of Mechanical and Industrial Engineering and the Director of the Laboratory for Responsible Manufacturing, Northeastern University. He received his BE in Electronics Engineering from Birla Institute of Technology and Science, MBA from Bryant University, and MSIE and Ph.D. in Industrial Engineering from Purdue University. He is a registered professional engineer in the State of Massachusetts. Dr. Gupta's research interests span the areas of Production/Manufacturing Systems and Operations Research. He is mostly interested in Environmentally Conscious Manufacturing, Reverse and Closed-Loop Supply Chains, Disassembly Modeling and Remanufacturing. He has authored or coauthored ten books and well over 500 technical papers published in edited books, journals and international conference proceedings. His publications have received over ten thousand citations from researchers all over the world in journals, proceedings, books, and dissertations. He has traveled to all seven continents viz., Africa, Antarctica, Asia, Australia, Europe, North America and South America and presented his work at international conferences on six continents. Dr. Gupta has taught over 150 courses in such areas as operations research, inventory theory, queuing theory, engineering economy, supply chain management, and production planning and control. Among the many recognitions received, he is the recipient of outstanding research award and outstanding industrial engineering professor award (in recognition of teaching excellence) from Northeastern University as well as a national outstanding doctoral **dissertation advisor award.**

Kishore POCHAMPALLY

Kishore Pochampally is a Professor of Quantitative Studies, Operations and Project Management at Southern New Hampshire University (SNHU) in Manchester (NH). His prior academic experience is as a Post-doctoral Fellow at Massachusetts Institute of Technology (M.I.T.) in Cambridge (MA). He holds M.S. and Ph.D. in Industrial Engineering from Northeastern University in Boston (MA) and a B.E. in Mechanical Engineering from National Institute of Technology in India.

Kishore teaches lean six sigma, business statistics/analytics, project management, and operations management, He consistently receives outstanding student evaluations, and has been nominated twice (finalist) for the teaching excellence award at SNHU.

Kishore has authored numerous technical papers for international journals and conference proceedings. His research work has been cited by other researchers on 6 continents. He has also published 4 books, in the fields of six sigma, reliability analysis, supply chain design, and design of experiments.

Kishore is a Six Sigma Black Belt (ASQ), Project Management Professional (PMP®), and Certified Analytics Professional (CAP®). He conducts corporate workshops on lean six sigma and project management, and trains professionals for the PMP® exam and six sigma green/black belt exams.

Emel AKTAŞ

Dr Emel Aktas is a Senior Lecturer in Logistics and Supply Chain Management at Cranfield School of Management. She specialises in mathematical modelling and decision analysis with applications in the transport, retail, and manufacturing sectors.
Her recent research focuses on food supply chain management, with one project (SAFE-Q) on minimising waste in the food supply chains and another (U-TURN) on logistics collaboration practises for distribution of food in the cities.
Her work has appeared in European Journal of Operational Research, International Journal of Production Economics, and Computers and Human Behaviour.

Elif KONGAR

Dr. Elif Kongar is a Professor of Technology Management and Mechanical Engineering, and Chair of the Technology Management Department at the School of Engineering, University of Bridgeport (UB). During her tenure at UB, she established research and graduate concentrations and coursework in several areas, including simulation and modeling, service management and engineering, and economic and environmental sustainability.
Her main area of research is economically and environmentally sustainable waste recovery systems and operations. She also works on projects that aim at increasing female participation in engineering disciplines and at improving K-12 STEM, undergraduate and graduate engineering education programs. She has founded the Sustainable Energy and Environment Laboratory while leading the development of blended and distance learning curricula at the department. She supervises several M.S. and Ph.D. students who participate in the research conducted in the Laboratory.
Dr. Kongar is the author of numerous journal and conference papers, the recipient of several research grants within her scholarly areas, and has presented her work at various national and international conferences.
Prof. Kongar received her BS and MS degrees in industrial engineering from Yildiz Technical University, and PhD degree in industrial engineering from Northeastern University. Before joining the University of Bridgeport, Dr. Kongar was a Visiting Researcher in the Center for Industrial Ecology at Yale University. She also served as the Coordinator and Lecturer of the Logistics certificate program at Yildiz Technical University where she held an Assistant Professor position.
She is a member of the ASEE, SWE, the Scientific Research Society (Sigma Xi), the Industrial Engineering Honor Society (Alpha Pi Mu), the Phi Beta Delta Honor Society and the Phi Kappa Phi Honor Society. Professor Kongar is the recipient of the Connecticut Technology Council (CTC) 2014 Women of Innovation® award.

Program at a Glance

Registration will be open from 9:00AM to 4:00PM Day 1, and 9:30AM to 4:PM on Day 2 at the lobby of Building 4.

Day 1: October 19, 2017 Thursday

10:00 - 10:30	**Opening Cerenomy** *B4.Theatre Hall*				
10:30 - 11:30	**Supply Chain Management** (Surendra M. GUPTA) *B4.Theatre Hall*				
11:30 - 12:15	**Coffee Break** *B4.Theatre Hall Foyer*				
12:15 - 13:15	**Sustainable waste recovery systems and operations** (Elif KONGAR) *B4.Theatre Hall*				
13:15 - 14:00	**Lunch**				
14:00 - 15:30	**Parallel Sessions**				
	Lectures I	**Big Data Analytics in Logistics**	**Other Topics in Logistics and Supply Chains**	**Social Responsibility in Logistics and Supply Chains**	**Sustainability in Logistics and Supply Chains**
	B4.TH	B5.407	B5.408	B5.413	B5.414
15:30 - 15:45	**Coffee Break** *B4.Theatre Hall Foyer*				
15:45 - 17:45	**Parallel Sessions**				
	Lectures II	**Best Practices in Logistics and Supply Chains**	**Green Logistics and Supply Chain Management**	**Other Topics in Logistics and Supply Chains**	**Transportation and Warehouse Management**
	B4.TH	B5.407	B5.408	B5.413	B5.414

Day 2: October 20, 2017 Friday

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(Kishore POCHAMPALLY)
B4.Theatre Hall</td></tr>
<tr><td>11:30 - 12:00</td><td colspan="5">Coffee Break
B4.Theatre Hall Foyer</td></tr>
<tr><td>12:00 - 13:00</td><td colspan="5">Food Supply Chain Management
Emel AKTAŞ
B4.Theatre Hall</td></tr>
<tr><td>13:00 - 14:00</td><td colspan="5">Lunch</td></tr>
<tr><td rowspan="3">14:00 - 15:30</td><td colspan="5">Parallel Sessions</td></tr>
<tr><td>Lectures III</td><td>Service Supply Chains</td><td>Transportation and Warehouse Management</td><td>Retail Logistics and Supply Chains</td><td>Sustainability in Logistics and Supply Chains</td></tr>
<tr><td>B4.TH</td><td>B5.407</td><td>B5.408</td><td>B5.413</td><td>B5.414</td></tr>
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<tr><td rowspan="3">15:45 - 17:45</td><td colspan="5">Parallel Sessions</td></tr>
<tr><td>Logistics 4.0</td><td>Innovation and Technology Management</td><td>Other Topics in Logistics and Supply Chains</td><td>Other Topics in Logistics and Supply Chains</td><td>Transportation and Warehouse Management</td></tr>
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Thursday, October 19th

10:30-11:30	Plenary Session **Supply Chain Management** Surendra M. GUPTA Forward supply chains consist of all activities required to transform virgin materials into consumer-requested goods. Reverse supply chains (RSC) consist of a series of activities required to collect used products from consumers and reprocess them to either recover their leftover market values or dispose of them. Taken together, they form closed-loop supply chains (CLSC). It has become common for companies involved in the forward (traditional) supply chain to also carry out collection and reprocessing of used products (reverse supply chain). Strict environmental regulations and diminishing raw material resources have intensified the importance of reverse supply chains at an increasing rate. In addition to being environment friendly, effective management of reverse supply chain operations leads to higher profitability by reducing transportation, inventory, and warehousing costs. Moreover, reverse supply chain operations have a strong impact on the operations of a forward supply chain such as occupancy of storage spaces and transportation capacity. The introduction of reverse supply chains has created many challenges in the areas of network design, transportation, selection of used products, selection and evaluation of suppliers, performance measurement, marketing-related issues, end-of-life (EOL) alternative selection, remanufacturing, disassembly, and product acquisition management to name a few. This presentation will highlight the main challenges of reverse supply chains and will provide an overview of a variety of techniques that have been adopted to address these challenges and opportunities for future research.
11:30-12:15	**Coffee Break**
12:15-13:15	Plenary Session **Sustainable Waste Recovery Systems and Operations** Elif KONGAR In a struggle between humankind and nature, nature tends to win. Thus, scientific research on new ways to reduce the environmental impact of anthropogenic systems is crucial for the well-being of women, children and men globally. This plenary session explores new ways to preserve and restore natural resources, alternative energy sources and different types of alternative energy, and how to regain the value embedded in waste. This plenary session provides an overview of issues that concern environmental sustainability and presents the current environmentally conscious research activities and collaborations within and outside the School of Engineering at the University of Bridgeport. Triple bottom line considerations that involve economically and environmentally solid and efficient reverse logistics and supply chain operations are detailed. Special emphasis is given to electromechanical products, which fall somewhere in between highly efficient and highly responsive products that constitute a majority of manufactured goods. Electrical and electronic equipment (EEE), which is the largest growing waste stream, is investigated in detail. Future directions for research and development are also provided highlighting Big Data's role in waste recovery and recycling research.
13:15-14:00	**Lunch**

19Th 14:00-15:30	Session 3A **Big Data Analytics in Logistics**	Session Chair: Kıvanç ONAN Room: B5.407
	Kivanc Onan **Technology Related Logistic Trends and Technology Usage in Humanitarian Logistics**	
	Esra Yaşar and Tuba Ulusoy **Extracting Value from the Big Data in Supply Chain: a Review of Applications**	
	Seyhan Teoman and Füsun Ülengİn **The Impact of Business Analytics Applications on Supply Chain Performance: a Literature Review**	
	Neslihan Turguttopbas and Nurcan Özyazıcı Sunay **A New Era in Supply Chain Management : Big Data Capabilities**	
19Th 14:00-15:30	Session 3B **Other Topics in Logistics and Supply Chains**	Session Chair: Gülçin Büyüközkan Room: B5.408
	Orhan Feyzioglu, Celal Alpay Havle and Gulcin Buyukozkan **Airline Service Quality Analysis by Using Fuzzy Cognitive Map Approach**	
	Oluwatoyin Osundiran and Leila Goedhals-Gerber **The Supply Chain of Relief Materials: a Guideline for Container Ports in Sub-Saharan Africa**	
	Senay Oğuztimur **Logistics Hub: a Magic Wand in Regional Plan Documents in Turkey**	
	Tuğçe Dabanlı and Derya Eren Akyol **Cooperative Game Theory in Supply Chain Management**	
19Th 14:00-15:30	Session 3C **Social Responsibility in Logistics and Supply Chains**	Session Chair: Surendra Gupta Room: B5.413
	Bandar Alkhayyal and Surendra Gupta **The Impact of Carbon Emissions Policies on Reverse Supply Chain Network Design**	
	Merva Dinç **Design of Reverse Logistics Network for Waste Tires with an Application in Turkey**	
	Buse Solmaz, Demet Yılmaz and Hüseyin Selçuk Kılıç **Reverse Logistics Network Design of Waste Batteries in Turkey**	
	Eren Şallı and Peral Toktaş Palut **Supplier Selection and Collaboration for Humanitarian Relief Supply Chains**	

19Th 14:00- 15:30	Session 3D **Sustainability in Logistics and Supply Chains**	Session Chair: Elif Kongar Room: B5.414
	Gazi Murat Duman and Elif Kongar **Combining Grey-AHP and Grey-TOPSIS Methods for Green Supplier Selection**	
	Tümay Yavuz **An Analysis for Project Logistics Opportunities and Challenges in Renewable Energy Projects in Turkey**	
	Omer Soner and Metin Celik **Conceptualizing Initial Framework of an Advanced Maritime Research to Conduct Ship Performance Monitoring via Statistical Learning Approaches**	
	Liangchuan Zhou and Surendra Gupta **Pricing Decisions for New and Remanufactured Products with Multiple Generations in a Dual-Channel Supply Chain**	
19Th 14:00- 15:30	Session 3E **Lectures**	
	Füsun Ülengin **Lojistik Yönetimininde İş Analitiği**	
	Mehmet Tanyas **Depo Yönetimi**	
15:30- 15:45	**Coffee Break**	
19Th 15:45- 17:45	Session 4A **UND Special Session: Best Practices in Logistics and Supply Chains**	Session Chair: İlker Topcu Room: B5.407
	Olcay Polat, Ömer Faruk Ünal, Leyla Özgür Polat and Aşkıner Güngör **An Integrated Forward-Reverse Logistics Network Design for Electrolytic Copper Conductor Reel Distribution**	
	Mehmet Kart, Tümay Yavuz and Seyithan Yıldız **Digital Transformation of Sales and Operations Planning in B2B Environment**	
	Irmak Daldır and Ömür Tosun **Comparison in Automotive Sector**	
	Bora Çekyay, Mine Işık, Füsun Ülengin, Özgür Kabak, Ilker Topcu, Ozay Ozaydin, Peral Toktas Palut, Sule Onsel Ekici and Burcin Bozkaya **Logistics Process Improvement of Kapıkule Border Crossing**	

19Th 15:45-17:45	Session 4B **Green Logistics and Supply Chain Management**	Session Chair: Emel Aktaş Room: B5.408
	Emel Aktas, Michael Bourlakis and Dimitris Zissis **Grocery Last Mile Distribution: Results from the U-TURN Pilot 3**	
	Leyla Özgür Polat and Aşkıner Güngör **A Closed-Loop Supply Chain Network Design for WEEE Including Refurbishing Decisions**	
	Yildiz Şahin, Pinar Yıldız Kumru and Öznur Ergül **Supplier Evaluation with Fuzzy Moora Method in Green Supply Chain**	
	Belkız Torğul, Ahmet Peker and Turan Paksoy **A Hybrid Fuzzy Multi Criteria Decision Making Approach for Multi Objective Supplier Selection**	
	Önder Belgin, İsmail Karaoğlan and Fulya Altıparmak **An Exact Algortihm for Two-Echelon Vehicle Routing Problem with Simultaneous Pickup and Delivery**	
19Th 15:45-17:45	Session 4C **Other Topics in Logistics and Supply Chains**	Session Chair: Çiğdem Kadaifçi Room: B5.413
	Veysel Tatar and Meriç Burçin Özer **The Future of Supply Chain Management in the Cloud Computing**	
	A.Zafer Acar and Pınar Gürol **Employees' Technology Usage Adaptation Impact on Companies' Logistics Service Performance**	
	Yasemin Kocaoglu, Batuhan Kocaoglu and Alev Taskin Gumus **Supply Chain Optimization Studies: Literature Review and Classification**	
	Mehmet Tanyaş and Atiye Tümenbatur **Producer Selection Model on the Supplier Portal of Agricultural Products –Fuzzy Ahp**	
	Mehmet Tanyaş, Umut Rıfat Tuzkaya and Atiye Tümenbatur **Logistic Center Design Methodology: Malatya Application**	

19Th 15:45-17:45	Session 4D **Transportation and Warehouse Management**	Session Chair: Mehmet Tanyaş Room: B5.414
	İlknur Yardımcı and Mehmet Tanyaş **A Research on the Examination of New Approaches in Transportation Sector**	
	Funda Samanlioglu, Sila Abali and Ozlem Bayraktar **Electric Vehicle Charging Stations and Charger Type Decisions in Istanbul**	
	Nihat Engin Toklu, Seda Yanık and Roberto Montemanni **The Traveling Salesman Problem Under Dynamic Uncertainty**	
	Hasibe İmamoğlu, Büşra Binici, Hüseyin Selçuk Kılıç, Nurgül Bora and Gizem Berkdemir **A Mathematical Model for Space Utilization Improvement in Warehouses**	
	İlhan Atik **Air Cargo Transportation and Evaluation of Situation in Turkey**	
19Th 15:45-17:45	Session 4E **Lectures**	
	Batuhan Kocaoğlu **Satış ve Operasyon Planlama**	
	Gülçin Büyüközkan **Tedarik Zinciri 4.0**	

Friday, October 20th

10:30-11:30	Plenary Session **Big Data** Kishore POCHAMPALLY The panel speech begins with discussion of several examples of how supply chains are making new decisions today by utilizing "big data" that is readily available. These decisions range from what to print on the back of the receipt at a gas/petrol station to how many nurses to schedule at a hospital on a Friday night. Then, an application of logistic regression and maximum likelihood estimation to predict a supplier's efficiency is presented. This example considers average machine age and average number of shifts per week as the independent factors. Finally, a real-world example of how a large supply chain can use chi-squared testing to verify association between retail location and sales of a product stock-keeping-unit (SKU), is illustrated.
11:30-12:00	**Coffee Break**
12:00-13:00	Plenary Session **Food Supply Chain Management** Emel AKTAŞ The food sector has economic and political significance for all countries. A highly fragmented and heavily regulated sector, it has become increasingly complex owing to globalisation and geographical decoupling of production and consumption activities. In this talk, an overview of global food flows is presented using publicly available data. Comparative analyses are made between Turkey and the UK with focus on food retail. A relevant concept, food security is unpacked and performance of countries in food security is reported. The interrelations between food, water, and energy systems are highlighted. The talk concludes with opportunities and future research directions in logistics and supply chain management for the food sector.
13:00-14:00	**Lunch**

20th 14:00-15:30	Session 7A **Service Supply Chains**	Session Chair: Prem Prakash Mishra Room: B5.407
	Bengisu Yavuzyilmaz, Fatma Jeddah Hasabubaba, Işılay Talay Değirmenci and Vivienne Joan Wildes **Food Waste Management in Hotels**	
	Prem Prakash Mishra **Algorithmic Approach to Optimization of Queued Commodity Flow Through Critical Path with Time-Cost Analysis**	
	G.Nilay Yücenur, Bora Üreden, Metin Demirci and Yavuz Dönmez **Evaluation of Suppliers for Risky Spaces in Construction Projects Wth Ahp and Anp Under Fuzzy Environment: Case from Istanbul**	
	Mohamed El-Mehalawi **Project Manufacturing as a Phase in Industrial Project Supply Chain**	
20th 14:00-15:30	Session 7B **Transportation and Warehouse Management**	Session Chair: İlhan Atik Room: B5.408
	Egemen Berki Çimen, Ömer Çelepçıkay and Caner Okutkan **Low Volume Store Planning for Workload Balancing and Truckload**	
	Safak Kiris, Derya Deliktas and Ozden Ustun **Order Picking Problem in a Warehouse with Bi-Objective Genetic Algorithm Approach: Case Study**	
	Gulcin Buyukozkan and Esin Mukul **Smart Transportation Strategy Selection for Logistics Companies**	
	İlhan Atik **Investigation of Cost Concept in Turkey for Air Cargo Management**	
20th 14:00-15:30	Session 7C **Retail Logistics and Supply Chains**	Session Chair: Batuhan Kocağolu Room: B5.413
	Aycan Kaya, İlkan Reyhanoğlu, Emre Ordulu and Ferhan Çebi **An Integrated Approach for Multi-Echelon Inventory Management Problem**	
	Gizem Ilhan, Ceren Eroglu, Zehra Duzgit and Ayhan Ozgur Toy **Access Point Location Selection Problem for a Logistics Company**	
	Seyithan Yıldız and Batuhan Kocaoğlu **Creating Product Groups and Aggregating SKUs for Dairy Products**	
	Batuhan Eren Engin and Turan Paksoy **An Environmentally Conscious Multi-Objective Weber Problem for Green Location and Distribution Planning: a Fuzzy Weighted Additive Approach**	

20th 14:00-15:30	Session 7D **Sustainability in Logistics and Supply Chains**	Session Chair: Ahmet Balcioglu Room: B5.414
	Fatih Tüysüz and Nurdan Yıldız **A Simulation Based Multi-Criteria Approach for the Analysis of Sustainability Factors in Supply Chains**	
	Ahmet Balcioglu **Assessing the Effect of Relocating Urban Distribution Centers on Goods Movement in an Urban Context - a Modeling Approach for Decision Makers**	
	Cagatay Kandemir and Metin Celik **Application of EFQM Excellence Model to Review the Organizational Structures in Turkish Ship Recycling Industry**	
	Muharrem Ata and Jbid Arsenyan **Green Packaging: a Literature Review**	
20th 14:00-15:30	Session 7E **Lectures**	
	Umut Tuzkaya **Taşımacılık Yönetimi**	
	Özgür Kabak **Tedarik Zincirinde Optimizasyon**	
15:30-15:45	**Coffee Break**	
20th 15:45-17:45	Session 8A **Innovation and Technology Management**	Session Chair: Özay Özaydın Room: B5.407
	Emine Es Yurek and H. Cenk Ozmutlu **Analysis of Traveling Salesman Problem with Drones Under Varying Drone Speed**	
	İlknur Yardımcı and Mehmet Tanyaş **Correct Integration of Multiple Channels with Omnichannel Perspective**	
	Şermin Şirin Fındık, Mehtap Dursun and Nazli Goker **Business Process Reenginering for the Central Sterilization Unit**	
	Ammar Alqahtani and Surendra Gupta **Remanufacturing Industry 4.0**	
	Louis Hickman and Mesut Akdere **Information Technology Leadership: Implications for Innovation**	

20th 15:45-17:45	Session 8B **Other Topics in Logistics and Supply Chains**	Session Chair: Umut Tuzkaya Room: B5.408
	Umut Tuzkaya, Gülfem Tuzkaya, Büşra Yılmazer and Zeynep Tuğçe Kalender **A Logistics Allocation Model for Freight Villages: a Case Study for Turkey**	
	Erhan Altıntaş and Tuncay Özcan **Sales Forecasting by Using Intermittent Demand Models in E-Retailing**	
	Mehmet Tanyaş and Mehmet Aziz Çimtay **City Logistic and Lezs: Situation in Turkey**	
	Irmak Daldır and Ömür Tosun **Determining the Performance Criteria for Warehouse and Their Importance Sequence**	
20th 15:45-17:45	Session 8C **Other Topics in Logistics and Supply Chains**	Session Chair: Edyta Klosa Room: B5.413
	Niyazi Ozkan and Fahrettin Eldemir **Single Hub Capacity Allocation Model for Air Cargo Firms**	
	Edyta Klosa **The Attitudes Towards Development of Logistics Personnel Through Trainings in Polish Companies Representing Different Sizes and Types of Business Activity**	
	Merve Güler, Ferhat Duran and Gulcin Buyukozkan **Business Intelligence System Selection for Logistics Companies**	
	Buğra Bayender and Ahmet Balcıoğlu **Application of a Supplier Selection and Evaluation in Spare Parts Sector Using an Analytic Hierarchy Process Method**	
20th 15:45-17:45	Session 8D **Transportation and Warehouse Management**	Session Chair: Bora Çekyay Room: B5.414
	Fahrettin Eldemir and Mustafa Egemen Taner **Ant Colony Metaheuristic for Quay Crane Sequencing in Container Terminals**	
	Serhat Saylam, Haldun Süral and Melih Çelik **The Two-Picker Order Picking Problem**	
	Olcay Polat, Seckin Aydin, Leyla Polat and Can B. Kalayci **A Parallel Variable Neighborhood Search Based Solution Approach to Design the Service Network for a Beverage Distribution Company**	
	Derya Deliktas and Ozden Ustun **Bus Stop Selection for Employees with Bi-Objective Particle Swarm Optimization Approach: Case Study**	

20th 15:45-17:45	Session 8E **Logistics 4.0**	Session Chair: Peral Toktaş Palut Room: B5.409
	Elif Koç Tekin, Alper Kılıç and Demir Ali Akyar **Perceptions and Barriers in Implementing Industry 4.0 Conceptions in Container Terminals**	
	Sinan Apak, Fulya Taşel and Burak Küçük **A Literature Review of Digitalized Supply Chain and Logistics 4.0**	
	Handan Hacıalioğlu and Erkut Akkartal **Supply Chain 4.0 Implementations in Industry 4.0**	
	Elvan Deniz, Özgür Yalçınkaya and Gonca Tunçel Memiş **Simulation Modelling of Crane Double Cycling Strategy in Marine Terminal Logistics**	

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PROJECT MANUFACTURING AS A PHASE IN INDUSTRIAL PROJECT SUPPLY CHAIN

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Abstract *– The value spent through supply chain activities in industrial projects represent around 70% of the project value. Industrial or EPC (engineering, procurement, and construction) projects rely heavily on procuring ETO (engineer to order) components. Examples of industrial projects are found in the industries of oil and gas, power generation, mining, pharmaceutical, etc. There are four main tasks in supply chain for these projects. The first task is design, the second is engineering in collaboration with the supplier, the third is fabrication of the parts, and the fourth is the delivery. This paper focuses on planning and controls of the fabrication task. This is the longest task in the supply chain phases. A typical industrial project has a good control over the other three phases but much less control over fabrication which results in many surprises before the product delivery.*

Key Words*: Engineer-to-Order, EPC Projects, Industrial Projects, Project Manufacturing*

Introduction

This paper presents and redefines the concept of project manufacturing that is based on a unique and temporary product. The paper examines the scheduling, sequencing, and resource pooling operations required for a plant dedicated to project manufacturing. A methodology for automating the creation of a schedule using the critical path method is outlined in the paper. An implementation is discussed to prove the usability of the proposed procedure. The goal of this procedure is twofold. The first is to integrate the manufacturing schedule with the rest of the project schedule which gives the project management team more control over the whole project including the manufacturing phase. The second is to introduce a new method for managing and resource loading in production plants dedicated to project manufacturing. That enables the production controls personnel to manage each project individually. In the same time, they combine all projects worked concurrently at the plant.

Project manufacturing or Engineer-to-Order (EtO) is known and practiced in the industry but not in a formal way. Project manufacturing is to produce or assemble one unit of each unique product. Although it is a manufacturing environment, it follows the definition of a project because of being temporary and unique. In mass production, there is a production or assembly line that produces thousands of units from a certain product. The methods used for production planning, scheduling, and controls of mass production cannot be employed to project manufacturing. Instead, a company that owns or operates manufacturing plants dedicated to manufacturing or assembly of projects use job-shop techniques to schedule and controls their production. These companies try to implement state of the art production process improvements that are designed mainly for production of high volume such as mass production or job-shop manufacturing.

Blevins [1] introduced the topic of project manufacturing in a very nice and simple way. He stated that the project manufacturing business has a set of islands and urged that they need to be integrated for a better planning and controls. Fox et al [2] introduced a comprehensive list of challenges and sources of complexity that face project manufacturing. Interested readers are encouraged to review Fox's article. Some of these challenges are:

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- Giving an authority to the customer. That is typical in project environments but not very helpful in scheduling project manufacturing.
- Change of priorities of individual customers makes the project manufacturing schedule to stop and resume several times during the lifecycle of the project.
- High number of components that are needed for the assembly of a single sub-product. For example a side wall of a boiler may need more than 100 tubes in different shapes and sizes.
- Components for the same sub-assembly may have a high variation in delivery times.

Abdelmaguid and Nassef [3] stated that the job shop scheduling problem (JSP) is a traditional decision making problem that is encountered in low volume–high variety manufacturing systems which are known as job shops. Although job-shop scheduling is dedicated for low volume manufacturing, it is still a good technique for repetitive products but not as good for a project manufacturing. Every final product and all of its components are totally different from any other product. Therefore, it is unwise to apply an approach for repetitive products into non-repetitive parts.

Another simple reason to examine project manufacturing problems is that manufacturing the product is one part of the whole project. Integrating production schedule with the rest of the project schedule will be a nightmare if production is scheduled using job-shop approach. Caron and Fiore [4] urged to find an innovative approach to integrate manufacturing and logistics with project management. Their approach was suitable back then before the popularity of the enterprise project management tools. On their study of construction project complexity, Bertelsen and Koskela [5] urged that using two different systems for project management and project production adds to both the complexity of the project and the uncertainty of the objectives.

Table 1 shows some differences between the repetitive production and project manufacturing. These differences are given to emphasize the need of a different method for scheduling and controlling project manufacturing.

Table 1: Difference Repetitive and Project Manufacturing

Category	Repetitive Manufacturing	ETO / Project Manufacturing
Products	Makes standard products	Products are unique
Pricing	Uses a price list	Estimates, quotes, and Bidding
Components per sub-assembly	Low number	High number
Inventory	Based on part number	No Inventory
Number of Engineering Changes	No or only a few	Significant
Value	Low value	Typically higher in value
Production routing	Standard	Customized for every product
Lead time	days or weeks	months or years
Shipping	Ships from finished goods	Ships from WIP(work-in-progress)
Progress measures	Cost variance from standard cost	Cost variance from Original budget

This paper presents an approach for scheduling and control of project manufacturing using the critical path method. The approach provides solutions to the two requirements of the project manufacturing business:

i. Integrating the fabrication schedule with the rest of the industrial project schedule. Usually, industrial or EPC projects have a detailed schedule for engineering and construction but no details for the supply chain activities. The proposed method provides all levels of details for procurement and fabrication activities.
ii. Managing the overall workload of the manufacturing plant using enterprise project controls systems. Workload is the collective demand on the plant facilities caused by concurrent projects ordered by different customers.

In fact, this approach has been implemented in a few plants dedicated to project manufacturing of heavy power generation products. The approach simplified the planning and controls that used to be performed using job-shop methodologies. It provided more flexibility in stopping the project and resuming it again.

The proposed system can be integrated with the manufacturing execution system of the plant. That will make it fully automated which can provide real time status of the project. If there are not enough capabilities to integrate the system with manufacturing execution systems, it can be implemented by itself and the initial schedule and its progress could be updated manually.

The rest of the paper is dedicated to the description of the system and how it is integrated with other systems. The description of how to use the system and to get the benefit from it is also outlined below.

Creating a Manufacturing Project Schedule

For every project or product, a unique routing sheet is always developed by the manufacturing engineering team. The routing sheet consists of a set of routing sheets for shippable products or subassemblies of the final product. Every shippable product is considered as a single node in the work breakdown structure (WBS) of the whole project. Each routing sheet at a WBS node consists of a set of work-orders. A work order describes the sequence of operations that are needed to produce a smaller subassembly. Products from work orders may be assembled using a set of operations described in another work order. A work order may have one or more operations.

Typically each operation in the routing sheet contains the following:

- operation duration
- labor class
- number of needed man-hours
- work center
- number of machine hours
- material being processed
- number of material units

In the critical path method (CPM) world, each operation can be considered an activity. Therefore, the routing sheet allows the creation of the activity list complete with its duration, labor resources, machine resources, and material resources. If the routing sheet is in electronic format, which is most probably the case, it can be easily converted into a list of activities in the project scheduling software. That activity list will be complete with all resources loaded. Moving activity data from the routing sheet into the scheduling system can be automated and can be performed in few moments even if the project is very large.

To have a complete schedule, one important feature is still missing. That is the activity sequence. Examining the workflow of project manufacturing, it is found that for every project or product, there is a unique engineering bill of material (EBOM) not a standard BOM. Knowing that each work-order represents a component or part in the product, the EBOM specifies the parent assembly of each subassembly. That kind of parent-child relationships, allows for generating activity sequencing. Consider the following example:

> Παρτ X ισ α συβασσεμβλψ οφ παρτ Δ. Παρτ X ισ ασσεμβλεδ βψ ωελδινγ παρτσ A ανδ B.□Παρτ A□ισ α 40 φεετ τυβε. Ιτ□νεεδσ□το□4 οπερατιονσ; χλεανινγ, μιλλινγ, βενδινγ, ανδ ηεατ τρεατμεντ. Παρτ B□ισ α φλανγε ανδ□νεεδσ ονλψ τωο οπερατιονσ; δριλλινγ ανδ□γρινδινγ.□Τηεν τηε σεθυενχε ωιλλ βε A1, A2, A3, A4, X1, X2, X3, Δ1.□Ιν παραλλελ, τηερε ωιλλ βε ανοτηερ σεθυενχε B1, B2, X1, X2, X3, Δ1□ασ σηοωνιν Φιγυρε 1.□□

Following that procedure, activity sequencing can be easily generated and automated. The WBS of the project should be recognized and followed during generating the activity list either manually or automatically. Imposing activity sequence on top of that will produce a rotated shape of the EBOM.

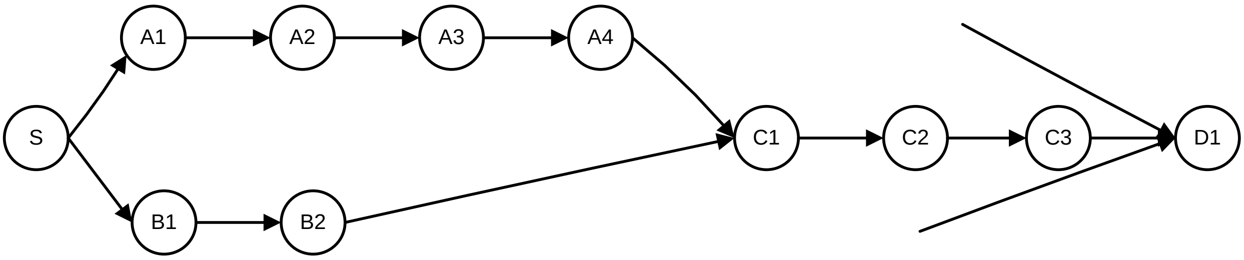

Figure 1: Activity Sequencing Example

These two steps generate the initial resource loaded manufacturing schedule of the project. It is generated using the CPM and can be easily integrated with the rest of the project schedule. The benefit of the integration is known to most people in the field of project scheduling. Any changes in the engineering schedule will affect the manufacturing schedule as soon as they are recorded. Although such a situation is not favorable in a manufacturing environment, it is the fact of life. Changes on engineering schedules and their reflections on manufacturing schedules are much easier to handle using the integrated schedule than having two different scheduling systems. However, these changes complicate the resource management of the manufacturing plant as shown below.

Figure 2 shows the flow of information to perform the procedure mentioned above. It is assumed that both the routing sheets and the EBOM are generated and posted into the ERP system of the performing organization. The two blocks in different color are assumed to be performed once in the lifetime of the system and then updated when changes happen. These are meant to build the global structures such organization chart and resource hierarchy of the manufacturing plant in the scheduling system.

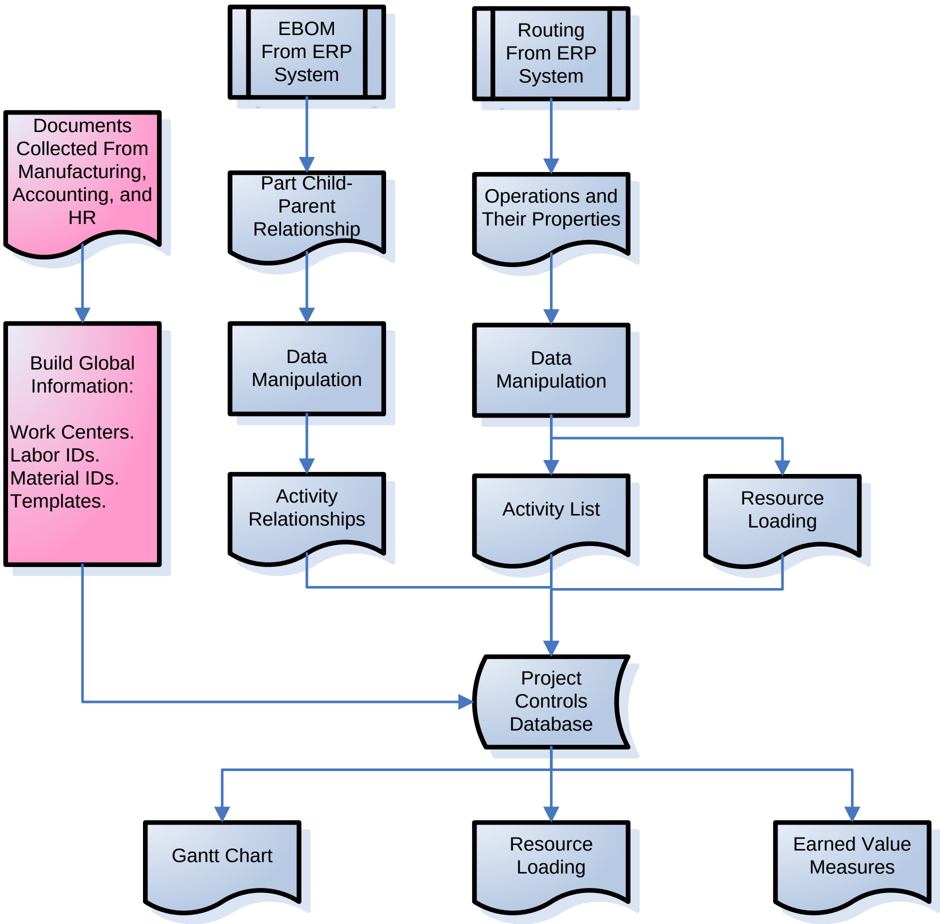

Figure 2: Process Data Flow

Updating the Manufacturing Schedule

In most manufacturing plants, there is a manufacturing execution system which collects actual information from the shop floor. The system collects real-time information about each operation in the routing sheet. It collects the following information:

- Operation start time and date
- Time elapsed on an operation
- Labor hours charged to an operation
- Machine hours charged to an operation
- Material consumed so far
- Number of units completed
- Operation finish time

A baseline based on the initial schedule should be generated for future comparison with the project progress. On a daily, weekly, or biweekly basis, the project schedule can be updated automatically by extracting the actual start date, actual duration, actual labor hours, actual machine hours, and actual material processed from the manufacturing execution system. If the process is automated, the update cycle might be daily. If it is performed manually the update cycle might me weekly or biweekly. The number of unites completed determines the physical or realistic percent complete of each activity. The earned value measures (EVM) can be employed with a great confidence since the percentage complete of the activity is based on a total objective measure. Therefore, the system will be able to report the project progress and more.

Suppose that the baseline states that the activity duration is 100 hours and it requires 200 labor-hours to bend 1000 tubes. Two workers will be working on this activity for 100 hours. After 5 working shifts, 40 hours of the duration are gone, 80 labor hours are charged, and 300 tubes are completed. Using the EVM, this activity is over budget and behind schedule. However, there is another conclusion that can be captured. It was assumed that each tube will be bent using 0.2 labor hours. The progress shows that each tube consumed 0.27 of labor hours. That concludes that there is a problem with the process efficiency. This is different from accelerating a construction or engineering activity to finish on time. The situation here is about the efficiency of the manufacturing process which should be corrected. The measures do not only give progress of the activity but also they report problems with the production process. Manufacturing management should pay attention to these problems.

Resource Loading for Project Manufacturing Plant

One of the biggest advantages of the enterprise control systems is the combination of resource requirements for different projects. Combining the demand on resources helps the manufacturing managers plan their resources and prioritize the workload. Figure 3 shows a requirement for milling mechanist role for all projects currently active in the enterprise database (that are the active projects in the plant). This helps the manager of the milling group prepare for the peak resource allocation on milling mechanist by training other workers. Those with a secondary role as milling mechanist will serve as primary worker when they are needed.

Another planning scenario for the manager of the milling department is when he is negotiating with the project managers to move some of the activities back and forth in order to get rid of the demand peak. Of course the project manager needs to consult with the manufacturing scheduler on the possible effects moving an activity will cause on the overall schedule due to the dependency of other activities.

Is it possible to find one crew so heavily over-allocated? Yes, it is. Project managers usually know their employees. They know who gets the job right from the first time, or can give the initial results fast, or works with minimal supervision, or has many years of experience. During the initial planning of the project, they ask to put that crew on their project team. The result an over-allocation of a certain crew while under-allocation of other crews. It is the responsibility of the functional manager to reallocate the extra load to other crews who can also perform the job. The functional manager can coach the less experienced resource to achieve the job efficiently. These resources work for the functional manager who is assumed to know most of the details of their work. By keeping a close eye on the load of each resource in the group, the resource manager can avoid the situation of over-allocation from happening.

Changes on the start date of the project or the start and finish of certain activities are imposed by the client or the engineering group. These changes will force the project and its resource load to move back and forth. That will make the requirements on resources dynamic and uncertain as noted by Wullink et al [6]. Although it complicates the resource management process, it reflects the real life. The proposed system of managing resources using the CPM may seem to oversimplify the situation but implementing it in a few plants proved more efficient than computational systems. The CPM gives the true picture to the resource managers and leaves the decisions to them. Computational methods make the decisions without human involvements. They are also data hungry.

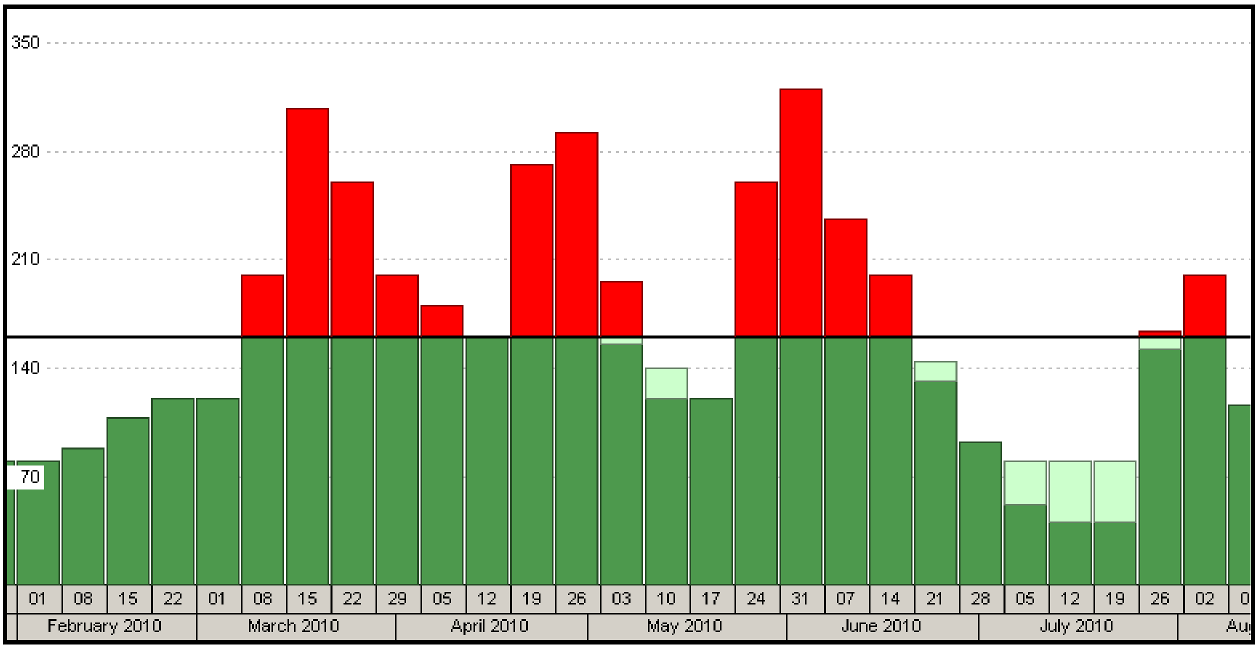

Figure 3: Role-Requirements Histogram

Managing all resources needed for all active projects in the manufacturing plant helps in *identifying bottlenecks*. Manufacturing projects use high value machines like an overhead crane, a mobile 100 ton crane, a large sized milling machine, etc. If such a machine is overloaded, it represents a bottleneck and everything else will be scheduled around it. To upgrade from one unit of that equipment, another unit should be added. Because adding one unit is so expensive and requires a big investment, it is important to make sure that both the added unit and the existing units are almost fully utilized. In a project manufacturing plant, most resources are always under loaded with the exception of one work center, which is always over loaded. A typical project uses only some of the work centers. However, one work center is being used by all projects that come to the plant. This is the over allocated machine. When a new project is assigned to the plant, it is scheduled based on the availability of the over allocated work center.

The author was helping the plant by implementing the concepts and tools of enterprise project manufacturing systems. The project/production controls team was used to allocating only human resources, but was advised to allocate all resources needed for all activities. They did so for a few months until they found that the over allocated work center was the bottleneck driving the schedule of everything else. Actually, this bottleneck causes more problems to the plant than the scheduling problems do. In a follow up visit to the plant, it was found that they only allocated and planned for the bottleneck work center, while not paying any attention to the rest of the resources. Although it sounds reasonable, it is not recommended to forget about the wasted hours of the under allocated resources.

To maximize the utilization of the under allocated resources, the plant is advised to acquire a second unit of work center similar to the one that is over allocated. However, with that investment, will the second machine be reasonably utilized? There is a need to optimize between the two factors to make the decision that is best for the organization. If there are many projects assigned to the plant, in order for the two units to be reasonably loaded, then the plant would go with the option of acquiring another unit. If this assumption is not true, they may study another solution to minimize the waste in the under allocated areas.

The proposed system provides a methodology to answering all of these questions and to generating different what-if scenarios. It provides a the big picture of the resource loading for the plant in a dynamic environment that can be apply the optimization methods to level resources or leave the task to the resource managers as described above. It also provides a tool to respond to customers about estimates and quotes for new projects. Knowing the current and projected resource load, plant management can determine when a new job will fit in the plant schedule. Although the estimate is not a clear answer as noted by Wullink et al (2004), every customer requires a time and cost quotation for their project.

Conclusions

The technique described in this paper is the automatic generation of the initial schedule and the automatic update and progress recording. To generate a detailed schedule for a large fabrication project, it takes at least three weeks from the planner to build it manually without loading resources. If resources are to be loaded into the schedule, it will consume additional two weeks and will not be accurate due to usual human errors. The new system generates the initial schedule loaded with resources in less than five minutes and gets the progress information in no more than two minutes per project. Further modification may enhance the system to reduce the processing time and allow a group of projects to run by batches. The proposed system makes use of the enterprise project portfolio management systems to manage the resource loading of the whole plant.

The proposed system facilitates integrating the fabrication schedule with the rest of the project schedule while enabling the resource management in the manufacturing plant. The system was implemented in two project manufacturing plants and proved effective in spite of its simplicity. The system does not use sophisticated computational methods but relies heavily on the use of CPM and the common sense. The simplicity of the system makes the manufacturing managers comfortable in using it which adds to its success in the implementations.

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SIMULATION MODELLING OF CRANE DOUBLE CYCLING STRATEGY IN MARINE TERMINAL LOGISTICS

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Abstract *−Crane double cycling is a quay crane operation strategy that minimizes an empty trip of the equipment involved in the vessel operation. From the perspective of quay crane, a quay crane unloads a container onto a horizontal transport vehicle, such as yard tractor, automated guided vehicle or straddle carrier. From the perspective of the transport vehicle, a vehicle delivers a loading container to a quay crane and instead of directly returning to the storage yard for the next loading container, the vehicle accesses another quay crane which can deliver an unloading container to the vehicle itself. The quay crane double cycling problem is a special case of the well-known quay crane scheduling problem, the main aim is to find a complete quay crane working schedule with its objective typically being the minimization of the makespan for the vessel operation, the minimization of the total completion time of quay crane, or the combination of both. In this study, the problem is studied via simulation modeling, which is one of the powerful analysis tools available for the design and operation of complex processes or systems. The data of the problem (crane, rubber tired gantry cranes service operation times and etc.) are collected from The Container Loading & Unloading Services of Izmir Port. A discrete event simulation model is developed by using Arena software to model port operations. The objective of the model is to decide a quay crane operation strategy that minimizing an empty trip (Crane, RTG and Truck service operation time) of the equipment involved in the vessel operation.*

Keywords *−Marine container terminals, Crane double cycling, Quay crane operation strategy, Simulation*

INTRODUCTION

The quay crane double cycling problem (QCDCP) is a special case of the well-known quay crane scheduling problem (QCSP), the main objective of which is to find a complete Quay Crane (QC) working schedule with its objective typically being the minimization of the makespan for the vessel operation. Furthermore, crane double cycling is a quay crane (QC) operation strategy that minimizing an empty trip (Crane, RTG and Truck service operation time) of the equipment involved in the vessel operation. From the perspective of QC, a QC unloads a container onto a horizontal transport vehicle, such as yard tractor (YT), automated guided vehicle (AGV) or straddle carrier (SC), and instead of returning the crane's empty spreader back to the ship, the QC picks up another container available from the shore to load into the ship. From the perspective of the transport vehicle, a vehicle delivers a loading container to a QC and instead of directly returning to the storage yard for the next loading container, the vehicle accesses another QC which can deliver an unloading container to the vehicle itself(Ku and Arthanari,2014). In this study, the problem is solved with simulation modeling. Simulation helps to improve the port operations and provides predictions of outcomes and performance measures. Different scenarios can also be tested in a simulation model and the results can be studied and analyzed. Also, the process of Container Loading & Unloading services of Izmir port's data such as (Crane, RTG service operation time) is considered for modeling and analyzing. A discrete event simulation model is developed using Arena to model generic port operations for the bottlenecks of the vessel operations.

MATERIALS AND METHODS

In the system, there are one quay crane, one truck and one vessel. The containers to be loaded/unloaded in vessel operation are in the size of 40 foot (2 TEU). The problem is solved with simulation modeling in ARENA (Pegden et al, 1990).

Following tools are used for simulating the container terminals system:
-Rockwell Arena Simulation Program for developing the simulation model
-Arena Input Analyzer for determining the probability distributions
-Arena Output Analyzer for verification/validation and output analysis

PROBLEM DEFINITION AND OBJECTIVES

The operations of the cranes on the assigned vessels involve the schedule that the cranes should follow when loading and unloading containers. Containers are then removed by cranes or other methods and sometimes exchanged by loaded or empty ones; loaded containers are either moved to storage area or container yard by trucks or rubber tired gantry cranes (RTG) or moved from one transportation method to another. Simulation studies are usually used to develop approaches for improving the performance of dynamic and complex systems like intermodal terminal ports.

The handled system has two main topics: Discharging (unloading) operations of containers and loading operations of containers. The flow chart of the container discharging process for the selected system is given in Figure1. According to this process, the flow chart of the container loading operation is depicted in Figure 2.

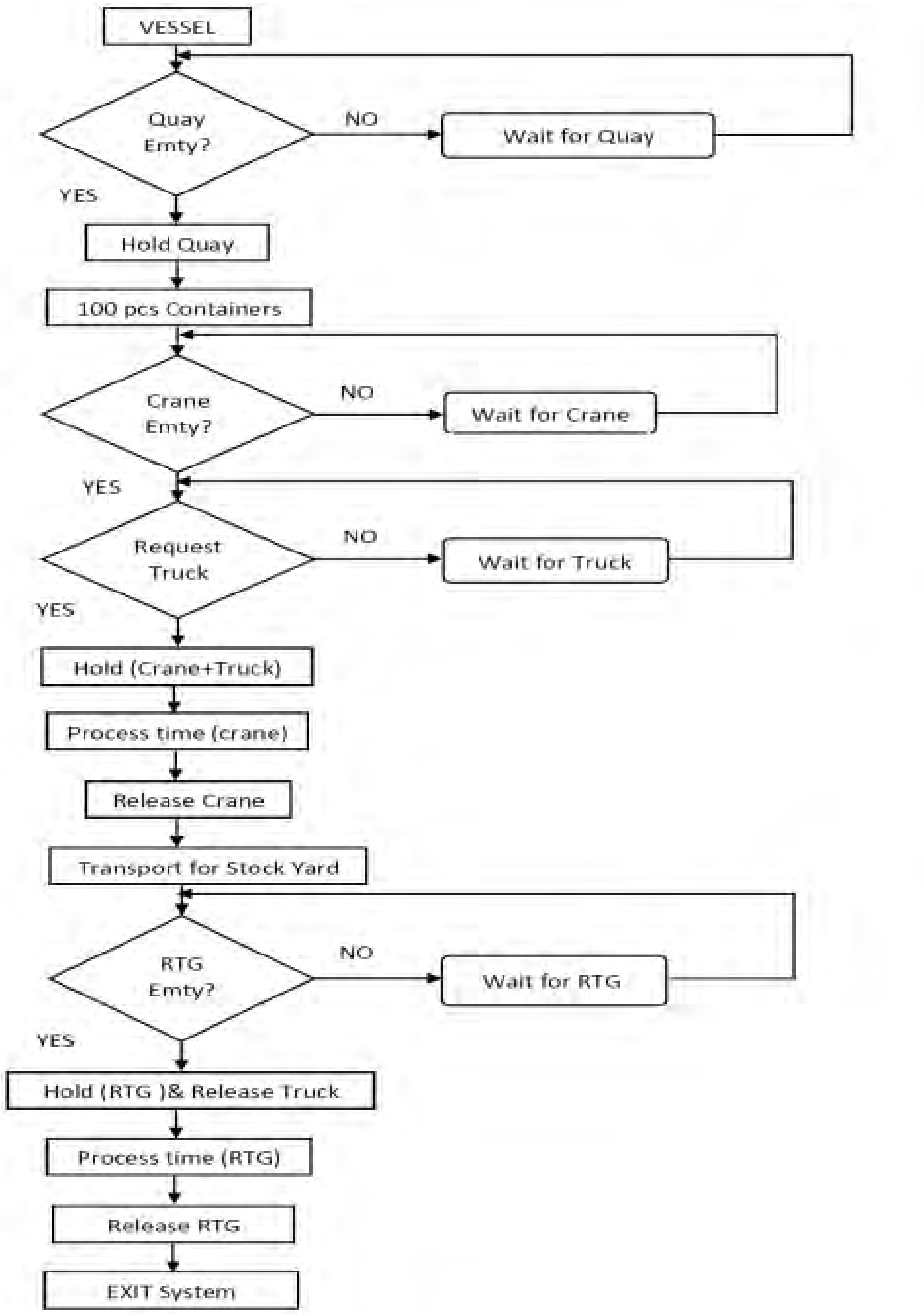

Figure 1. Flowchart of the container discharging process

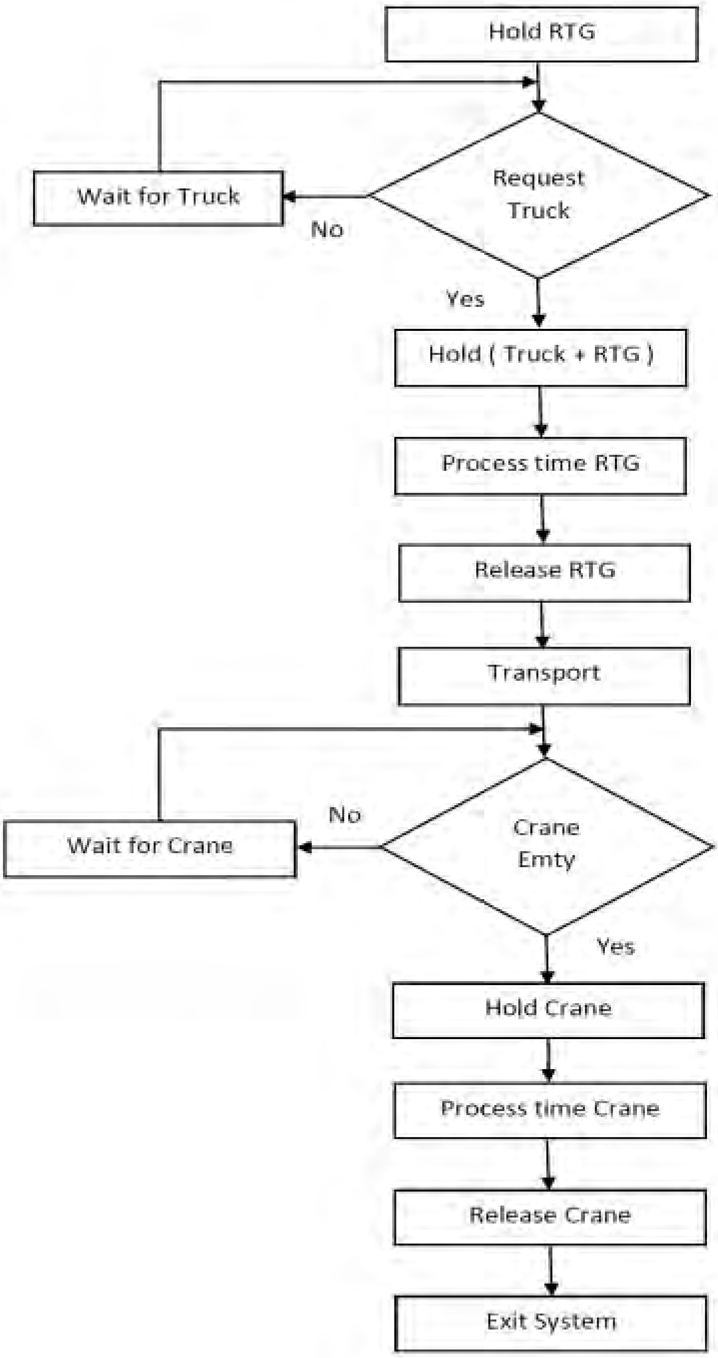

Figure 2. Flowchart of the container loading process

Three types of resources are defined in the simulation model. These are one Crane, one Quay and one RTG. Additionally, we have only one transporter (truck). Truck velocity is assumed as 20 km per hour. It is also assumed that vessel capacity is 100 pcs container. The process at the port starts by the arrival of one of the intermodal transporters, that is, vessel. When a vessel arrives to the terminal and seizes a Quay, quay crane is used to unload the vessel by moving the containers from the vessel board to the truck. The truck is usually available to receive containers from the crane. However if no truck is available, the crane will have to wait for an empty truck. The truck transports the containers to the storage area and parks in the assigned isle and waits for processing. A RTG transfers the container from the truck to the stack of containers. This process continues for several hours or a day until the vessel is emptied from all the containers that must be unloaded. After unloading the vessel, the loading process begins and follows the same steps previously explained but in a reversed way; the RTG transfers container from the container stack onto the truck, which travels to the vessel, and lastly the crane transfers the container from the truck to the vessel's board until the vessel is loaded with all the assigned containers before setting sail and departing the port.

STEPS OF THE CONTAINER SIMULATIONS MODEL

The purpose of the model

The purpose of the model (crane double cycling) is to determine a quay crane (QC) operation strategy that minimizes an empty trip of the equipment involved in the vessel operation.

Assumptions

-The service times of the Crane and RTG are collected by observations. The distributions of service operation times are determined by using Input Analyzer.
-There are one Crane, one RTG and one Truck for each container.
-Truck velocity is assumed as 20 km per hour.
-Data related to the process of container loading & unloading services of Izmir port such as (Crane, RTG service operation time) are used for modeling and analyzing.
-It is assumed that vessel capacity is 100 pcs container.

Elements and Blocks of the Simulation Model

Elements of the simulation model are given in Figure 3.In addition, Blocks of the model can be seen in Figures 4 through 6.

Attributes

TimeIn:it is defined to record loading & unloading service times of the containers and data by tallies element.

Resources

3 types of resources are defined in the simulation model. These are: Quay, Crane, RTG.

Queues

There are 6 types of queues in the simulation model: Quayq, Craneq, RTGq, Truckq, Craneqy, RTGqy, Truckqy.

Variables

For recording the data, variables (ks) are defined.

Dstats

It is defined to record the utilization of resources and also approximate number of containers in the queues.

Tallies

It is defined to record the overall flow times of containers and times spent of containers (loading & unloading) such as Overall Flow Time.

Outputs

Outputs element is included in the model to record and create an output file. This data will be used to compare the overall flow time of the simulation model.

Replicate

Replication number is determined as 10. The model is run through 8 hours (480 minutes).

Trace

Trace element is used for verification of the system.

Transport

Transporters element describes the operating characteristics of the transporters used in the model. Only one type of transporters (truck) is defined in the simulation model.

Distances

It is defined for the transporter's system map with travel distances between all stations.

Stations

The stations element defines information about the stations used in the model. These are: Loading station, Unloading station, Loading station.

Sequences

The sequences element defines some one or more station-visitation sequences.

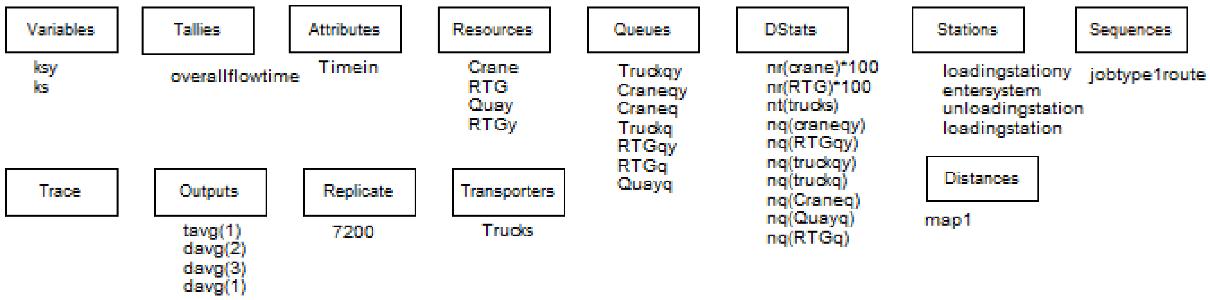

Figure 3. Elements of the model

Vessel/Entity arrivals are defined in the CREATE block. Once an entity (vessel) waits in quay queue, then it seizes quay with the SIEZE block. It spends time in the DELAY block with a distribution of Norm (30, 0.07). The enter system and NS are assigned with the ASSIGN block. An entity is converted from vessel to containers (100 pcs) with the DUBLICATE block. After joining the loading station, container seizes crane. It spends operation time with Norm (2.13, 0.05) in the DELAY block. Then it releases the Crane. The truck is requested for transportation from loading station to unloading station with REQUEST and after TRANSPORT blocks. The container join the RTG queue, seizes the RTG, spends operation time with Norm (3.99, 0.10), then it releases the RTG.

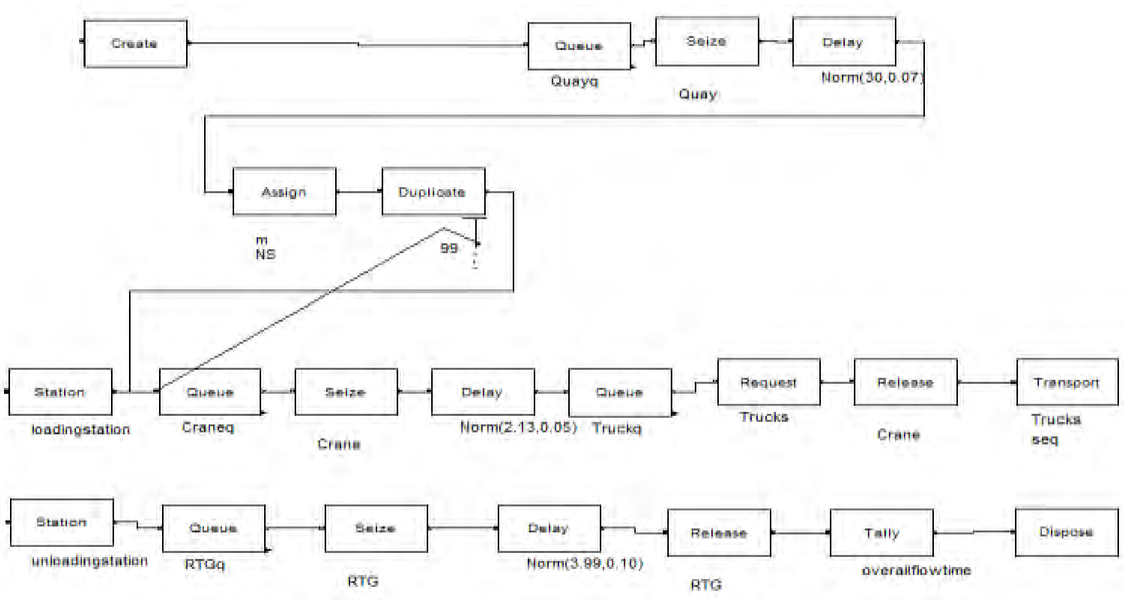

Figure 4. The models blocks 1(Unloading)

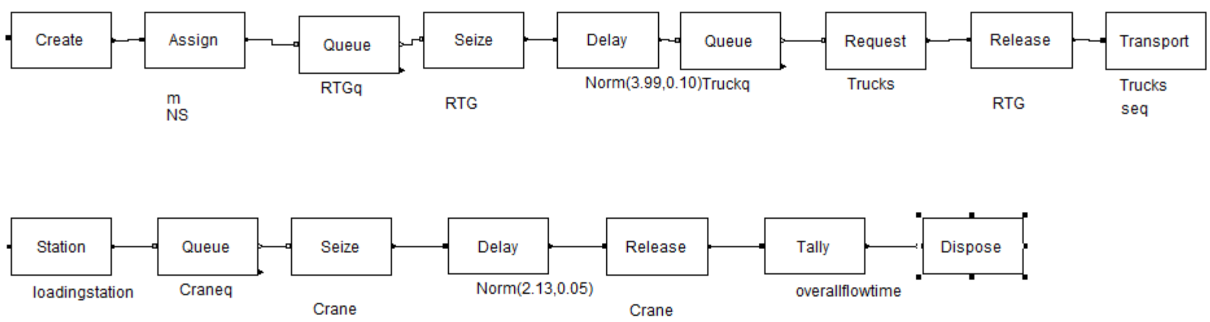

Figure 5. The models blocks 2 (Loading)

The variable (ks) is assigned with second ASSIGN block. After the BRANCH block, if 100 containers have been unloaded from the vessel, proceed to load the container into the vessel. If the number of containers is less than 100, container loading continues. The container join the RTGy queue, seizes the RTG, spend operation time with Norm (3.99, 0.10), then releases the RTG. Next, the truck is requested for transport from unloading station to loading station with REQUEST and after TRANSPORT blocks. After joining the loading station, container seizes crane. It spends operation time with Norm (2.13, 0.05) in the DELAY block. Then it releases the Crane. It is defined to record the overall flow times of containers and times spent of containers such as Overall Flow Time with TALLY block. Finally, the containers exit the system.

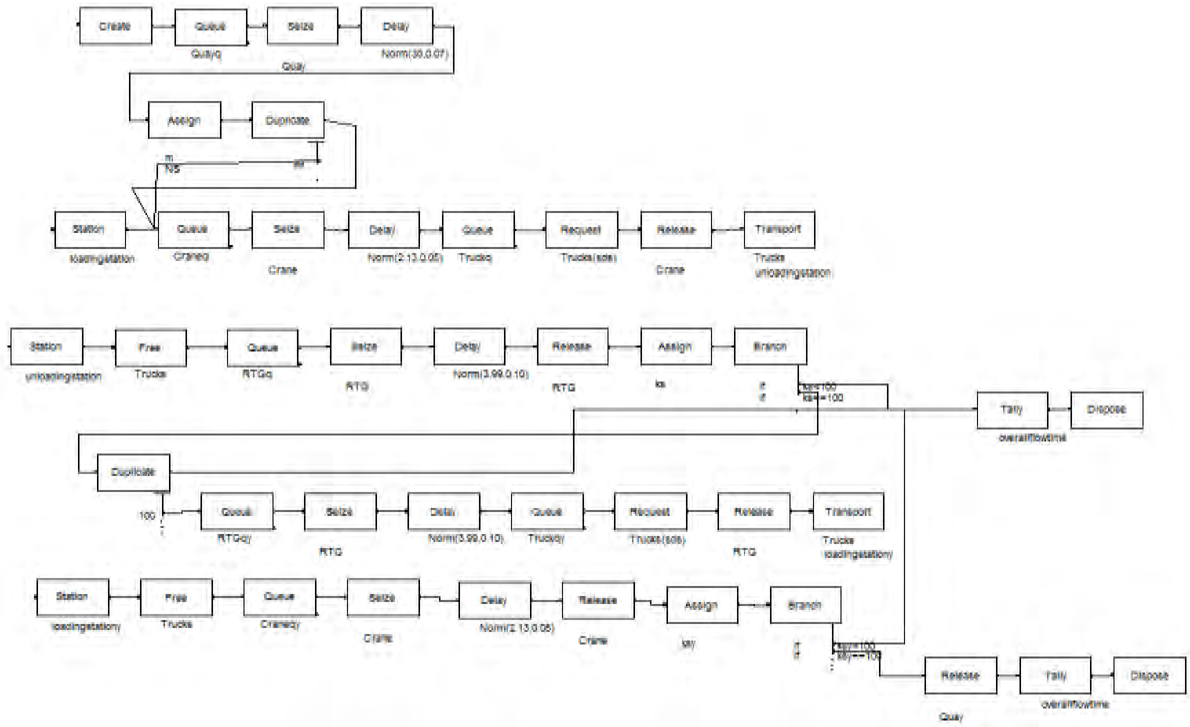

Figure 6. The models blocks 3 (Loading & Unloading)

Verification of the System

The TRACE element executes a simulation model by moving entities block by block through the model and is used for verification of the simulation model. Then, a constant number of entities are sent to the system and followed to check whether the entities flow between blocks as required. The output report is examined whether the results are reasonable or not.

RESULTS AND EVALUATION

The average Overall Flow Time is calculated as 50,906 minutes in one observation for the first simulation model. This duration is acceptable. The average Overall Flow Time is calculated as 39,029 minutes in one observation for the second simulation model. This duration is also acceptable.

Some statistics are calculated by DSTATS element in order to measure the system's performance: They are queue statistics (Quayq, Craneq, RTGq and Trucksq), resource statistics (Crane, Quay and RTG utilization) and transporter statistics (Truck utilization).

We can draw the following major conclusions from the results of the solution report: The number of containers waiting for Trucks is very low but the number of containers waiting for Crane and RTG are high. These results are associated with RTG, Crane, and Truck utilization identifiers (51%, 48%, 91%) and the results are associated RTG and Crane length of queue identifiers (22). Also the system's average overall flow time is calculated 3343,2 minutes for 200 observations.

The performance of the selected system is measured in three ways: Flow times; Resources, transporter and queue statistics.

CONCLUSION

In this study, the seaside operations planning in container terminals in general and the crane double cycling models specifically are studied. The processes in the model are constructed based on the operations that take place at the port including loading/unloading containers from the vessel and moving containers to the container yard. The simulation results indicate that the lengths of the Crane and RTG queues are high. In this manner, we note that the bottlenecks of the system are RTG and Crane queues. The purpose of the model (crane double cycling) is to determine a quay crane (QC) operation strategy that minimizes an empty trip of the equipment involved in the vessel operation. We thus conclude that the RTG and Crane performances should be improved as they have a great impact on the performance measures of the system.

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AN ENVIRONMENTALLY CONSCIOUS MULTI-OBJECTIVE WEBER PROBLEM FOR GREEN LOCATION AND DISTRIBUTION PLANNING: A FUZZY WEIGHTED ADDITIVE APPROACH

Batuhan Eren ENGİN[1], Turan PAKSOY[2]

Abstract *− In this study, a multi-objective Weber (p-median) problem is treated in order to determine the location of the warehouses to be opened and the distribution plans of products from the potential warehouses to the final customers, in an environmentally conscious manner. The company carries out the distribution with three types of vehicles. The first type is a vehicle with a small size (Van) and a high unit transportation cost, but with a low carbon emission and high velocity. The second type of vehicle (truck) is a slightly larger vehicle with lower transportation cost per unit, but it is an option with slower velocity that emits more carbon compared to van. The third type of vehicle (heavy truck) is a vehicle with the lowest transportation cost per unit which has the slowest velocity and it releases the highest amount of carbon emissions among the vehicle types. Three conflicting objectives are considered to be minimized, i.e.; the demand weighted total transportation cost, the total delivery time and the total carbon emissions emitted in the network. As the different objective functions come with different units in this case, we adopted a fuzzy weighted additive approach to reduce multi-objective optimization function into a simple weighted additive model through achievement functions and the weights of each individual objective function are determined by Analytic Hierarchy Process.*

Keywords − Analytic Hierarchy process, fuzzy weighted additive solution approach, multi-objective optimization, p-median

INTRODUCTION

As the climate change-induced environmental degradation raises concerns among the governments, legislations and protective regulations put into action that force companies decrease their environmental footprint. In developed countries (such as Canada, United Kingdom, Australia, Scandinavian countries), carbon taxes (based on the idea that polluter pays) have been enacted or proposed, which means that the companies emitting more carbon than a predetermined level is charged a varying cost per ton of carbon. And, if you tax carbon as such, companies will either use fewer fossil fuels, reducing the amount of carbon emission, or seek alternative methods in operations, manufacturing or transportation. And if set high enough, it becomes a powerful monetary disincentive that in turn courages switching to greener methods, simply by making it more economically rewarding to move to carbon efficient techniques. No need to mention that going green does not only end up with environmental benefits, by doing so, it raises brand image perceived by customers.

When it comes to Turkey, carbon taxes is not yet to come. Turkey became a party to the Kyoto Protocol on August 26, 2009 and United Nations Framework Convention on Climate Change (UNFCC) on May 24, 2004. Turkey has not been considered responsible of emission reduction or limitation in the first period (2008-2012), second period (2012-2016) and third period (2016-2020) of the Kyoto Protocol [1]. Due to some regulations regarding special consumption tax and tax for removal of old vehicles from traffic in 2003-2004, a reduction of 4.9% in CO_2 was achieved. Still, there are several significant measures need to be undertaken to cut the carbon emission level in Turkey.

According to the Climate Change report published by [2], based on global emission from 2010, CO_2 emission level accounted for 65% of global greenhouse gases emission (GHG), and fossil fuel use is the primary source of CO_2 emission. Transportation accounted for 14% of global GHG [2]. This situation led the European Commission to put forward two regulatory proposals setting the mandatory CO_2 for new cars and vans in 2020. A key element of the proposal was that a target value of 95 g/km of CO_2 for 2020 is set for the new passenger vehicle fleet, and 147 g/km of CO_2 for vans, yet the European Commission has so far not done the

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same for trucks, which are responsible for around a quarter of road transport emissions and that share of emissions could increase by 2030, according to the Commission [3].

Companies intend to find the balance between organizational cost and environmental footprint, which is a challenging practice, as these objectives are usually conflicting. In this case, from a practical point, managers are willing to find a good compromise solution to both satisfy economic and environmental goals.

Our motivation is to propose a fuzzy weighted solution approach for supply chain (SC) companies willing to optimize multi-objective optimization problem. The remainder of the paper is as follows: Section 2 includes a brief review on studies dealing with green supply chain and fuzzy weighted solution approach. Section 3 describes the problem definition and formulation. Section 4 explains fuzzy weighted solution approach used to solve multi-objective optimization problems. Finally in Section 5, the approach is illustrated by a case problem. Conclusions and future directions appear next.

RELATED WORKS

Fahimnia et al. [4] proposed mixed-integer nonlinear mathematical model for a supply chain model dealing with tradeoff between cost and environmental degradation including carbon emissions, energy consumption and waste generation. The model also included multiple transport lot sizing and flexible holding capacity of warehouses. There are multiple products produced in manufacturing plants using machine centers with different characteristics (older machines are cheaper, but less carbon efficient), transported to customers through warehouses via different type of trucks including small, medium and large trucks. The objective in the proposed model was to determine the tactical planning decisions, including production and distribution allocation strategies for the planning horizon, in a way to minimize the overall cost while reducing the environmental footprint. The multiple objective function of the proposed mathematical model are converted into one weighted-sum objective function by expressing the emission, energy and waste values in equivalent dollar amount.

Chan et al. [5] developed models for three echelon SC distribution problem considering multiple-time periods, multi-products and uncertain demands. The distribution is carried out by multiple types of trucks differing in hiring cost, mileage, size and velocity. The two objectives were the cost and responsiveness of the supply chain. The distribution problem is solved using the non-dominated sorting genetic algorithm (NSGA-II).

As another example to multi-objective SC optimization, Kadzinski et al. [6] investigated different solution approaches to solve multi-objective green supply chain problems. The three objectives were costs, CO_2, which is one of the Green House Gases and fine coal dust, and the solution approaches were weighted sum method in which the multiple objectives are transformed into a single one through a convex combination, epsilon constraint method, and two evolutionary algorithms, namely NSGA-II and Strength Pareto Evolutionary Algorithm 2 (SPEA2). These algorithms are based on the notion of Pareto dominance which is used for identifying the solutions that will breed and those to be replaced. Talaei et al. [7] proposed a mixed integer linear programming model for a facility location/allocation, multi-product closed-loop green supply chain network consisting of manufacturing/remanufacturing and collection/inspection centers as well as disposal center and markets, minimizing the network total costs and also the amount of carbon emitted out by the network. Fuzzy programming approach is implemented to cope with the uncertainties of the variable costs and demand rate. Also, they used ε-constraint approach to solve the bi-objective model.

As to the solution approach review, Fuzzy weighted solution approach developed by [8] has been mostly used for multi-objective supplier selection problem [9-15]. Shaw et al. [11] used two approaches developed by [16] and [8]. Supplier selection problems involve selection the best supplier with regard to the some criteria, such as price, quality, customer service, or delivery. The objectives include, for example, the minimization of costs, maximization of quality and maximization of on-time delivery etc.

PROBLEM DEFINITION AND FORMULATION

In this study, a multi-objective P-median problem is developed in order to determine the location of the warehouses to be opened and the distribution plans of products from the potential warehouses to the final customers, in an environmentally conscious manner. The company carries out the distribution with three types of vehicles. The first type is a vehicle with a small size (van) and a high unit transportation cost, but with a low carbon emission and fast delivery time (t_1). The second type of vehicle (truck) is a slightly larger vehicle with lower transportation cost per unit, but it is an option with slower delivery time (t_2) that emits more carbon compared to van. The third type of vehicle (heavy truck) is a vehicle with the lowest transportation cost per unit which has the slowest delivery time (t_3) and it releases the highest amount of carbon emissions among the vehicle types.

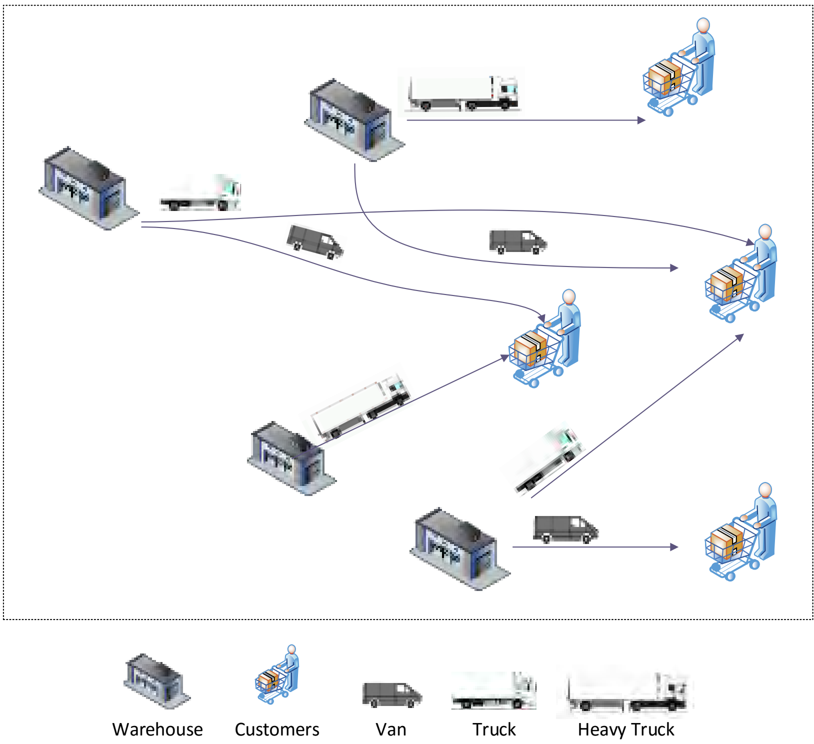

Figure 1. Supply chain network scheme

The following assumptions are considered for mathematical modeling:

- Demand of customers is deterministic and known in advance.
- Unit transportation cost, velocity and emission rate are available for van, truck and heavy truck.
- Potential location of warehouses are known in advance.

Three conflicting objectives are considered to be minimized, i.e.; the demand weighted total transportation cost (classic Weber objective function), the total delivery time ($t_1+t_2+t_3$) and the total carbon emissions emitted in the network. As the different objective functions come with different units in this case, we adopted a fuzzy weighted additive approach, proposed by [8], to reduce multi-objective optimization function into a simple weighted additive model through achievement functions and the weights of each individual objective function are determined by Analytic Hierarchy Process.

Sets and decision variables

The sets and indices used in this model are as follows:

W set of warehouses, indexed by w
K set of vehicle types, indexed by k
I set of point of sale, indexed by i

Binary decision variables are as follows:

$$X_{wki} = \begin{cases} 1, \text{if point of sale } i \text{ is served by vehicle type } k \text{ departed from warehouse } w \\ 0, otherwise \end{cases}$$

Another binary decision variable is needed to determine if warehouses are opened or not.

$$Y_w = \begin{cases} 1, & If\ warehouse\ w \text{ is opened} \\ 0, & otherwise \end{cases}$$

Parameters

d_{wi}	The distance between point of sale i and warehouse w
wd_i	The weight of demand for point of sale i
c_k	The unit transportation cost of vehicle type k
v_k	The velocity of vehicle type k
CO_k	Average carbon emission of vehicle type k
t_{wki}	Duration of transportation from warehouse w to the point of sale i with vehicle type k
P	Maximum predetermined number of warehouse that can be opened
ρ_1	Coefficient for Cost function
ρ_2	Coefficient for Total duration of transport
ρ_3	Coefficient for Total carbon emission

Objective Functions

Three conflicting objectives are considered to be minimized. The first objective function (Z_1) is the demand weighted total transportation cost (classic Weber objective function). The second objective function (Z_2) specifies the total duration of transport in the network, and the third objective function (Z_3) specifies the total carbon emissions.

$Z_1 = \sum_{\text{w,i,k}} wd_i * d_{wi} * c_k * x_{wki}$ (1)

$Z_2 = \sum_{\text{w,i,k}} t_{wki}$ (2)

$Z_3 = \sum_{\text{w,i,k}} x_{wki} * CO_k$ (3)

$Z = \rho_1 Z_1 + \rho_2 Z_2 + \rho_3 Z_3$ (4)

Subject to:

$\sum_{w,k} x_{wki} = 1,\ \ i \in I$ (5)

$x_{wki} \le y_w;\ \ (\text{i} \in \text{I}), (\text{w} \in \text{W}), (\text{k} \in \text{K})$ (6)

$\sum_w y_w = P$ (7)

$60 * x_{wki} * d_{wi} \div v_k = t_{wki};\ \ (\text{i} \in \text{I}), (\text{w} \in \text{W}), (\text{k} \in \text{K})$ (8)

$x_{wki}, y_w \in \{0,1\};\ \ (\text{i} \in \text{I}), (\text{w} \in \text{W}), (\text{k} \in \text{K})$ (9)

(1), (2) and (3) calculate the demand weighted total transportation cost, total duration of transport in the network, and the total carbon emissions, respectively. (4) is the weighted sum of these objective functions. (5) ensures that each customer will be served exactly by one warehouse using one type of truck. (6) ensures the opening of a warehouse if it is used. (7) restricts the number of opened warehouse is equal to p. (8) calculates the duration of transportation from warehouse w to the point of sale i with vehicle type k. (9) states the variables are binary.

SOLUTION APPROACH: FUZZY WEIGHTED ADDITIVE MODEL

Fuzzy weighted additive approach, developed by [8], is adopted to deal with multi-objective optimization function. By using their method, multi-objective objective function is reduced to a simple weighted additive model through achievement functions. Weights (ρ_1, ρ_2, ρ_3) are assigned by decision maker to reflect three objective functions' weight. The basic weighted additive model proposed by [8] for a maximization problem is as follows:

Maximize $V(\mu) = \sum_{i=1}^{m} \rho_i \mu_i$ (10)

Subject to:
$\mu_i = \frac{G_i(X) - L_i}{g_i - L_i}$ (11)
$AX \leq b$ (12)
$\mu_i \leq 1$ (13)
$X, \mu_i \geq 0, \quad i = 1,2, \dots, m$ (14)

Where X is an n-vector with components $x_1, x_2, , \dots, x_n$ and $AX \leq b$ are system constraints in vector notation. A linear membership function μ_i for the i-th fuzzy goal $G_i(X) \geq g_i$, can be expressed according to [16, 17] as;

$$\mu_i = \begin{cases} 1 & if\ G_i(X) \geq g_i \\ \frac{G_i(X) - L_i}{g_i - L_i} & if\ L_i \leq G_i(X) \leq g_i \\ 0 & if\ G_i(X) \leq L_i \end{cases} \quad (15)$$

where L_i is the lower tolerance limit for the fuzzy goal $G_i(X)$. In case of the goal $G_i(X) \leq g_i$, the membership function is defined as:

$$\mu_i = \begin{cases} 1 & if\ G_i(X) \leq g_i \\ \frac{U_i - G_i(X)}{U_i - g_i} & if\ g_i \leq G_i(X) \leq U_i \\ 0 & if\ G_i(X) \geq U_i \end{cases} \quad (16)$$

where U_i is the upper tolerance limit. In the objective function, the term V(μ) is called the fuzzy achievement function. This is a single objective optimization problem that can be solved by basic technique.

AN ILLUSTRATIVE EXAMPLE: A CASE STUDY

The real-life data is obtained from a wholesale company based in Ankara, Turkey. The company plans to open warehouses and assign its customers (universities and high schools) to each opened warehouse, meanwhile minimizing the total transportation cost (Z_1), total duration of transport (Z_2) and total carbon emissions (Z_3) in the network. The decision maker from the company performed pairwise comparison of three objective function using a scale from 1 to 9, which is given in Table 1 and after that, Analytical Hierarchy Process (AHP) is used to obtain the weights for each objective function, which is a multi-objective technique introduced by [18]. It can be read from the Table 1 that total transportation cost (Z_1) is more important than total duration of transport (Z_2) and slightly more important than total carbon emissions (Z_3). And, total carbon emissions (Z_3) is slightly more important than total duration of transport (Z_2). More information on AHP and its implementation can be found in [18]. The transportation costs per kilometer of van, truck, and heavy truck are 40, 30 and 20 Turkish liras, respectively. The CO_2 emissions per kilometer in gram for van, truck and heavy truck are 168.3, 200 and 250.2, respectively.

TABLE 1. PAIRWISE COMPARISON MATRIX FOR THREE OBJ. FUNC.

Objective Functions	Z_1	Z_2	Z_3
Z_1	1	5	3
Z_2	1/5	1	1/3
Z_3	1/3	3	1

Through pairwise comparison matrix, which is a consistent evaluation, weight vector is found as $\rho = [0.633\ 0.106\ 0.259]^T$. These weights are multiplied with each membership function of fuzzy linear programming. The next step is to calculate the achievement (membership) functions, μ_i. The first step in order to calculate the achievement functions is to run the model optimizing a single objective at a time. After solving the first objective (Z_1), the lower bound optimal value of first objective is obtained. The process is repeated for the remaining two objectives one by one. The lower bound and upper bound for each of the objectives are calculated using the same set of constraints. The fuzzy formulation is done using the weighted additive model proposed by [8]. Table 2 represents the upper and lower bound for each objective function.

TABLE 2. THE UPPER AND LOWER BOUND FOR EACH OBJECTIVE FUNCTION.

	Values found for each objectives		
Optimized	$\boldsymbol{Z_1}$ (TL)	$\boldsymbol{Z_2}$ (min)	$\boldsymbol{Z_3}$ (gram)
$\boldsymbol{Z_1}$	1761	229.5	5000
$\boldsymbol{Z_2}$	3522	147.5	3366
$\boldsymbol{Z_3}$	7648.8	308.4	3366

The minimum and maximum values of total cost (Z_1), total duration of transport (Z_2) and total carbon emission (Z_3) are given in Table 3.

TABLE 3. MINIMUM AND MAXIMUM VALUES OF EACH OBJECTIVE

Obj. Num	**Objective Function**	**μ=1**	**μ=0**
1	Z_1	1761	7649
2	Z_2	147	308
3	Z_3	3366	5000

Assuming that membership functions are linear, the achievement functions are as follows:

$$\mu_1 = \begin{cases} 1 & if\ Z_1 \leq 1761 \\ \frac{7649-(\sum_{\mathrm{w,i,k}} wd_i * d_{wi} * c_k * X_{wki})}{7649-1761} & if\ 1761 \leq Z_1 \leq 7649 \\ 0 & if\ Z_1 \geq 7649 \end{cases} \quad (17)$$

$$\mu_2 = \begin{cases} 1 & if\ Z_2 \leq 147 \\ \frac{308-(\sum_{\mathrm{w,i,k}} \frac{d_{wi} * x_{wki}}{v_k} * 60)}{308-147} & if\ 147 \leq Z_2 \leq 308 \\ 0 & if\ Z_2 \geq 308 \end{cases} \quad (18)$$

$$\mu_3 = \begin{cases} 1 & if\ Z_3 \leq 3366 \\ \frac{5000-(\sum_{\mathrm{w,i,k}} X_{wki} * CO_k)}{5000-3366} & if\ 3366 \leq Z_3 \leq 5000 \\ 0 & if\ Z_3 \geq 5000 \end{cases} \quad (19)$$

Using these achievement functions, the new mathematical formulation for Green P-median location and distribution problem is as follows:

Maximize $0.633 * \mu_1 + 0.106 * \mu_2 + 0.259 * \mu_3$
Subject to,

$$\mu_1 \leq \frac{7649 - (\sum_{\mathrm{w,i,k}} wd_i * d_{wi} * c_k * X_{wki})}{5888}$$

$$\mu_2 \leq \frac{308 - (\sum_{\mathrm{w,i,k}} \frac{d_{wi} * x_{wki}}{v_k} * 60)}{161}$$

$$\mu_3 \leq \frac{5000 - (\sum_{\mathrm{w,i,k}} X_{wki} * CO_k)}{1634} \quad (20)$$

$$\sum_{w,k} x_{wki} = 1,\ \ i \in I$$

$$x_{wki} \leq y_w; \quad (\mathrm{i} \in \mathrm{I}), (\mathrm{w} \in \mathrm{W}), (\mathrm{k} \in \mathrm{K})$$

$$\sum_{w} y_w = p$$

$$\frac{d_{wi} * x_{wki}}{v_k} * 60 = t_{wki}; \quad (i \in I), (w \in W), (k \in K)$$

$$x_{wki}, y_w \in \{0,1\}; \quad (i \in I), (w \in W), (k \in K)$$

SOLUTION SUMMARY AND CONCLUSION

The model represented in (20) is implemented using ILOG's CPLEX Concert Technology (version 12.6) in Visual Studio environment in C# language. The optimal solution to the fuzzy mathematical model is given in Table 4 below. Fuzzy achievement functions and corresponding objective function values per one cycle of operations in network are obtained.

According to the optimal solution given in Table 4, Warehouse 1, 3 and 7 should be opened in order to minimize the total transportation cost, total duration of transport and total carbon emission altogether.

TABLE 4. OPTIMAL SOLUTION

$\boldsymbol{X_{wki}}$	$\boldsymbol{X_{1,1,2}, X_{1,1,3}, X_{1,1,4}, X_{1,1,6}, X_{1,1,9}, X_{1,1,12}, X_{1,3,5}, X_{7,1,1}, X_{7,1,13}, X_{7,1,14}, X_{7,1,16}, X_{3,1,7}, X_{3,1,8}, X_{3,1,10}, X_{3,1,11}, X_{3,1,17}, X_{3,1,18}, X_{3,1,19}, X_{3,1,20} = 1}$
$\boldsymbol{Y_w}$	$Y_1 = Y_3 = Y_7 = 1$
$\boldsymbol{Min\ Z_1[1761, 7649]}$	2985 (TL)
$\boldsymbol{Min\ Z_2[161, 308]}$	166 (Minute)
$\boldsymbol{Min\ Z_3[3366, 5000]}$	3529 (Gram)
μ_1	0.792
μ_2	0.881
μ_3	0.900

As the climate change-induced environmental degradation raises concerns among the governments, legislations and protective regulations put into action that force companies decrease their environmental footprint. This led companies to simultaneously optimize their organizational cost and environmental footprint.

In this study, a fuzzy approach was proposed to deal with multi-objective p-median problem. Three conflicting objectives considered to be minimized were the demand weighted total transportation cost, the total delivery time and the total carbon emissions emitted in the network. The network consists of warehouses, of which the potential location are known in advance, and customers. The decision was to determine the location of the warehouses to be opened and the distribution plans of products from the potential warehouses to the final customers using three types of vehicles. The vehicles possess different cost, velocity and carbon emission, which leads to a trade-off between the objectives. We used a fuzzy weighted additive approach, proposed by [8], to reduce multi-objective optimization function into a simple weighted additive model through achievement functions and the weights of each individual objective function were determined by AHP. The model tested using real data obtained from a logistic company based in Ankara, Turkey. As a future direction, demands of customers, transportation cost and carbon emission levels and velocities of vehicles may be taken as fuzzy parameters.

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SUPPLIER SELECTION AND COLLABORATION FOR HUMANITARIAN RELIEF SUPPLY CHAINS

Eren Şallı, Peral Toktaş-Palut

Abstract *− Humanitarian logistics is mainly divided into the following three planning stages in the disaster life cycle: (pre-disaster) mitigation phase, (post-disaster) response phase, and recovery phase. Relief supplier selection and collaboration is a very crucial part of the pre-disaster period to overcome the difficulties in the response phase which could not be done by government itself. The main objective of this study is to select the most appropriate relief suppliers in the pre-disaster period in terms of determined criteria. As a case study, the Anatolian side of Istanbul, Turkey is considered as the affected area. In order to achieve this goal, first Interpretive Structural Modeling (ISM) is used to identify and rank the criteria and to find the interactions among them. Among 15 criteria determined through the literature review and face to face surveys with experts, seven of them are found to be more important and affecting than the others. These criteria are geographic position, collaboration attribute, using information technology tools, data accuracy, evaluation and certification system, resource and information sharing, and trust development. Second, Analytic Network Process (ANP) is used to determine the weights of the criteria selected by the ISM method. Finally, the candidate suppliers are evaluated and ranked in terms of these criteria using the Analytic Hierarchy Process (AHP)-Rating technique. The framework proposed in this study provides practitioners with a tool for planning and carrying out humanitarian logistics activities.*

Keywords *− Analytic Network Process (ANP), Humanitarian logistics, Interpretive Structural Modeling (ISM), Supplier selection.*

1. INTRODUCTION

Emergency logistics (EL) operates in environments with uncertain and dynamic features. Uncertain events occur not only on the supply side (involving relief resources and relief suppliers, for example) but also on the demand side (involving relief demand and affected people, for example). Such uncertain events are usually highly dynamic under the conditions of a disaster. Owing to the complex and varying nature of these operational environments, no organization – not even a government – can manage the EL for such large-scale disasters without collaborating with others [1]. Clearly, relief supply collaboration is critical to managing EL following natural disasters [2]. The fundamental reason for engaging in relief supply collaboration is that the host government cannot successfully run EL alone during post-disaster phases. Accordingly, the government seeks relief suppliers with whom to coordinate cross-supplier relief activities and joint actions to ensure effectiveness. Collaboration can improve the supply chain performance in terms of better stability of impacts and service level [3]. Nevertheless, many domestic non-governmental organizations (NGOs) self-deploy and distribute relief resources without collaborating with the government, potentially causing an imbalance in the distribution, and an oversupply or undersupply, of relief resources to affected areas. Relief undersupply in the affected areas means shortages of relief resources, including crew and commodity. Such shortages may worsen hunger and suffering, increase the mortality rate, and incidences of looting. For example, in 2005, after Hurricane Katrina in the USA, one of Louisiana's greatest shortages was portable toilets, which were requested for the Superdome but never arrived there, as more than 20,000 people were forced to reside inside the dome without working plumbing for nearly a week [4]. Desperation gripped the Philippine Islands devastated by Typhoon Haiyan in 2013; the looting turned deadly and survivors panicked over shortages of food, water, and medicine; some dug up underground water pipes and smashed them open [5]. In contrast, relief oversupply may occur in other affected areas. The deployment of an unsuitable stock of relief resources in the affected areas may lead to redundancy, the overconsumption of logistical resources, and even congestion in the system [6]. For example, five months after the 2004 Asian tsunami, approximately one-third of the relief containers were still blocked in airport customs [7]; there was an excessive accumulation of relief supplies at refuge centers during the response period after the 1999 Taiwan earthquake [8]. In the 2011 Sendai earthquake and Japanese tsunami, many such goods arrived in Onagawa City. Used clothing was sent to the shelters; however, 80% of the clothes were returned to the distribution center and about 7.7 tones of the donated goods had to be recycled [9]. These impacts increase over time: as the duration of a supply–demand imbalance increases, the impact of the disaster increases. Failure to control efficiently such an impact may cause a secondary disaster.

A large-scale disaster may or may not make the government dysfunctional. For instance, the 2010 Haiti earthquake caused serious damages and many government buildings were destroyed, which disrupted the Haitian government. On the other hand, in the aftermath of the 2013 Lushan earthquake in China, the government was functional to operate EL responses. The government represents not only the most powerful relief supplier but also the coordinator for relief supply collaboration.

To achieve collaboration in the supply of relief with potential relief supplier, governments should solve the following crucial problems that commonly NGOs cause:

- The willingness to engage in relief supply collaboration varies among NGOs. Each NGO has its own nature (including management philosophy, capabilities, and culture) that affects its willingness to collaborate with government or other NGOs. Some experienced NGOs willingly collaborate with governments; others may have their own operational standards and prefer to work independently rather than with specific units, such as the military [1]. For instance, NGOs may be reluctant to share information with other organizations which gives them a competitive advantage in attracting media [2]. Even NGOs sharing the same principles may be reluctant to work together [10]. For example, the French Red Cross and the International Federation of Red Cross and Red Crescent (IFRC) share the same name, but they do not accept clear reporting lines [10].
- The types and quantities of relief resources (including relief workers and relief supplies) that are provided by NGOs vary. NGOs may include charity organizations, private companies, private rescuers, and medical teams. Each NGO provides its own relief resources to the affected people. For example, supermarkets donate various cleaning tools, pet shops provide pet supplies, and families give gifts. Besides, NGOs donation may determine the relief resources distributed [11]. Inappropriate donations include; laptops needing electricity where the infrastructure has been destroyed; heavy clothing not suitable for tropical regions [12].
- The number of NGOs that participate in relief supply tasks varies over time. A large number of NGOs may become involved in supplying relief in the aftermath of a disaster [1]. However, the response time for EL support and relief supply distribution varies among NGOs. For example, given the geographical distribution of NGOs, NGOs near the affected areas usually arrive sooner than those who are far from the affected areas; many NGOs arrive at a country to deliver aid only if and when donor funding becomes available [2]. Consequently, many NGO's involvement and operation are somewhat unpredictable.
- Some countries established facilities like a warehouse in order to store relief items such as tents, sleeping bags, blankets, medical first aid kits, dry food and water in pre-disaster period. After the disaster, they will act as both supply points for the stored items and regional coordination centers in relief operations. One such facility was already established in 2006 in Istanbul. AKOM has identified 40 potential locations for establishing additional facilities in Istanbul. The main criteria used in determining these locations are accessibility by at least two alternative roads, proximity to major highways and availability of land. Discussions with

AKOM and other response agency representatives revealed that it would not be practical to establish a large number of facilities that stay non-functional until a disaster occurs. Instead, they find it meaningful to utilize some of the relief supplier's location as a joint facility location.

To overcome these uncertainties and dynamic critical problems that are related to NGOs, and to alleviate their possible impact, this study propose a novel relief supply collaboration approach to address the issue of imbalanced relief supply-demand impact for EL operations in rapid response to the needs of affected people in the aftermath of large-scale disasters. This study has a distinctive feature which separates it from previous studies. To select the most proper relief suppliers in pre-disaster period, first Interpretive Structural Modeling (ISM) is used to identify and rank the criteria and to find the interactions among them. Second, Analytic Network Process (ANP) is used to determine the weights of the criteria selected by the ISM method. Finally, the candidate suppliers are evaluated and ranked in terms of these criteria using the Analytic Hierarchy Process (AHP)- Rating technique. The remainder of the paper is organized as follows. In Section 2, Interpretive Structural Modeling (ISM) is applied to determine the criteria used in relief supplier selection. In Section 3, Analytic Network Process (ANP) is conducted to determine the weights of the criteria. In Section 4, potential suppliers are evaluated; and finally, in Section 5, concluding remarks are given.

2. INTERPRETIVE STRUCTURAL MODELING (ISM)

The criteria involved in the supplier selection have been chosen by face to face survey as well as literature review. A questionnaire consisting of these factors is designed for the survey. The respondents for the survey are selected randomly from different functional areas of Alternative Logistics Company which is conducting emergency logistic activity on the behalf of AFAD. Based on the survey conducted, the major influencing criteria involved in supplier selection are collaboration attribute, resource size, quality improvement, cost minimization, flexibility, trust development, lead time reduction, long term strategic goals, capability, relational orientation, resource and information sharing, evaluation and certification system, geographic position, using information technology tools, and data accuracy.

ISM methodology suggests the use of expert opinions based on various management techniques such as brainstorming, nominal technique, etc. in developing the contextual relationship among the variables. Thus, in this study for identifying the contextual relationship among the interactions for the supplier selection criteria; four experts, two from the Alternative Logistics, one from academia and one from AKOM are consulted for this study. Keeping in mind the contextual relationship for each element, the existence of a relation between any two criteria (i and j) and the associated direction of the relation is questioned. Four symbols are used to denote the direction of relationship between the criteria (i and j):

(1) V – criteria i will help alleviates criteria j;
(2) A – criteria j will be alleviated by criteria i;
(3) X – criteria i and j will help achieve each other; and
(4) O – criteria i and j are unrelated

2.1. Initial Reachability Matrix

The initial reachability matrix is transformed into a binary matrix, called the structural self interaction by substituting V, A, X, O by 1 and 0 as per the case. The rules for the substitution of 1 and 0 are the following:

(1) If the (i, j) entry in the SSIM is V, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry becomes 0.
(2) If the (i, j) entry in the SSIM is A, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry becomes 1.

(3) If the (i, j) entry in the SSIM is X, then the (i, j) entry in the reachability matrix becomes 1 and the (j, i) entry also becomes 1.
(4) If the (i, j) entry in the SSIM is O, then the (i, j) entry in the reachability matrix becomes 0 and the (j, i) entry also becomes 0. The Structural Self-Interection Matrix (SSIM) is shown in Table 1.

Table 1. Structural Self-Interection Matrix

Criteria	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	0	1	1	0	1	0	1	1	0	0	0	0	0	0	0
3	0	0	1	0	0	1	0	0	1	1	0	1	0	0	0
4	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0
5	0	1	0	1	1	0	1	0	1	0	0	0	0	0	0
6	0	1	0	0	1	1	1	0	1	0	0	1	0	0	1
7	0	0	1	1	0	0	1	0	1	0	0	0	0	0	0
8	0	1	1	1	1	1	1	1	1	0	1	0	1	1	1
9	0	1	1	1	1	0	1	1	1	1	0	0	0	0	0
10	0	1	1	1	1	1	1	1	1	1	1	1	0	0	1
11	0	1	1	1	1	1	1	0	1	0	1	0	0	0	1
12	0	0	1	0	0	1	0	1	1	0	1	1	0	1	1
13	0	1	1	1	0	0	1	1	1	0	1	0	1	0	0
14	0	1	1	1	1	1	1	0	1	1	1	0	0	1	1
15	0	0	1	1	1	1	1	0	1	1	0	0	0	0	1

As a result of transivity process and level partition, driver and dependence power of the variables are determined. The variables are classified into four clusters (Figure 1). The first cluster consists of the autonomous criteria that have weak driver power and weak dependence. These criteria are relatively disconnected from the system, with which they have only few links, which may be strong. Second cluster consists of the dependent criteria that have weak driver power but strong dependence. Third cluster has the linkage criteria that have strong driving power and also strong dependence. These criteria are unstable in the fact that any action on these criteria will have an effect on the others and also a feedback on themselves. Fourth cluster includes the independent criteria having strong driving power but weak dependence. It is observed that a variable with a very strong driving power called the key variables falls into the category of independent or linkage criteria. The driving power and the dependence of each of these criteria are shown in Figure 1.

2.2. Result and Analysis

The criteria hindering the supplier selection pose considerable challenges both for managers and policymakers in humanitarian logistics activity. Some of the major criteria have been highlighted here and put into an ISM model to analyze the interaction between the criteria.

These criteria need to be developed for the success in supplier selection. The driver-dependence diagram shown in Figure 1 gives some valuable insights about the relative importance and the interdependencies among the criteria. This can give better insights to the company so that they can proactively deal with these criteria. Some of the observations from the ISM model, which give important managerial implications, are discussed below.

It is observed from Figure 2 that ***Geographic position*** (criterion 13) is a very significant factor for the supplier selection process, so it forms the base of the hierarchy. ***Resource size*** (criterion 2), ***Quality improvement*** (criterion 3), ***Cost minimization*** (criterion 4), ***Flexibility*** (criterion 5), ***Lead time reduction*** (criterion 7), ***Long term strategic goals*** (criterion 8), ***Capability*** (criterion 9), ***Relational orientation*** (criterion 10) which depicts the successful supplier development process. These variables have appeared at the top of the hierarchy. The ***Geographic position*** criterion lead to the following criteria ***collaboration attribute***, ***using information and technology tools***. These two criteria lead to ***trust development, resource and information sharing, evaluation and certification system, data accuracy*** criteria. It is also observed from Figure 1 that there are no autonomous criterion seen in the driver-dependence diagram. The absence of these criteria brings light to the fact that all the considered criteria influence the supplier selection in the humanitarian relief supply chain.

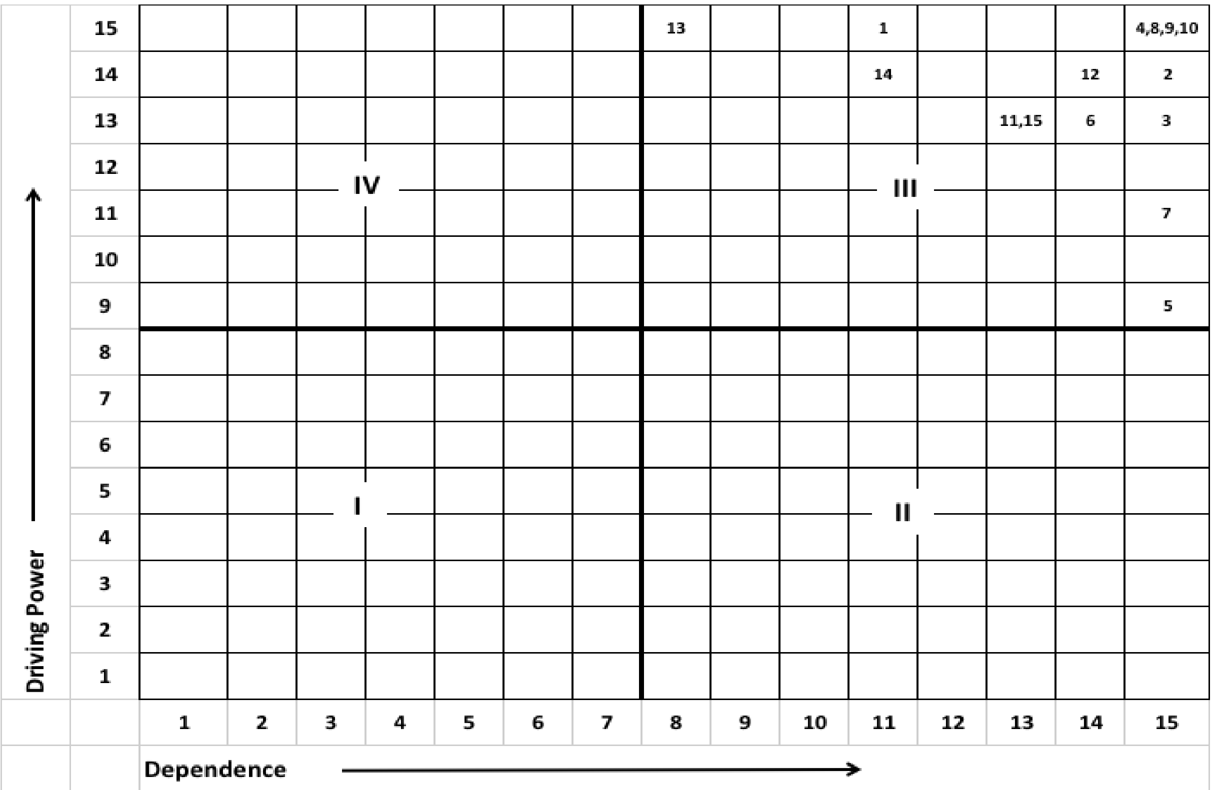

Figure 1. Driving and dependence power diagram for criteria

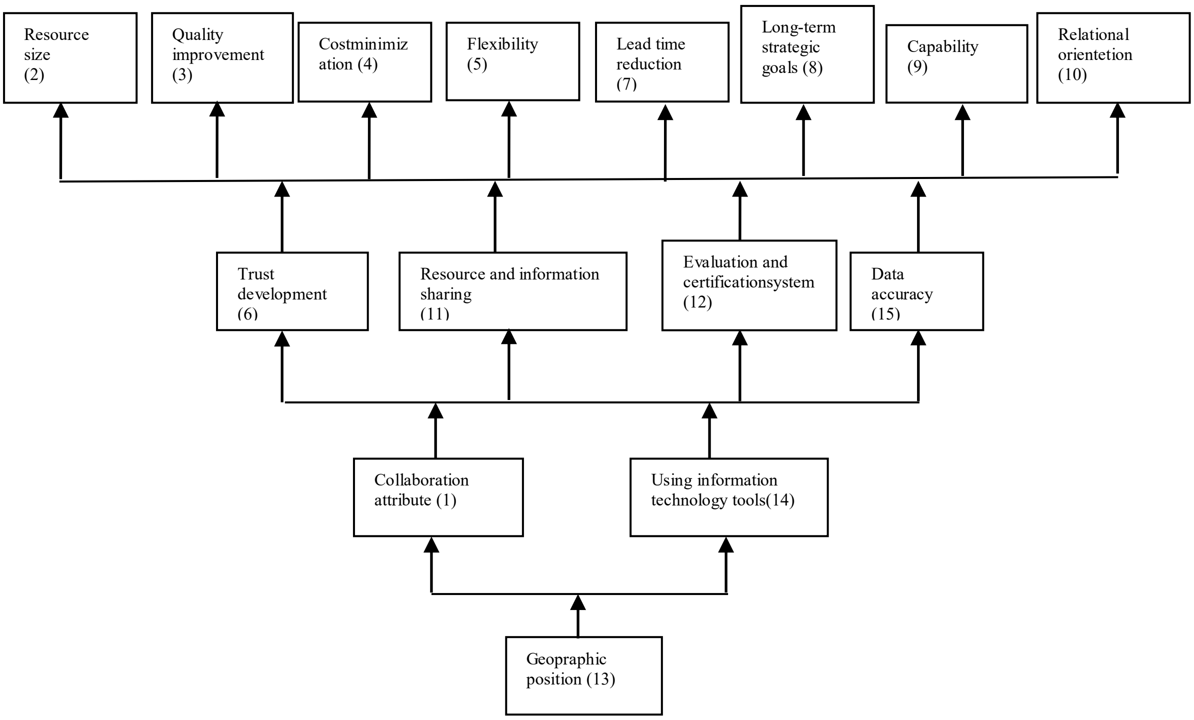

Figure 2. ISM-based supplier selection criteria model

3. ANALYTIC NETWORK PROCESS (ANP)

Among 15 criteria determined through the literature review and face to face surveys with experts, seven of them are found to be more important and affecting the others after using ISM. These criteria are geographic position, collaboration attribute, using information technology tools, data accuracy, evaluation and certification system, resource and information sharing, and trust development. Then, Analytic Network Process is conducted with the same group that conducted ISM**.** The ANP-based model is implemented by several steps. First, pairwise comparision matrice is formed so as to determine inner dependencies in criteria cluster based on Saaty'scale. During the assesment process there may occur a problem in terms of consistency. Therefore inconsistency ratios for every matrices are checked in order to determine the misevaluation of comparisons. Inconsistency ratios are generally acceptable up to the limit of 0.10, while some scholars offer a limit up to 0.20 [13]. If all matrices are consistent, the process can proceed to the next step. If not, inconsistent matrices should be reassessed in order to provide consistency for all matrices. In this case there is no problem in terms of the consistency value, which is under the limit, considering the Saaty'scale. Second, supermatrix are formed consisting of unweighted super matrix, weighted super matrix and limit super matrix, which are respectively formed one after the other through proper computation. Finally, the limit supermatrix provides priorities of criteria. In fact, values of the limit supermatrix stand for the overall priorities, which embrace the cumulative influence of each element of the network on every other element, with which it interacts. In particular the computations related to ANP application have been carried out effortlessly by the software Superdecisions. Weighted super matrix, limit super matrix and priorities of criteria are given Table 2, Table 3 and Table 4 respectively.

Table 2. Weighted super matrix

CRITERIA	1.Collaboration attribute	6.Trust Development	11. Resource and information sharing	12. Evaluation and certification system	13. Geographic position	14.Using information technology tools	15. Data accuracy
1.Collaboration attribute	0	0,14577	0,105103	0,129695	0,8	0,289751	0,161977
6.Trust Development	0	0	0,08858	0,063239	0	0,152004	0,119545
11. Resource and information sharing	0,338015	0,335612	0	0,134024	0	0	0,167986
12. Evaluation and certification system	0	0,041726	0,063316	0	0,2	0,117061	0,041979
13. Geographic position	0,444329	0,126675	0,383725	0,145097	0	0,441184	0,104296
14.Using information technology tools	0,162196	0,202875	0,206062	0,29002	0	0	0,404217
15. Data accuracy	0,05546	0,147341	0,153214	0,237926	0	0	0

Table 3. Limit super matrix

CRITERIA	1.Collaboration attribute	6.Trust Development	11. Resource and information sharing	12. Evaluation and certification system	13. Geographic position	14.Using information technology tools	15. Data accuracy
1.Collaboration attribute	0,287652	0,287652	0,287652	0,287652	0,287652	0,287652	0,287652
6.Trust Development	0,044303	0,044303	0,044303	0,044303	0,044303	0,044303	0,044303
11. Resource and information sharing	0,133302	0,133302	0,133302	0,133302	0,133302	0,133302	0,133302
12. Evaluation and certification system	0,080438	0,080438	0,080438	0,080438	0,080438	0,080438	0,080438
13. Geographic position	0,260742	0,260742	0,260742	0,260742	0,260742	0,260742	0,260742
14.Using information technology tools	0,13152	0,13152	0,13152	0,13152	0,13152	0,13152	0,13152
15. Data accuracy	0,062043	0,062043	0,062043	0,062043	0,062043	0,062043	0,062043

Table 4. Priorities of criteria

CRITERIA	**1.Collaboration attribute**	**6.Trust Development**	**11. Resource and information sharing**	**12. Evaluation and certification system**	**13. Geographic position**	**14.Using information technology tools**	**15. Data accuracy**
Limiting value	0.29	0.05	0.13	0.08	0.26	0.13	0.06
Normalized value	0.29	0.05	0.13	0.08	0.26	0.13	0.06

4. EVALUATION OF POTENTIAL SUPPLIERS

In this part, it is tried to determine the potential relief suppliers, located in the Anatolian side of İstanbul, that might be involved in humanitarian logistics activities. This investigation includes charitable organizations and private companies. 20 suppliers are evaluated in terms of determined and weighted criteria. This study surveys experienced government's crews working in EL that are responsible for emergency response training during normal times and for collecting the relief resources supplied by the government and manager of Alternative Logistics who is conducting emergency logistics activities on behalf of AFAD. These members measure all of the corresponding criteria of NGO. The survey responses by these crews are the data used for the AHP-rating technique. Here it is established rating categories for each covering criterion and prioritize the categories by pairwise comparing them for preference. Alternatives are evaluated by selecting the appropriate rating category on each criterion as given in Table 5. The rating categories for the criterion are Very good, Good, Average, Bad and Very bad. The criteria are compared for preference using a pair-wise comparison matrice in the usual way. To obtain the idealized priorities, we normalize by dividing by the largest of the priorities. The idealized priorities are used for the ratings. Table 6 gives the verbal ratings of the twenty alternatives on each covering criterion and Table 7 gives their corresponding numerical ratings from Table 6 with their totals and rank of the group.

Table 5. The prioritized ratings categories for all criteria

Criteria rating	**1.Collaboration attribute**	**6.Trust development**	**11. Resource and information sharing**	**12. Evaluation and certification system**	**13. Geographic position**	**14.Using information technology tools**	**15. Data accuracy**
Very good	1	1	1	1	1	1	1
good	0.63	0.65	0.53	0.71	0.54	0.68	0.59
average	0.38	0.41	0.37	0.31	0.34	0.42	0.27
bad	0.12	0.11	0.11	0.18	0.17	0.13	0.10
Very bad	0.02	0.04	0.02	0.09	0.04	0.03	0.02

Table 6. Ratings for the alternatives on each criterion

Criteria	Geographic Position	Collaboration attribute	Using information technology tools	Trust development	Resources and information sharing	Evaluation and certification system	Data accuracy
Suppliers	0,26	0,29	0,13	0,05	0,13	0,08	0,06
1.World Atlantis Shopping Mall	*Average*	*High*	*High*	*Bad*	*Average*	*Bad*	*Low*
2.Asyapark Outlet Shopping Mall	*Average*	*Average*	*High*	*Average*	*Average*	*Bad*	*Average*
3.Beşyıldız Shopping Mall	*Average*	*High*	*High*	*Verybad*	*Average*	*Average*	*Average*
4.Kardıyum Shopping Mall	*Average*	*High*	*Average*	*Bad*	*Average*	*Average*	*Low*
5.Neomarin Shopping Mall	*Good*	*Very high*	*High*	*Good*	*Very High*	*Very good*	*Very high*
6.Plato Shopping Mall	*Average*	*Average*	*Average*	*Bad*	*Low*	*Average*	*Average*
20.Metro Shopping Mall	*Very good*	*Very high*	*Very High*	*Very good*	*Very High*	*Very good*	*Very high*

Table 7. Numerical values for ratings given in Table 6

Criteria	Geographic Position	Collaboration attribute	Using information technology tools	Trust development	Resources and information sharing	Evaluation and certification system	Data accuracy	TOTAL WEIGHT	RANK
Suppliers	0,26	0,29	0,13	0,05	0,13	0,08	0,06		
1.World Atlantis Shopping Mall	0,34	0.63	0.68	0.11	0.37	0.18	0.1	0.4335	15
2.Asyapark Outlet Shopping Mall	0,34	0.38	0.68	0.41	0.37	0.18	0,27	0,3862	18
3.Beşyıldız Shopping Mall	0,34	0.63	0.68	0.04	0.37	0.31	0,27	0.4506	14
4.Kardiyum Shopping Mall	0,34	0,63	0,42	0.11	0.37	0.31	0,1	0.4101	16
5.Neomarin Shopping Mall	0,54	1	0.68	0.65	1	1	1	0.8213	8
6.Plato Shopping Mall	0,34	0.38	0,42	0.11	0,11	0.31	0,27	0,314	19
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
20.Metro Shopping Mall	1	1	1	1	1	1	1	1	3

As a result of final evaluation of potential relief suppliers in terms of the rating categories, final ranking is formed as given in Table 8.

Table 8. Final ratings of suppliers

Number	Suppliers	Rank	Weight
1	Carrefoursa Shopping Mall	1	1
2	Maltepe Park Shopping Mall	2	1
3	Metro Shopping Mall	3	1
4	Buyaka Shopping Mall	4	1
5	Tepe Nautilus Shopping Mall	5	1
6	Palladium Shopping Mall	6	0,9825
⋮	⋮	⋮	⋮
20	Rings Shopping Mall	20	0,283

5. CONCLUSION

The main objectives of this study is to select the most proper relief suppliers in pre- disaster period in terms of some of the important criteria which are determined.

In order to determine the most appropriate suppliers, first, Interpretive Structural Modeling (ISM) is applied to identify and rank the criteria used for the supplier selection and to find the interactions among the criteria. At the beginning, 15 criteria are determined which are selected by literature review and face to face survey. After using ISM some of the criteria are eliminated and only 7 criteria remained. Second, Analytic Network Process (ANP) is used to determine the weights of the criteria which are selected in the former phase. Third, the potential relief suppliers that might be involved in humanitarian logistics activities are determined. These suppliers are evaluated in terms of 7 criteria, *Geographic Position, Collaboration attribute, Using information technology tools, Trust development, Resources and information sharing, Evaluation and certification system, Data accuracy,* by using

AHP-RATE technique. Finally, the potential suppliers are ranked in terms of total weights so as to be used for humanitarian logistic activities as a suppliers.

Future research may consider other key criteria for selecting the most appropriate suppliers to collaborate for humanitarian logistics activities. Furthermore, future study may also expand the number of potential suppliers and diversity of suppliers. In this study, suppliers are selected by subjective criteria determined by experts. As a further study, mathematical modeling could be conducted in order to refrain from subjectivity.

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EVALUATION OF RAILING PRODUCERS FOR RISKY SPACES IN CONSTRUCTION PROJECTS WITH AHP AND ANP UNDER FUZZY ENVIRONMENT: CASE FROM ISTANBUL

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Abstract *– For construction project's risky spaces we suggested a hierarchical model for choosing the appropriate supplier for buying railings by applying multi-criteria decision making (MCDM) methods: Analytic Hierarchy Process and Analytic Network Process based on linguistic variables under fuzzy environment. Two methods were suggested to be used in our proposed hierarchical model. Firstly, fuzzy AHP methodology was used for analyzing the 4 main criteria (cost, job security, quality and firm characteristics) and 12 sub-criteria, secondly fuzzy ANP methodology was applied for representing the inter-relationships among these main criteria. The suppliers were evaluated by 3 professionals. The proposed model was explained by an illustrative example, all comparisons and evaluations were made with triangular numbers with fuzzy sets and final results were compared.*

Keywords *– AHP, ANP, fuzzy sets, job security, supplier selection problem, triangular numbers.*

1. INTRODUCTION

According to the Social Security Institution's job security reports, in 2015, 1730 workers lost their life in occupational accidents. 426 workers from 1730 lost their life in construction sector. That means the construction sector is the first business line in all sectors with 25% of death rate in 2015. In 2015, 277 workers were dead by falling from highs in construction sector. The death rate by falling from highs was [(277/426)*100 = 65.02] 65%. Because of this reason in order to prevent occupational accidents which are happened by falling from high in this sector, it is first necessary to carry out railings on spaces which are danger for falling.

In this paper, there is a MCDM problem for choosing the most suitable railing producer. In literature there are lots of solution methods for MCDM problem. For example, Dozic and Kalic (2015) used AHP for an aircraft type selection problem, Chemweno et al. (2015) developed a risk assessment selection methodology with ANP, Keshtkar (2017) made performance analysis by TOPSIS and Carrillo and Jorge (2016) used data envelop analysis (DEA) approach to ranking alternatives.

In recent researches fuzzy logic has been used for again these types of problems. For example, Karaman and Akman (2017) applied fuzzy AHP to airline industry for choosing corporate social responsibility criteria selection problem, Nilashi et al. (2016) determined the importance of factors using fuzzy ANP, Marbini and Kangi (2017) used fuzzy TOPSIS for a group decision making with an application to Tehran stock exchange and Wanke et al. (2016) assessed productive efficiency in Nigerian airports using fuzzy DEA.

And also in some researchers have been using more than one MCDM method for solution their problems and made comparisons with the results. For example, Junior et al. (2014) used TOPSIS and AHP methods with fuzzy logic, Sakthivel et al. (2015) used a hybrid MCDM approach based on TOPSIS and ANP and Beltran et al. (2014) used ANP and AHP for investment project selection problem.

In this paper, because of its ease of use we used fuzzy AHP and then secondly we used fuzzy ANP for analyzing the inter-relationships among main criteria under fuzzy environment. Using interval judgments than judgments with crisp value is more useful and realistic.

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We suggested a model with four stages such as main objective, criteria, sub-criteria and alternatives. The comparisons were made with linguistic variables by the professionals from construction sector. Fuzzy numbers were used for all pair-wise comparison matrixes in this study.

As an outline in this paper: Section 2 discusses occupational health, job security and some statistics from Turkey. Section 3 contains the application steps AHP and ANP methods for our problem which is choosing railing producers for risky spaces in construction. Section 4 contains the comparisons of results and conclusion.

2. OCCUPATIONAL HEALTH AND JOB SECURITY

Health is one of the most important and complex issues faced by our country today. Because Turkey has one of the worst records in case of accidents at work and the workplace has a central role to play in this problem.

Occupational health is about work places and employees. The managers and firms should supply safety work conditions in their companies and they should protect their workers from all hazards. Occupational health's objectives are improving working environment, forming organizational and working culture and increasing productivity.

Employers are required by law to provide safe and healthy workplaces. The workplace must be free of recognized hazards, from chemical exposure to lifting hazards. The employees have to be protected from chemical, physical, biological, psychological and ergonomic hazards.

2.1 Some Statistics from Turkey

According to the Social Security Institution's job security reports in 2005, 73.923 work accidents were happened and 1096 people were died. In 2006, 79.027 work accidents were happened and 1601 people were died. In 2007, 80.602 work accidents were happened. In 2008, 1.865.115 working days were lost. In 2009, 64319 work accidents were happened, 1171 people were died and 1.589.000 working days were lost.

In Turkey the most of the occupational diseases' reasons cannot be found. Meanwhile in the World, the ratio of working accidents is %44 and the ratio of occupational diseases is %56, in Turkey the ratio of working accidents is %99 and the ratio of occupational diseases is %1. The cost of work accidents and occupational diseases is very high for Turkey economy.

In Turkey in every 6.5 minutes, there are approximately 220 job accident are being happened. Because of these accidents more than 4 people die in every 6 hours and more than 8 people are disabled in every 3 hours [13]. That's why the job security studies and precautions are very important in Turkey.

3. PROPOSED MODEL FOR A RAILING PRODUCER SELECTION PROBLEM FOR RISKY SPACES IN CONSTRUCTION PROJECT

Our proposed hierarchical model has four levels. Such as the overall objective is placed at level 1 (choosing the most suitable railing producer according to our proposed model), criteria at level 2 (cost, job security, quality, producer characteristics), sub-criteria at level 3 (price, time bargain, transportation cost, compliance with regulation, robustness, manufacturing suitability, product quality, production quality, OHSAS 18001, reliability, timely delivery, technology availability) and the decision alternatives at level 4. Fig. 1 shows proposed MCDM problem model.

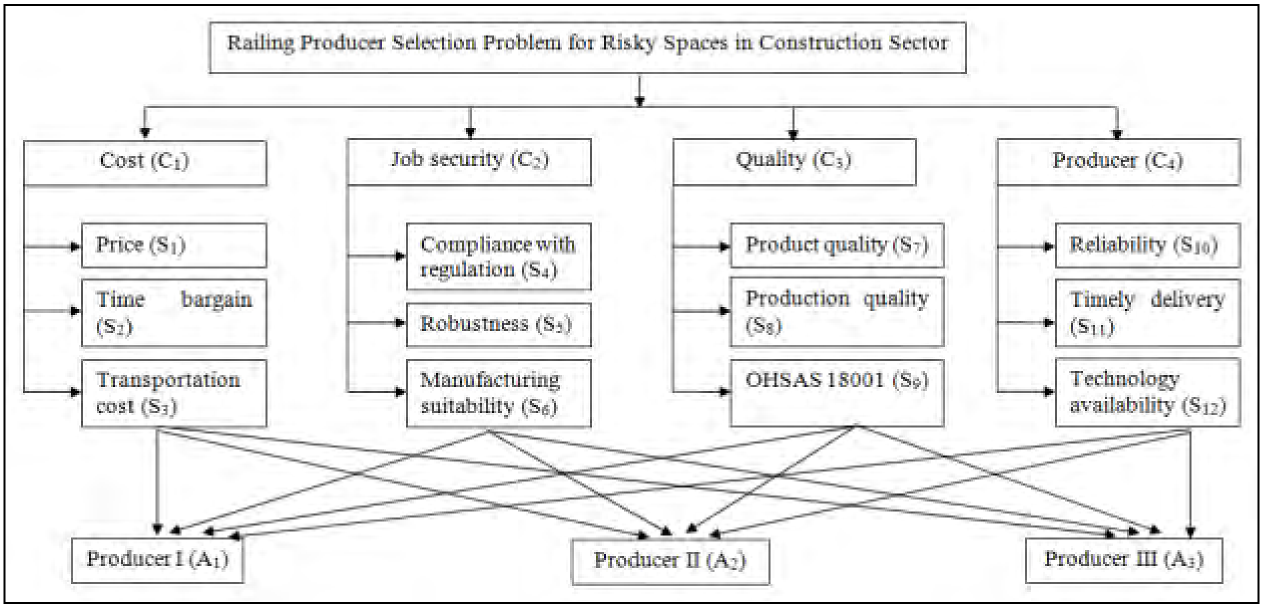

Figure 1. Proposed Model for a Railing Producer Selection Problem

3.1 Proposed Model's Selection Criteria and Sub-criteria

Cost, job security, quality and producer characteristics are the criteria of this study. The criteria are shown by C_i ($i = 1, 2, 3, 4$), sub-criteria are shown by S_j ($j = 1, 2, \ldots, 12$) and alternative railing producers are symbolized by A_k ($k = 1, 2, 3$). The criteria and sub-criteria which are categorized and are examined in this paper were formed by the experts from construction sector.

Cost (C_1) criterion consists of price (S_1), time bargain (S_2) and transportation cost (S_3); Job security (C_2) criterion consist of compliance with regulation (S_4), robustness (S_5) and manufacturing suitability (S_6); Quality (C_3) criterion consist of product quality (S_7), production quality (S_8), OHSAS 18001 (S_9); Producer characteristics (C_4) criterion consist of reliability (S_{10}), timely delivery (S_{11}) and technology availability (S_{12}) sub-criteria.

This paper is the first study in literature which consists OHSAS 18001 sub-criterion. Although, in literature there are a few studies which consist job security as a criterion but there is no knowledge about OHSAS standards in these papers.

3.2 Railing producer alternatives for risky spaces in construction sector

According to hierarchical model, above explained criteria help in determining the most appropriate railing producer for a construction project. In our study, three alternative producers for a railing are evaluated depending on our proposed model's criteria.
The judgments are made by 3 professionals one of them is A class job security specialist/Forest industry engineer, one of them is A class job security specialist/Geophysical engineer and one of them is B class job security specialist/Machine engineer.

4. TWO DIFFERENT SOLUTIONS WITH TRIANGULAR NUMBERS

In this paper, two different solution methods are used for solving our hierarchical model such as AHP and ANP with linguistic variables under fuzzy environment. They are the most effective methods for determining the relative weights of the different criteria (Peniwati, 2007; Beltran et al., 2013; Chung et al., 2005). These methods' application steps are simple and easily accessible for. In this section, the methodologies' application steps are performed respectively. The results are compared at the end of the section.

4.1 The first solution with fuzzy AHP

In a solution step, we use Chang's (1996) extent analysis method. This method is easier than other fuzzy AHP approaches because of its application steps. Dağdeviren et al. (2007)'s paper was explained Chang's (1996) extent analysis approach' steps. We took the application steps from this paper.

First of all we evaluated the criteria to respect the goal, and then evaluated all sub-criteria to respect the criteria which they belong to and at the end we assessed three alternatives with sub-criteria and criteria's weights. We used questionnaires for all comparisons. Table 1 shows the fuzzy evaluation matrix for all criteria.

Table 1. The Fuzzy Evaluation Matrix for Criteria

	Cost	Job security	Quality	Producer characteristics
Cost	1, 1, 1	2/5, 1/2, 2/3	2/3, 1, 3/2	3/2, 2, 5/2
Job security	3/2, 2, 5/2	1, 1, 1	3/2, 2, 5/2	5/2, 3, 7/2
Quality	2/3, 1, 3/2	2/5, 1/2, 2/3	1, 1, 1	3/2, 2, 5/2
Producer characteristics	2/5, 1/2, 2/3	2/7, 1/3, 2/5	2/5, 1/2, 2/3	1, 1, 1

$W_G = (0.18, 0.55, 0.18, 0.09)^T$.

After evaluating the criteria to respect the goal then all sub-criteria were evaluated. The pairwise matrixes are shown in Table 2-5 for all sub-criteria.

Table 2. Evaluation Matrix for Cost

	Price	Time bargain	Transportation cost
Price	1, 1, 1	3/2, 2, 5/2	3/2, 2, 5/2
Time bargain	2/5, 1/2, 2/3	1, 1, 1	2/3, 1, 3/2
Transportation cost	2/5, 1/2, 2/3	2/3, 1, 3/2	1, 1, 1

$W_C = (0.70, 0.15, 0.15)^T$.

Table 3. Evaluation Matrix for Job Security

	Compliance with regulation	Robustness	Manufacturing suitability
Compliance with regulation	1, 1, 1	2/5, 1/2, 2/3	2/3, 1, 3/2
Robustness	3/2, 2, 5/2	1, 1, 1	3/2, 2, 5/2
Manufacturing suitability	2/3, 1, 3/2	2/3, 1/2, 2/3	1, 1, 1

$W_{JS} = (0.15, 0.70, 0.15)^T$.

Table 4. Evaluation Matrix for Quality

	Product quality	Production quality	OHSAS 18001
Product quality	1, 1, 1	3/2, 2, 5/2	5/2, 3, 7/2
Production quality	2/5, 1/2, 2/3	1, 1, 1	3/2, 2, 5/2
OHSAS 18001	2/7, 1/3, 2/5	2/5, 1/2, 2/3	1, 1, 1

$W_Q = (0.82, 0.16, 0.02)^T$.

Table 5. Evaluation Matrix for Producer Characteristics

	Reliability	Timely delivery	Technology availability
Reliability	1, 1, 1	2/3, 1, 3/2	3/2, 2, 5/2
Timely delivery	2/3, 1, 3/2	1, 1, 1	3/2, 2, 5/2
Technology availability	2/5, 1/2, 2/3	2/5, 1/2, 2/3	1, 1, 1

$W_{PC} = (0.06, 0.47, 0.47)^T$.

The sensitivity analysis ratio which is the condition that determines the consistency of the most appropriate railing producer selection problem should be less than 0.10 or equal to 0.10. As a result of the

analysis made in the Expert Choice program, the consistency ratio was obtained as 0.07. Thus, it has been clear that the results of the comparisons' evaluations and obtained final results are reliable.
Finally, the producer which has the highest score is the result. It is the most suitable railing producer for construction project in Turkey according to our proposed model structure. Table 6 shows the results.

Table 6. Main Sub-criteria of the Goal

	Cost	Job security	Quality	Characteristics	Alternative priority weight
Criteria weights	0.18	0.55	0.18	0.09	
Producer I	0.63	0.35	0.06	0.61	0.37
Producer II	0.25	0.47	0.48	0.35	**0.42**
Producer III	0.12	0.18	0.46	0.04	0.21

From Table 6, analyzing priority weights for criteria's, sub-criteria's and alternative railing producers' combination to decide priority weights, obviously the second alternative is the most suitable railing producer according to our proposed model.

4.2 The second solution with fuzzy ANP

In fuzzy ANP methodology interdependent weights of the criteria are calculated and evaluated. In Fig. 2 there is an ANP structure for our proposed model for inner-relationships among criteria. The pairwise comparison matrix is formed for quality (Table 7). Similar calculations are also repeated for the other criteria (Table 8-10). The steps of the proposed fuzzy ANP methodology are taken from Ertay et al.'s (2005) paper.

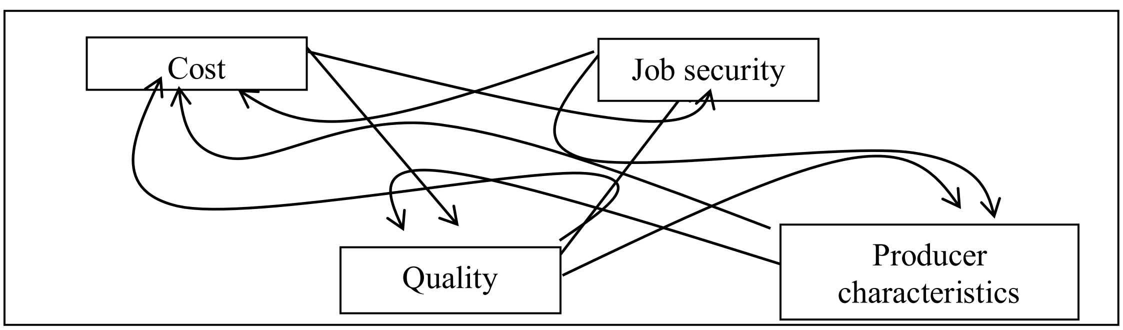

Figure 2. Inner-Relationships among Criteria for Our Proposed Model

Table 7. Criteria's Comparison Matrix for Cost

	Job security	Quality	Producer characteristics
Job security	1, 1, 1	2/7, 1/3, 2/5	2/5, 1/2, 2/3
Quality	5/2, 3, 7/2	1, 1, 1	3/2, 2, 5/2
Producer characteristics	3/2, 2, 5/2	2/5, 1/2, 2/3	1, 1, 1

$W_1 = (0.16, 0.82, 0.02)^T$.

Table 8. Criteria's Comparison Matrix for Job Security

	Cost	Quality	Producer characteristics
Cost	1, 1, 1	2/3, 1, 3/2	3/2, 2, 5/2
Quality	2/3, 1, 3/2	1, 1, 1	3/2, 2, 5/2
Producer characteristics	2/5, 1/2, 2/3	2/5, 1/2, 2/3	1, 1, 1

$W_2 = (0.47, 0.47, 0.06)^T$.

Table 9. Criteria's Comparison Matrix for Quality

	Cost	Job security	Producer characteristics
Cost	1, 1, 1	2/5, 1/2, 2/3	2/3, 1, 3/2
Job security	3/2, 2, 5/2	1, 1, 1	3/2, 2, 5/2
Producer characteristics	2/3, 1, 3/2	2/5, 1/2, 2/3	1, 1, 1

$W_3 = (0.15, 0.70, 0.15)^T$.

Table 10. Criteria's Comparison Matrix for Producer Characteristics

	Cost	Job security	Quality
Cost	1, 1, 1	2/5, 1/2, 2/3	2/5, 1/2, 2/3
Job security	3/2, 2, 5/2	1, 1, 1	2/3, 1, 3/2
Quality	3/2, 2, 5/2	2/3, 1, 3/2	1, 1, 1

$W_4 = (0.06, 0.47, 0.47)^T$.

We used computed relative importance weights for forming the dependence matrix of the criterion. We multiplied the dependence matrix of the criteria for a calculation of interdependent weights of the criteria. The factors' interdependent weights were calculated as below:

$$\begin{bmatrix} Cost \\ Job\,\mathrm{security} \\ Quality \\ \mathrm{Pr}\,oducercharacteristics \end{bmatrix} = \begin{bmatrix} 1.00 & 0.47 & 0.15 & 0.06 \\ 0.16 & 1.00 & 0.70 & 0.47 \\ 0.82 & 0.47 & 1.00 & 0.47 \\ 0.02 & 0.06 & 0.15 & 1.00 \end{bmatrix} \otimes \begin{bmatrix} 0.18 \\ 0.55 \\ 0.18 \\ 0.09 \end{bmatrix} = \begin{bmatrix} 0.24 \\ 0.37 \\ 0.31 \\ 0.08 \end{bmatrix}$$

After interdependent weights of criteria calculations, some differences are observes in results which was shown in Table 6. The weight value was changed from 0.18 to 0.24 for cost, 0.55 to 0.37 for job security, 0.18 to 0.31 for quality and 0.09 to 0.08 for producer characteristics.

In the last step of the method, global weights are calculated for all sub-criteria by using interdependent weights of the criteria and local weights sub-criteria. We multiplied the local weight of the sub-criteria with the interdependent weight of the criterion to which it belongs for calculating the global sub-criteria weights by. In Table 11 shows the computed values.

Table 11. Sub-criteria's Global Weights

Local weights of criteria		Sub-criteria	Local weights	Global weights
Cost	0.24			
		Price	0.70	0.17
		Time bargain	0.15	0.04
		Transportation cost	0.15	0.04
Job security	0.37			
		Compliance with regulation	0.15	0.06
		Robustness	0.70	0.26
		Manufacturing suitability	0.15	0.06
Quality	0.31			
		Product quality	0.82	0.25
		Production quality	0.16	0.05
		OHSAS 18001	0.02	0.00
Producer characteristics	0.08			
		Reliability	0.06	0.00
		Timely delivery	0.47	0.04
		Technology availability	0.47	0.04

Finally, according to the reflection of the interrelations within the criteria, the overall priorities of producers are calculated as follows:

$$[\text{Producers' sub-criteria weights}] \otimes [\text{Global weights of sub-criteria}] = \begin{bmatrix} 0.35 \\ 0.41 \\ 0.24 \end{bmatrix}$$

We analyzed the same hierarchical proposed model with fuzzy ANP. Due to the fuzzy ANP analysis, optional producers were ordered as Producer II, Producer I and Producer III as the same fuzzy AHP solution. Table 12 and Fig. 3 show the comparison results.

Table 12. The Comparison of the Results both in AHP and ANP

	Producer I	Producer II	Producer III
AHP weights	0.37	0.42	0.21
AHP ranking	2	**1**	3
ANP weights	0.35	0.41	0.24
ANP rankings	2	**1**	3

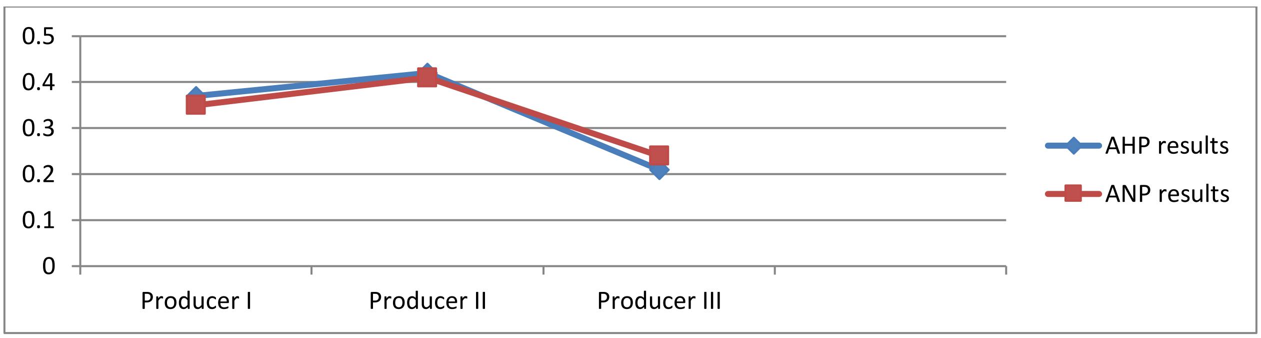

Figure 3. The Comparison of Fuzzy AHP and Fuzzy ANP Results

5. CONCLUSION

Railing producer selection for risky spaces is very important problem in construction sector. That's why this problem must be examined by the construction professionals in detail. In this paper we proposed a model for selection of the best railing producer for our sample company's project with fuzzy AHP and fuzzy ANP approaches.

The results produced by two MCDM methods were compared. The main criteria and sub-criteria were decided and each factor affecting the selection strategies were analyzed and discussed.

In conclusion, Producer II is the most preferred producer according to the final score both fuzzy AHP analysis and fuzzy ANP analysis. Because it has the highest priority weight score and Producer I is the next recommended one after Producer II.

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AIR CARGO TRANSPORTATION AND EVALUATION OF SITUATION IN TURKEY

İlhan ATİK[1]

Abstract – *Consumers all over the world want to meet the goods and services they need as soon as possible and cheaper than others. All over the World, only 1% of the goods are carried by air cargo operations in one year. However, the economic value of these goods is 35% of all goods. Countries with intensive air cargo connections in different countries have the advantage of economic growth and a 1% increase in air cargo volume is caused by a 6.3% increase in total exports and imports. Although our country is one of the greatest economies in the world, our country is not at the desired place in the global air cargo market. In the air cargo transportation of our country; due to its geographical location, it is possible to transport high-volume transit cargoes. As a political approach to increase this, it is necessary to make a commitment to become a global player by making bilateral air transport agreements. It is important for our country to reach the desired level of air cargo transportation in the future. In this study; Our country, which has the potential of rapid growth in a short period of time by using the advantage provided by its geographical location, will be tried to express expectations about the future by evaluating air Cargo transportation.*

Keywords – *Air Cargo, Aviation Sector, Global Trade, Transportation.*

INTRODUCTION

The definition of air Cargo is the transportation of any goods, except passenger luggage, from one place to another by air. In connection with this, air cargo transportation is the packaging, labeling, preparation of documents in accordance with ICAO and IATA regulations of all goods except postal and baggage, taking into account the country and carrier restrictions, and being shipped by an aircraft [1].

Recently, global trade has played a key role in encouraging collaboration and economic development. It also makes countries more competitive and productive. Global trade supports the growth of income and the reduction of poverty by playing a key role in making the countries more efficient. Trade accelerating with globalization is greater three times the level it was in the early 1950s. Air cargo in global trade is an important stakeholder. Air cargo transportation has become one of the important components of this growth. Because the concept of speed is one of the main determinants of global competition in the stages of goods reaching the market from the producers and reaching the consumer from the market. For this reason, the transportation of goods by air has played an important role in world trade. In the study published by ATAG (The Air Transport Action Group) in 2016, it was stated that the work carried out in the aviation sector was 3.8 times more efficient than other works. The development in the aviation sector has helped to make activities more efficient in many sectors with information transfer and other functions [2].

While the World Trade Organization has used many approaches to measure the level of economic development of countries, a new approach, referred to as Global Value Chains (GVC), has recently come to the forefront. GVC means that; countries specialize in narrowly defined tasks such as research, development or assembly. It refers to the level of development of countries in the integrated business network, which enables them to produce products with high added value such as cars, computers, mobile phones and airplanes, using the goods obtained from other countries with the acquired ability. The World Trade Organization estimates that since the 1990s, half of global trade has been achieved through the sale of materials used in the production of high value-added products. In IATA report about "Air Transport and Global Value Chains", it is estimated that countries with intensive air cargo links to different countries have higher GVC values, 1% increase in air cargo volume, 6.3% increase in total exports and imports [3].

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In addition, passenger income decreased over time, and the passenger demand for the market was unsatisfactory, which led airline carriers to turn to the cargo market. Worldwide increase in cargo volume has increased the importance of effective management of cargo capacity. The aviation industry, which is one of the biggest contributors to global refinement, is able to accelerate investments by accelerating production by carrying more than 3,57 billion passengers and 52,2 million tonnes of cargo in 2016.

The global economic impact of aviation, which provides employment for 9,9 million people from direct and totaly 62,7 million people, is stated as 664 billion dollars. The aviation sector, which accounts for 3,5 % of the gross domestic product, provides countries with long-term development [4].

In 2015, airlines transported 52.2 million metric tons of goods valued at USD 5.6 trillion. Air Cargo is key in supporting the current global trading system, with an estimated 35% of value of global trade carried by air that is less than 1% by volume [5]. Similarly, air cargo has doubled every 10 years since 1970, and this trend is expected to continue at an average growth rate of over 6% per year over the next 20 years, according to Boeing's World Air Cargo Forecast. These expectations are also influenced by the emergence of integrated on-time production, logistics networks, and rapid development of electronic commerce at global level [6].

In our country, Airline companies operating in the sector have increased after the legal arrangements made since 2003. After these arrangements, the aviation sector grew rapidly, infrastructure and fleet investments increased, the number of connections increased, and the prices of the tickets were cheaper. In the period of 2003-2015, the aviation sector in Turkey grew by 15% on average, while the world aviation sector grew by an annual average of 5%. While the number of employees working in the sector in our country was around 65 thousand in 2003, it exceeded 187 by the end of 2014. In the last twelve years, the total sector of the industry has increased by 12 times to reach 26.6 billion dollars from 2.2 billion dollars. According to the ICAO annual report; Turkey is ranked 10th in the RPK (Revenue Per Kilometer) order, 11th in the RTK (Revenue Ton-Kilometer) order and 14th in the FTK (Freight Ton-Kilometer) order. Also; Our country ranks 3rd in Europe and 9th in the world in passenger rankings [7].

In the study; It will firstly be expressed as a special structure that separates air cargo transport from other transport modes. The factors affecting this mode will be explained and the potential and problems regarding the development of the sector will be expressed by evaluating our country in terms of world air cargo transportation.

STRUCTURES AND EFFECTS OF AIR CARGO TRANSPORTATION

The rapid communication and internet development resulting from the change in information technology at global level has led to major changes in all industries including the air cargo transportation sector.

Parallel to the change in technology, international transit lines and the change in the aviation sector also have an important place in investment decisions of companies operating globally [8].

When the factors affecting and directing air transportation activities in the world are examined;

- International political relations,
- Economic, political and military organizations in which the countries are members,
- Economic liberalization movements,
- Economic trends at global level,
- Consumer expectations and educational opportunities can be evaluated in this context [9].

The marketing of industrial products, their transport to target markets, human interactions, electronic commerce and the free movement of goods / services as a result of globalization are also important variables in terms of air cargo transport. Globalization has been a developing element for air cargo transport.

Advantages of aır cargo system compared to other transportatıon methods are listed below;

- Shortening the delivery time by carrying it at high speed,
- Thus saving customers from the storage problem,

- It is the most protected transportation option of many risks that may result in damage to property due to stealing, theft and abduction events in traffic accidents due to providing safe services and similar reasons,
- Using the global airport network to operate in many geographies close and far,
- Internationally recognized high safety and security applications,
- Use of high quality equipment and personnel for loading, unloading,
- Effective time management in planned and unplanned transport,
- Insurance premium cost is more efficient [10].

Air cargo transportation has all the advantages listed above but also negative aspects. These are listed below.

- Weight and volume limitations of cargo carrying aircraft,
- More rapidly affected by climate conditions than other transport modes,
- Fixed capital investments and operating costs are more expensive than others,
- Air cargo carriage does not have a line balance like passenger carriage,
- Short-distance transport is not cost effective compared to other modes of transport,
- To be extremely sensitive to fuel prices,
- This sector needs a strong financial structure and an effective vocational education structure due to its capital and qualified labor-intensive structure.

In the study by Gökduman (2006) is mentioned that the tonnage cost per kilometer of scheduled passenger and freight transport costs is quite high compared to all other modes of transport. Only in the case of freight aircraft, this cost is quite low, but it is still high compared to other modes [11]. The labor and fuel costs constitute 60% of the operating costs in the air cargo transportation when the specialist staff in the air cargo sector is higher than the other sectors and the costs arising from the whole employees being subject to specific training are taken into consideration [12].

Considering the strengths and weaknesses of air cargo transport, it is used especially for transporting the listed below.

- Transporting loads such as fish, fruit, vegetables and flowers to distant places in a short time,
- Horse, zoo animals, live animal transportation,
- Transportation of Gold, platinum, precious metal, art works and valuable documents in a safe way,
- Transportation of machine spare parts, motors, generators, etc., for emergency operations,
- Transportation of measuring equipment, optical and electronic devices.

EVALUATION OF AIR CARGO TRANSPORTATION IN OUR COUNTRY

Aviation Sector In Turkey

Facilities enabling the development of air cargo transport in the world and our country can be counted as: Regular growth of countries' gross domestic product, growing efficiency of trade liberalization agreements and international organizations, commercial liberalization, open-airspace agreements, commercial relations, manufacture of wide-body cargo aircraft, start-up of private air cargo institutions and consideration of just in-time production as an important aspect of global competition. In addition; commercial quotas and embargo, economic crises, environmental regulations, inadequate access to airport, high costs, terrorism and wars, legal regulations and inadequate physical infrastructure are some other problem areas for development of air cargo transportation [13].

In the report on the forecasts of the period 2016-2017 by the Boeing company, it is stated that air cargo transport is adversely affected by the slow growth in the global economy, but for the next five years a rapid growth trend will be achieved, especially with the rapid growth experienced in global electronic commerce [14]. According to the report, it is expected that RTK (Toll-Ton-Kilometer) air cargo load will grow by 4.3% per annum during the next 20 years by 2035 and it will reach 509 billion RTK in 2035 from 223 billion RTK in 2015. In addition, it is stated that the number of cargo planes can increase by more than 70% in this period and reach to 3010 planes from 1770 flights.

In a report prepared by Boeing company for 2015, it is stated that the air Cargo transportation increased by 1.9% globally; in regional level, it increased by 6.5% in Asia-North America and Europe-Asia, 1.8% in Europe-North America; and decreased by 4.1% in South Asia-Europe and Latin America-North America regions [15]. In this statistic, the 7.4% increase realized by our country represents a very important value.

The airline sector in Turkey has performed three times as much as the world average in terms of growth. On a global scale, while the growth rate of the industry over the last twelve years is around 5%, Turkey has grown by 15%. Employment in the sector in Turkey exceeded 187,000 by the end of 2014, the total giro reached 26.6 billion dollars; airline sector kept its growth acceleration with the increase in in the number of airports, aircrafts and passengers in our country. The number of active airports in our country reached 55 in 2015, the number of domestic passengers reached 102.5 million and the total number of passengers using airways reached 173.7 million at the end of 2016. The total number of aircrafts, which was 162 in 2003, reached 489 by the end of 2015, seat capacity reached 90.259 from 27.599, and cargo capacity reached 1.967.820 kilograms from 302.737 [16] . According to statistics of Directorate General of Civil Aviation, the general air cargo traffic in Turkey between the years between 2010-2016 are listed below [17].

Table 1: General Air Cargo Traffic in Turkey (2010-2016)

YEAR	DOMESTIC (TON)	INTERNATIONAL (TON)	TOTAL (TON)
2010	71.218	470.141	541.359
2011	76.268	508.204	584.472
2012	84.431	539.627	624.058
2013	100.097	631.864	731.961
2014	104.941	734.300	839.241
2015	101.447	803.314	904.761
2016	81.587	951.356	1.032.943

Air cargo transportation in our country is developing with economic developments in the same direction and will be the center of Istanbul Atatürk Airport. According to the data provided by the Directorate General of Civil Aviation, in 2016, air cargo traffic increased by 14,2% compared to the previous year, and the biggest share in this increase is in the amount of international Cargo. Air cargo transportation in Turkey has increased its efficiency by increasing its flight points and cargo transportation has been made to 552 flight points abroad from our country airports. Countries and continents with the most transport in 2015;

- European continent is on the lead, the transportation was made mostly to Germany.
- Asian continent ranks second, the transportation was made mostly to China in this continent.
- Middle East ranks third, the transportation was made mostly to United Arab Emirates in this continent.
- In the fourth line is North America, the transportation was made mostly to United States in this continent.
- In the fifth line is Africa, the transportation was made mostly to Nigeria in this continent.
- In the fifth line is South America, the transportation was made mostly to Brasil in this continent.
- Russia ranks seventh.

918,136 tons of cargo, 88,88% of the cargo carried, was moved from İstanbul Atatürk Airport. 93% of this cargo movement was carried out on international flights, 40% on cargo-only flights and 60% on passenger cargo flights.

Table 2: Cargo Aircraft List Of Institutions Which Transport Air Cargo In Our Country (31.12.2016)

INSTITUTION	Cargo Airplane	Quantity	Capacity (KG)	Total Capacity (KG)
Turkish Airlines	A330-200F	9	69.000	621.000
	A310-300F	2	38.610	77.220
ACT Airlines	B747-400	7	113.575	795.025
MNG Airlines Transportation	A300-C4-605R	4	47.250	189.000
	A300B4-600R	2	47.000	94.000
	A330-200F	1	70.000	70.000
ULS Airlines Cargo	A310-300	3	40.525	121.575

In our country, there are 13 air carriers which are cargo or freight forwarders in the civil aviation sector, with 28 cargo aircraft with a total cargo capacity of 1.967.820. The institutions which deal with air cargo transportation in Turkey can be listed as Turkish Cargo, established within the Turkish Airline, MNG Airlines Transportation, ACT Airlines and ULS Airlines Cargo. Table 2 contains a list of the cargo aircraft owned by these enterprises [18]-[19].

The Obstacles for The Development of Aviation Sector in Our Country and Solution Proposals

Considering its geopolitical importance, Turkey, the world's 18th largest economic power [20]; is in the middle of a region with high market volume. Our country has the easiest transportation opportunity to European Union, with a population of about 600 million and a gross national product of about 18 trillion dollars; to Russian Federation with a population of 140 million and a gross national product of about 1.3 trillion dollars; and to North Africa and Middle East with a population of 600 million and a gross national product of about 3.5 trillion dollars.

However, when we evaluate together the statistics mentioned above regarding air cargo transportation in the world and our country, it is seen that the geopolitical advantages of our country do not reflect this sector effectively.

Table 3: The Most Effective Airports In Terms Of Air Transportation In European Region (2013-2014)

AIRPORT	2013 Air Cargo (1000 TON)	2014 Air Cargo (1000 TON)	Shift (%)
1.Frankfurt	2094,7	2013,6	1,76
2.Paris (Charles de Gaulle)	1494,9	2033,2	36,01
3.Amsterdam (Schiphol)	1566,0	1670,7	6,69
4.Londra (Heathrow)	1513,9	1585,9	4,77
5.Leipzig (Halle)	877,3	904,1	3,06
6.Köln-Bonn	721,7	736,4	2,04
7.İstanbul (Atatürk)	630,7	728,5	15,5

According to Tablo-3 Istanbul Atatürk Airport could only rank seventh among the busiest airports in terms of air Cargo in European Region. In 2015, only 904 thousands of 522 million tonnes of cargo transported by air around the world were transported by our country. This shows that the share of our country in the air cargo transportation market is only 1.73% [21].

When the sector is examined in terms of the development of air cargo transportation in our country, the obstacles to the sector are below;

- A major cost factor for air cargo shipping companies is the fleet setup and the purchase of new aircraft,
- In the use of old aircraft, depending on the age of the aircraft, many airports are restricted due to noise and air pollution during landing and departure times,
- The limitations of cargo aircraft and the different characteristics of the cargo to be transported require that the cargo businesses have many different types of aircraft types,

- Such an approach would require investments that even big airline operators would have difficulty financing,
- The economic and political crises that may be faced at any time on the global and regional level affect the sector adversely,
- The problems caused by the bureaucracy and retards the solution, (The General Directorate of Civil Aviation, The Ministry of Interior, Ministry of Transport, Maritime Affairs and Communications, Mınıstry of Customs and Trade etc)
- Inability to achieve full compliance between legislation, infrastructure and personnel to speed up transit cargo operations,
- The fact that airports do not have infrastructure suitable for intermodal transport between air / road / rail and maritime transport,
- Although 66% to 75% of the air cargo in the world and Turkey is carried by passenger aircraft, while our country's airports are structured to manage passenger traffic, they can not provide adequate infrastructure for cargo operations [22].

Within this scope; the absence of an autonomous authority for accelerating the bureaucratic process of air cargo transport and effective legislation, inadequacy of customs, airport standards, infrastructure, equipment and qualifications, and the current fleet structure are obstacles to the global competition of our country.

CONCLUSION AND EVALUATION

Rapid change in technology leads to worldwide increase of communication and e-commerce, and thus the production-consumption concept gains international character. International trade goes with competition, speed, the right time and low cost.

Air cargo transportation is used effectively on a global scale in transporting all kinds of raw materials and intermediate goods which provide high added value in this struggle environment.

Within this scope; solutions to solve the problems are;

- Establishment of a ministry-level structure of all aviation activities in one hand in terms of rapid mobility required by global competition and geographical location,
- In the decision to create a fleet; cost accounting, new technology, range and fuel consumption should be considered,
- Establishment of infrastructural facilities where intermodal transportation between airway / road / railway and maritime transport becomes feasible,
- The regulation of the customs legislation of our country to cover the issues related to transit goods,
- Making airports serving only cargo operations,
- Improving the infrastructure suitable for cargo services in airports providing both passenger and cargo service
- Automation in all customs procedures,
- Carrying out transactions with educated employees,
- The construction of warehouses that can serve in international standards.

In the air cargo transportation of our country; due to its geographical location, it is possible to transport high-volume transit cargoes. As a political approach to increase this, it is necessary to make a commitment to become a global player by making bilateral air transport agreements. Especially, the 3rd airport, which is built in Istanbul, It is important for our country to reach the desired level of air cargo transportation in the future.

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AN EXACT ALGORTIHM FOR TWO-ECHELON VEHICLE ROUTING PROBLEM WITH SIMULTANEOUS PICKUP AND DELIVERY

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***Abstract* –** *Due to legal restrictions and environmental considerations multi-echelon distribution systems are widespread in distribution systems. Vehicle routing problem is an important area and solution to this problem has an important effect on the efficiency of the distribution system. In this study, two-echelon vehicle routing problem with simultaneous pickup and delivery (2E-VRPSPD) is considered. The considered distribution system has simultaneous pickup and deliveries in two echelons and satellites (intermediate depots) are capacitated. A node-based formulation is used to model the system and valid inequalities are utilized to strengthen the model. To obtain optimal solutions an exact method, cutting plane algorithm, is developed. The performances of proposed mathematical model and cutting plane algorithm and effects of valid inequalities are analyzed using test problems. According to the experimental analysis proposed cutting plane algorithm provides increase in solution quality.*

***Keywords* –** *Cutting Plane Algorithm, Simultaneous Pickup and Delivery, Two-Echelon Vehicle Routing Problem*

INTRODUCTION

In recent years, application areas of multi-echelon distribution systems are widespread because of the traffic congestion and environmental problems. Many application areas of multi-echelon distribution systems can be encountered in logistics enterprises and express delivery service companies, multi-modal freight transportation, grocery and hypermarkets products distribution, city logistics, etc. In these distribution systems all movements in the urban distribution with big and small vehicles in both echelons are considered as a whole and optimized simultaneously. One of the main problem areas in distribution systems is vehicle routing problem (VRP) and it has an important effect for an efficient distribution system. The most common type of multi-echelon distribution systems is two-echelon systems.

As the one kind of the VRP operations simultaneous pickup and delivery considers delivery and pickup activities at the same time by the same vehicle. All delivered goods are originated from the depot and all pickup goods are transported back to the depot in a simultaneous pickup and delivery system.

In this study, two-echelon vehicle routing problem with simultaneous pickup and deliveries (2E-VRPSPD) in two echelons with capacitated satellites is considered. A two index node-based mathematical model is developed for the problem and valid inequalities are used to strengthen the mathematical model. Then, a cutting plane algorithm (CPA) is proposed solve this NP-hard problem. In order to evaluate the performance of the proposed formulation and the CPA, small, medium and large size test instances are solved which are derived from the literature.

The rest of the paper is organized as follows. A literature review is presented of related work after the introduction and then problem definition, mathematical model and valid inequalities are given for 2E-VRPSPD. After that a detailed explanation for proposed cutting plane algorithm is given. Following section reports computational results of the experimental study and last section contains conclusion and future directions on the subject.

LITERATURE REVIEW

To the best of our knowledge, this is the first study considering simultaneous pickup and delivery activities in two-echelon VRP. Since the 2E-VRPSPD is not studied previously in the literature, we review the literature on 2E-VRP. The problem is introduced by Crainic et. al [1] as a new problem class for city logistics and general formulation for the problem is given in the paper. Studies on different type of 2E-VRP can be

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classified as exact algorithms, heuristic algorithms, and matheuristics according to the solution approaches. Studies using exact algorithms can be ordered as for 2E-VRP; branch and cut algorithm (Jepsen et al. [2], Perboli [3]), decomposition algorithms with a limited set of multi depot capacitated vehicle routing problems with side constraints (Baldacci et al. [4]), branch and price algorithm (Santos et.al [5]), integrated approach of mathematical programming and constraint programming (Sitek and Wikarek [6]), and mixed integer linear programming for the problem with environmental considerations (Soysal et al. [7]). The studies using heuristic algorithms are; clustering based heuristic (Crainic et.al [8]), fast clustering heuristic (Crainic et.al [9]), hybrid ant colony optimization algorithm (Meihua et al. [10]), adaptive large neighborhood search algorithm (Hemmelmayr et al.[11], Grangier et al. [12]), genetic algorithm and tabu search (Kergosien et al. [13]), large neighborhood search (Breunig et al.[14]), GRASP+VND (Zeng et al. [15]), memetic algorithm (Cetinkaya et al [16]), hybrid genetic algorithm (Ahmadizar et al. [17]) and GRASP with path relinking (Crainic et.al [18]). There is only one study using matheuristic by Perboli et al. [19]. Except from these studies, Crainic et al [20]. introduce a model with generalized travel cost that combines different components, such as operational, environmental, congestion, etc. for 2E-VRP.

TWO-ECHELON VEHICLE ROUTING PROBLEM WITH SIMULTANEOUS PICKUP AND DELIVERY

This section presents the definition of the 2E-VRPSPD, proposed two-index node based mathematical model and valid inequalities used to strengthen the model.

Problem Definition

The definition of the 2E-VRPSPD can be given as follows: $G=(N,A)$ is a complete directed network where N is the set of nodes and A is the set of arcs. N contains three subsets where N_0 is the set of depots, N_D is the set of satellites and N_C is the set of customers. The set of arcs A consists of the set of arcs between depot and satellites $(A_1=\{i,j\}, i \neq j \text{ ve } i,j \in N_0 \cup N_D)$ and the set of arcs between satellites and customers $(A_1=\{l,m\}, l \neq m \text{ ve } l,m \in N_C \cup N_D)$. Each arc (i,j) has a nonnegative cost (distance) c_{ij} in the first echelon and each arc (l,m) has a nonnegative cost (distance) c_{lm} in the second echelon. Each customer has delivery demand D_l and pickup demand P_l, each satellite has delivery demand D_i and pickup demand P_i. Delivery and pickup demands of the satellites are not known at the beginning and these demands for each satellite can be calculated after assignment of the customers to corresponding satellites. An unlimited fleet of homogeneous vehicles serve with the capacity of CV_1 in the first echelon and with the capacity of CV_2 in the second echelon and $CV_1 > CV_2$. The satellites have capacity of CD_i.

The problem is the assignment of customers to satellites at second echelon and to determine the vehicle routes with minimum total cost in first and second echelon under these assumptions: number of the customers and the satellites are known, demand of each customer is known and these demands are independent, satellites fulfill the demands of customers and depot fulfills the demands of satellites, single commodity is taken account, reorder does not allowed and transportation of the freights directly to the customers from depot does not allowed.

The constraints of the problem are depicted as: each vehicle is assigned to at most one route, each customer is served by exactly one vehicle, each route begins and ends at the depot in the first echelon, each route begins and ends at the same satellite in the second echelon, the total vehicle load at any point of the route does not exceed the vehicle capacity in each echelon.

Mathematical Formulation

To solve the problem, a two-index node-based mathematical model developed and the subtour elimination and vehicle capacity restrictions used in the model are the lifted version of the Miller-Tucker-Zemlin (MTZ) constraints proposed by Kara et. al [21]. The decision variables used to formulate the model are as follows:

$$x_{ij} = \begin{cases} 1, & \text{if a vehicle travels directly from node } i \text{ to node } j \text{ at first echelon } (\forall i, j \in N_0 \cup N_D) \\ 0, & \text{otherwise} \end{cases}$$

$$y_{lm} = \begin{cases} 1, & \text{if a vehicle travels directly from node } l \text{ to node } m \text{ at second echelon } (\forall l, m \in N_D \cup N_C) \\ 0, & \text{otherwise} \end{cases}$$

$$z_{li} = \begin{cases} 1, & \text{if customer } l \text{ is assigned to satellite } i \ (\forall i \in N_D, \forall l \in N_C) \\ 0, & \text{otherwise} \end{cases}$$

Additional variables used in model are; U_i, delivery load on vehicle just before having serviced satellite *i* ($\forall i \in N_D$); U_l, delivery load on vehicle just before having serviced customer *l* ($\forall l \in N_C$); V_i, pickup load on vehicle just before having serviced satellite *i* ($\forall i \in N_D$) and V_l; pickup load on vehicle just before having serviced customer *l* ($\forall l \in N_C$).

The two-index node-based mathematical of the 2E-VRPSPD is given below:

$$\min \sum_{i \in N} \sum_{j \in N} c_{ij} x_{ij} + \sum_{l \in N} \sum_{m \in N} c_{lm} y_{lm} \quad (1)$$

Subject to

$$\sum_{j \in N} x_{ij} = 1 \qquad \forall i \in N_D \quad (2)$$

$$\sum_{j \in N} x_{ij} = \sum_{j \in N} x_{ji} \qquad \forall i \in N \quad (3)$$

$$U_j - U_i + CV_1 x_{ij} \le CV_1 - D_j \qquad \forall i, j \in N_D \quad (4)$$

$$D_i \le U_i \le CV_1 \qquad \forall i \in N_D \quad (5)$$

$$V_i - V_j + CV_1 x_{ij} \le CV_1 - P_j \qquad \forall i, j \in N_D \quad (6)$$

$$P_i \le V_i \le CV_1 \qquad \forall i \in N_D \quad (7)$$

$$U_i + V_i - D_i \le CV_1 \qquad \forall i \in N_D \quad (8)$$

$$D_i + P_i \le CD_i \qquad \forall i \in N_D \quad (9)$$

$$D_i = \sum_{l \in N_C} z_{li} D_i \qquad \forall i \in N_D \quad (10)$$

$$P_i = \sum_{l \in N_C} z_{li} P_l \qquad \forall i \in N_D \quad (11)$$

$$\sum_{m \in N} y_{lm} = 1 \qquad \forall l \in N_C \quad (12)$$

$$\sum_{m \in N} y_{lm} = \sum_{m \in N} y_{ml} \qquad \forall l \in N \quad (13)$$

$$\sum_{i \in N_D} z_{li} = 1 \qquad \forall l \in N_C \quad (14)$$

$$y_{li} \le z_{li} \qquad \forall i \in N_D, \forall l \in N_C \quad (15)$$

$$y_{il} \le z_{il} \qquad \forall i \in N_D, \forall l \in N_C \quad (16)$$

$$y_{lm} + z_{li} + \sum_{s \in N_D, s \ne i} z_{ms} \le 2 \qquad \forall l, m \in N_C, l \ne m, \forall i \in N_D \quad (17)$$

$$U_m - U_l + CV_2 y_{lm} + (CV_2 - D_l - D_m) y_{ml} \le CV_2 - D_l \qquad \forall l, m \in N_C \quad (18)$$

$$D_l + \sum_{m \in N_C} y_{lm} D_m \le U_l \le CV_2 - (CV_2 - D_l) y_{li} \qquad \forall i \in N_D, \forall l \in N_C \quad (19)$$

$$V_l - V_m + CV_2 y_{lm} + (CV_2 - P_l - P_m) y_{lm} \le CV_2 - P_m \qquad \forall l, m \in N_C \quad (20)$$

$$P_l + \sum_{m\in N_C} y_{lm} P_m \le V_l \le CV_2 - (CV_2 - P_l) y_{il} \qquad \forall i \in N_D, \forall l \in N_C \qquad (21)$$

$$U_l + V_l - D_l \le CV_2 \qquad \forall l \in N_C \qquad (22)$$

$$x_{ij} \in \{0,1\},\ y_{lm} \in \{0,1\} \qquad \forall i, j \in N, \forall l, m \in N \qquad (23)$$

$$z_{il} \in \{0,1\} \qquad \forall i, \in N_D, \forall l \in N_C \qquad (25)$$

$$U_i, V_i, U_l, V_l \ge 0 \qquad \forall i, l \in N \qquad (26)$$

In the mathematical formulation, the objective function (1) minimizes the total transportation cost. Constraint set (2) guarantees that each satellite must be visited exactly once and constraint set (3), which is degree constraint, ensures that the number of entering and leaving arcs to each node are equal to each other. Constraint set (4) eliminates sub tours for delivery tours in the first echelon. Constraint set (5) provides lower and upper bounds of the additional variable U_i. Constraint set (6) eliminates sub tours for pickup tours. Constraint set (7) is lower and upper bounds of the additional variable V_i. Constraint set (8) ensures that load transported on route is smaller than the capacity of vehicle in the first echelon. Constraint set (9) guarantees that total pickup and delivery demands of the each satellite are equal or lower than the capacity of each satellite. Constraint sets (10) and (11) are to equalize the total pickup and delivery demands of the customers and satellites. In other words, the sum of the pickup and delivery demands of the customers assigned to each satellite must be equal to the pickup and delivery demands of the corresponding satellite. Constraint set (12) ensures that each customer must be visited exactly once and constraint set (13) guarantees that entering and leaving arcs to each node are equal. Constraint set (14) ensures that each customer must be assigned to only one depot. Constraint sets (15) – (17) prevent the illegal routes, i.e. starting and ending at the different depots. Constraint set (18) eliminates sub tours for delivery tours in the second echelon. Constraint sets (19) is lower and upper bounds of the additional variable U_l. Constraint set (20) eliminates sub tours for pickup tours in the second echelon. Constraint sets (21) is lower and upper bounds of the additional variable V_l. Constraint set (22) ensures that load transported on route is smaller than the capacity of vehicle in the second echelon. Constraint sets (23) to (26) are integrality constraints for decision variables.

Valid Inequalities

To strengthen the mathematical formulation valid inequalities are used which are adopted from the literature. First valid inequality bounds below the number of routes originating from depots.

$$\sum_{k\in N_D} \sum_{m\in N_C} y_{km} \ge r_{2E-VRPSPD}(N_C) \qquad (27)$$

where $r_{2E-VRPSPD}(N_C) = \left\lceil \max\left(\sum_{m\in N_C} d_m ; \sum_{m\in N_C} p_m\right) / CV_2 \right\rceil$ and $\lceil \bullet \rceil$ is the smallest integer bigger than $\bullet$. This valid inequality is firstly used by Achutan, Caccetta ve Hill [22] for vehicle routing problem. In a feasible 2E-VRPSPD solution, the number of routes must satisfy the minimum requirement of delivery and pickup demands separately. In other words, the equations below must be satisfied at the same time [23].

$$\sum_{k\in N_D} \sum_{m\in N_C} y_{km} \ge \left\lceil \sum_{m\in N_C} d_m / CV_2 \right\rceil \qquad (28)$$

$$\sum_{k\in N_D} \sum_{m\in N_C} y_{km} \ge \left\lceil \sum_{m\in N_C} p_m / CV_2 \right\rceil \qquad (29)$$

Second valid inequality is a special case of classical sub-tour elimination constraint of the TSP and ensures that any feasible route does not contain a sub-tour with only two customers [23].

$$y_{mn} + y_{nm} \le 1 \qquad \forall m, n \in N_C \qquad (30)$$

Third valid inequality is adopted for 2E-VRPSPD from a generalized large multi-star (GLM) inequality for VRP (Gouveia [24]; Letchford and Salazar-Gonzalez [25]).

$$\sum_{m\in S} \sum_{n\in N_C / S} y_{mn} \ge (1/CV_2)\left(\sum_{m\in s} d_m + \sum_{m\in S} \sum_{n\in N_C / S} d_m (y_{mn} + y_{nm})\right) \ \forall S \subseteq N_C, S \ne \varnothing \qquad (31)$$

$$\sum_{m\in S}\sum_{n\in N_C/S} y_{mn} \geq (1/CV_2)\left(\sum_{m\in s} p_m + \sum_{m\in S}\sum_{n\in N_C/S} p_m(y_{mn}+y_{nm})\right) \quad \forall S \subseteq N_C, S \neq \emptyset \tag{32}$$

Last valid inequality is derived from capacity and sub tour elimination constraint for VRP (Laporte et al. [26]). This constraint ensures that the number of vehicles visiting a set of customers (*S*) is not less than the lower bound.

$$\sum_{(m,n)\in S} y_{mn} \leq |S| - r_{2E-VRPSPD}(S) \qquad \forall s \subseteq N_C, S \geq 2 \tag{33}$$

where, $r_{2E-VRPSPD}(S)$ is calculated as given in (27).

CUTTING PLANE ALGORITHM

In this section, a Cutting Plane Algorithm (CPA) is proposed to obtain better solutions for 2E-VRPSPD. CPA is a technique which is used to solve integer programming problems and was proposed firstly by Ralph E. Gomory [27] as Gomory cuts. Weakness and slow convergence of Gomory cuts prevent them to use extensively. With the developments in Polyhedral Theory and usage of problem specific cuts, the CPA has become popular again in the integer mathematical programming [27].

The proposed CPA in this study has four main components:

1. *Initial Linear Model:* The initial linear model is obtained by relaxing the mathematical model. To obtain relaxed model, constraints (24) to (26) are relaxed as continuous variables between "0" and "1".
2. *Separation Algorithm:* While polynomial size valid inequalities can be added to mathematical models directly, a special separation algorithm is required for exponential size valid inequalities. To obtain node sets that violate the exponential size valid inequalities, a greedy heuristic has been used as in Karaoglan et al. [23].
3. *Upper Bound:* A good upper bound enables us to reduce number of nodes to explore and obtain solutions faster. For this purpose, in the proposed CPA, a hybrid metaheuristic called VND_LS has been used to obtain upper bounds for the problem. This algorithm is a combination of Variable Neighborhood Descent (VND) and Local Search (LS). To obtain an initial feasible solution, firstly customers are assigned to satellites in the second echelon and routes are constructed. While assigning the customers to satellites, the distance between customer and satellite is considered and customers are assigned the nearest satellite. The Nearest Neighborhood Heuristic (NNH) is utilized to construct the routes in each echelon. After obtaining a feasible initial solution, The VND_LS is used to improve it. To improve solutions, nine different neighborhood structures are used. These are Shift (1,0), Shift (2,0),Swap (1,1), Swap (2,1), Exchange, 2-Opt, Insertion, Satellite Change and Satellite Swap.
4. *Integer Solution:* The integer mathematical model with upper bound which includes all valid inequalities is solved using CPLEX with GAMS interface with limit of 2 hours. The performance of the proposed CPA is analyzed according to the gap value between upper and lower bounds and solution time.
5. *General Structure of the Proposed CP*A: The proposed CPA starts with relaxed linear programming formulation of 2E-VRPSPD. Until no improvement is obtained successively 10 times in the lower bound of the relaxed model, cuts are added using valid inequalities (31) to (33). The integer programming formulation including cuts is solved with an upper bound which is obtained using VND_LS.

COMPUTATIONAL STUDY

In this section, the results of our computational experiments are presented. First, the effects of valid inequalities on the mathematical formulation and then the performance of proposed CPA will be investigated by means of test problems. CPLEX (version 10.2) with GAMS interface was used to solve the mathematical model and relaxation. The VND_LS algorithm for upper bound was coded using C++ programming language.

Test Problems

To investigate the performance of mathematical model and relaxations, test instances were used in the literature (Christofides and Eilon [29], Crainic et al [30], Hemmelmayr et al. [11] and Baldacci et al. [4]). In order to generate the pickup and delivery demands for the customers and the satellites in each instance, demand separation approaches proposed by Salhi and Nagy [31] and Angelelli and Mansini [32] (denoted as *SN* and *AM*, respectively) were used. In SN approach two types of delivery and pickup demands are obtained and called as X type and Y type. In AM approach also there are two types of delivery and pickup demands are obtained and called as W type and Z type. Total number of instances generated by X and Y type is equal to 216 and total number of instances generated by Z and W type is equal to 348. Hence we consider totally 564 2E-VRPSPD instances in our computational experiment.

Effects of Valid Inequalities

To investigate the individual and integrated effects of valid inequalities on the mathematical model, the lower bound percentage gap for each test problem is considered. The lower bound percentage gap (ΔLB) for each instance is the gap between the LP relaxation bound (LB) and the upper bound (UB). The UB is the optimal/best known solution obtained solving the mathematical model with CPLEX for a maximum of 2 hours which includes all valid inequalities. ΔLB is calculated as $[(UB - LB)/UB] \times 100$. Table 1 reports the individual effects of valid inequalities on the formulation. In the table, the first three columns show the problem parameters, parameter value and number of problems. There are two types of problem parameters: number of satellites and customers, and demand separation strategy (DSS). Number of satellites varies from 2 to 10 and number of customers varies from 12 to 100. There are two types of demand separation strategies as AM (W-Z) and SN (X-Y). In the table, fourth column shows LB percentage gap for original model. Other columns show LB percentage gap with extra valid inequalities.

Table 1. Individual Effects of Valid Inequalities

Problem Parameters	Parameter Value	# of Problems	Original	(27)	(30)	(31,32)	(33)
# of Satellites and Customers	2-12	132	33,28	31,04	33,28	9,01	7,87
	2-21	48	23,67	21,93	23,65	22,72	3,07
	2-32	48	25,80	24,88	25,80	25,76	10,95
	2-50	120	26,87	23,25	16,05	26,85	22,77
	3-50	72	24,88	24,02	24,85	24,84	24,04
	4-50	16	19,63	18,54	18,03	19,63	15,85
	5-50	76	33,75	33,22	20,12	33,74	32,87
	6-50	4	28,75	28,75	28,60	28,75	23,43
	4-75	4	31,19	30,95	30,00	31,19	28,24
	5-75	4	37,23	37,06	37,22	37,23	34,00
	6-75	4	44,26	44,02	42,71	44,24	42,46
	4-100	4	46,19	45,30	46,02	46,19	44,47
	5-100	16	71,10	70,32	70,71	71,10	68,69
	6-100	4	66,20	65,91	65,44	66,20	65,11
	10-100	12	87,96	87,76	87,04	87,96	86,73
Average			**31,69**	**29,91**	**27,44**	**25,91**	**21,31**
DSS	W-Z	348	34,14	31,64	32,58	24,83	20,73
	X-Y	216	27,74	27,13	19,15	27,64	22,24
Average			**31,69**	**29,91**	**27,44**	**25,91**	**21,31**

It is observed from Table 2 that the valid inequalities have individual effects on the mathematical model to obtain tight bounds. Average LB gap is 31,69% for original model. By adding valid inequalities (27), (30), (31,32) and (33) separately to the mathematical model, the gap reduces to 29,91%; 27,44%; 25,91% and 21,31% respectively. The valid inequality (32) causes the highest reduction in LB gap. The problems with AM demand separation strategy have higher gap.

Performance of Proposed CPA

To investigate the performance of the proposed CPA, the mathematical model containing all valid inequalities was run on CPLEX 10.2 with GAMS interface. The performance measures are percentage gap (Gap) and CPU Time. The gap is calculated as $[(UB - LB)/UB]x100$ where UB is the upper bound obtained by CPLEX and LB is the lower bound which is the best lower bound obtained by solving formulation with CPLEX in two hours. The CPU time is the computational time for getting solution of mathematical formulation and limited to 2 hours.

Table 2 shows the performance of proposed CPA compared with mathematical formulation according to the number of satellites and customers, and DSS. , gap and CPU time of mathematical formulation and the proposed CPA usually increase according to number of satellites and number of customers. Average gap of mathematical formulation is 12,99% and average CPU time is 3624,51 seconds. These values are 3,74% and 3311,64 seconds for the proposed CPA. While mathematical model obtains 200 optimal solutions for 564 test instances, the proposed CPA increases the number of optimal solutions to 319. According to these results, the proposed CPA outperforms the mathematical formulation especially in gap and number of optimal solutions. The problems with AM demand separation strategy have higher gap in mathematical formulation and also proposed CPA.

Table 2. Performance of the Proposed CPA Compared to Mathematical Formulation

Problem Parameters	Parameter Value	# of Problem	Mathematical Formulation			CPA		
			Gap	CPU Time	# of Optimal Solutions	Gap	CPU Time	# of Optimal Solutions
# of Satellites and Customers	2-12	132	0,00	2,94	132	0,00	2,94	132
	2-21	48	5,45	3794,21	26	1,30	1607,07	40
	2-32	48	12,68	6923,76	2	8,08	6221,84	9
	2-50	120	12,64	4383,48	13	6,31	5054,60	40
	3-50	72	5,91	2736,47	19	1,51	2726,40	47
	4-50	16	10,51	7200,10	0	1,13	2787,40	11
	5-50	76	18,10	4167,48	8	2,44	3886,37	37
	6-50	4	26,74	7200,00	0	2,12	711,10	3
	4-75	4	24,88	7200,00	0	5,91	7200,00	0
	5-75	4	34,10	7200,00	0	9,75	7200,00	0
	6-75	4	41,78	7200,00	0	8,54	7200,00	0
	4-100	4	44,17	7200,00	0	14,79	7200,00	0
	5-100	16	68,44	7200,00	0	11,78	7200,00	0
	6-100	4	64,92	7200,00	0	14,44	7200,00	0
	10-100	12	77,55	7200,00	0	14,62	7214,27	0
Average (Total)			**12,99**	**3624,51**	**200**	**3,74**	**3311,64**	**319**
DSS	W-Z	348	12,72	3872,12	155	4,04	2780,05	222
	X-Y	216	13,43	3225,59	45	3,25	4168,09	97
Average (Total)			**12,99**	**3624,51**	**200**	**3624,51**	**200**	**319**

CONCLUSION

In this paper, a two-echelon vehicle routing problem with simultaneous pickup and delivery is considered. A two index node-based mathematical model for the problem has been proposed and it has been strengthened using valid inequalities which were developed for vehicle routing problem and location-routing problem in the literature. To increase the solution quality, a cutting plane algorithm, CPA, was used as an exact solution approach. Experimental studies have been carried out to investigate the effect of the valid inequalities and the performance of the proposed CPA using totally 564 instances derived from the literature. According to the computational studies, inclusion of valid inequalities in the mathematical model improves the lower bounds. Computational results over all test instances also show that the proposed CPA outperforms the mathematical formulation in terms of gap, CPU time and number of optimal solutions. As a future direction, new valid inequalities can be developed for the problem in order to strengthen the lower bounds. Exact algorithms such as branch and cut, branch and price, etc., can be developed to obtain optimal or near optimal solutions. Moreover, CPA can be used with different starting solution approaches.

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INFORMATION TECHNOLOGY LEADERSHIP: IMPLICATIONS FOR INNOVATION

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Abstract − *Information technology (IT) leadership is uniquely situated. IT leaders are expected to have expertise relating not just to IT but also to their organization and its industry. However, the work is poorly understood by the rest of the organization when, in fact, it can be vital to establishing competitive advantage and enhancing organizational performance. This literature review uncovers the effective IT leadership behaviors, including transformational leadership, that enable organizational success and discusses the implications for organizational innovation. Since the global recession of 2008, IT leaders have prioritized agility and innovation. Transformational leadership creates a climate conducive to innovation. Effective integration of IT leadership with decision-makers throughout the organization results in synergistic relationships, driving value for both IT unit and the wider organization. Such synergistic relationships enable a greater organizational capacity for change and innovation because IT is then integrated into larger operations, involved and involving stakeholders in decision-making.*

Keywords − *Information technology, innovation, leadership*

INTRODUCTION

Effective information technology (IT) leadership contributes to organizational success by enhancing agility [1], change management [2], increasing employee willingness to provide extra effort [3], improving creative behavior [4], and establishing competitive advantage [5]. IT, much like the innovation process [6], is knowledge-intensive, controversial, uncertain, and boundless. Effective IT leaders are constantly evaluating the current state of the organization to understand what changes must be made to progress toward the desired future state. Additionally, IT leaders are uniquely situated: their work is poorly understood by other organizational leaders, while they have insight into the functions of all major units since their work affects and is affected by all organizational changes. The operational business knowledge that IT leaders gain from their work, if actively nurtured and utilized, makes IT leaders potential partners who understand the levers of both the organization's industry and its idiosyncratic operations, making them invaluable partners in identifying and executing on opportunities for innovation.

Due to the value of IT leadership for organizational innovation process, this paper undertakes a literature review in order to identify effective IT leadership behaviors that can contribute to organizational innovation. We pay close attention to transformational leadership as it has been studied more than other types of leadership in the IT context, and transformational leadership (TL) is especially important for change and innovation because two of the four components of TL are that leaders be inspirational and that they provide intellectual stimulation [7] to followers. Agility and innovation have become extremely important for IT units since the Global Recession of 2008 [8], because business models have had to change to become more adaptive in response to global competition and rapidly changing market forces. To understand the relationship between IT leadership and innovation, relevant leadership literature is summarized to contextualize the findings of the literature review. Then the literature review uncovers investigations into effective IT leadership behaviors, paying close attention to any findings relating to change, agility, and innovation. Finally, the paper describes how IT leadership contributes to innovation processes, suggesting that effective IT leaders, if they and other business leaders commit to a working relationship, can help the organization become more innovative and adaptive.

LEADERSHIP

Studies of IT workers have focused extensively on the effects of TL, as will be evident from the next section. TL is defined by the four I's: idealized influence, individualized consideration, intellectual stimulation, and

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inspirational motivation [7]. The wide usage may partially be a result of the Multifactor Leadership Questionnaire (MLQ), a highly validated measurement instrument [9]. The MLQ measures a continuum of leadership behaviors. The lowest version of behavior is passive-avoidant leadership, which is comprised of laissez-faire and management by exception-passive behaviors. Laissez-faire behavior is demonstrated when a leader shows little or no interest in actually leading their followers. Management by exception-passive---- Transactional leadership is comprised of management by exception-active and contingent reward. TL is comprised for the four I's as mentioned above. Table 1 describes these behaviors in more detail.

Table 1. Passive-Avoidant, Transactional, and Transformational Leadership Behaviors

Leadership Style	Behavior	Description
Passive-Avoidant	Laissez-Faire	Also referred to as non-leadership, a leader who interacts minimally with followers.
Passive-Avoidant	Management by Exception-Passive	Focusing on employee mistakes, but not until performance evaluations.
Transactional	Management by Exception-Active	Actively monitoring employees for mistakes to quickly correct observed employee errors.
Transactional	Contingent Reward	Leaders influence followers by specifying payoffs and penalties for success and failure.
Transformational	Idealized Influence	Leaders who set a high standard of conduct and have a sense of vision.
Transformational	Individualized Consideration	Attends to the unique, individual needs of followers
Transformational	Intellectual Stimulation	Encourage followers to approach problems in an innovative manner
Transformational	Inspirational Motivation	Motivates employees via high expectations, symbols, and emotional appeals

Meta-analysis of TL shows it to be highly related to follower job satisfaction, follower satisfaction with leader, ratings of leadership effectiveness [10], and follower motivation [11]. Additionally, TL is highly related to leader-member exchange (LMX) through their shared reliance on development of respect, trust, setting clear role expectations, and a democratic approach to work issue resolution, such that it is unclear whether high LMX always requires high TL [12]. Reference [13] argued that effective CIOs utilize TL which enables organizational transformation, improving the return on IT investment. Results from leadership studies in the IT context are described in the next section.
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Leadership in the Information Technology Context

Within the organization, the IT function is highly specialized, requiring specialized knowledge both of IT but also of the business industry of their organization [14]. IT leadership, then, is bound up with IT intelligence, which can help shape organizational stability and organizational innovation [15]. Identifying the leadership behaviors that make for effective IT leaders is important because the organization can then hire, promote, and train based on the effective leadership behaviors identified here.

The study of leadership must differentiate between different levels in the organizational hierarchy. Within IT, low-level employees require technical knowledge, then collaboration becomes increasingly important for middle managers, and CIOs (or the highest ranking IT employee) require leadership and people management skills [16]. The CIO has been the focus of much research, and [16] pointed out that middle managers have received considerably less attention in IT research, although they can be an important source of collaboration since they are much more closely involved with individual projects.

CIO behaviors have been studied extensively in the IT alignment literature [17]. Alignment is not the focus here, although effective leadership is accepted as necessary for alignment. Trust is extremely important for the CIO to establish with the top management team (TMT) because it enables relationship building, and CIOs must have communication skills, political skills, and knowledge of both IT and the business to be effective [18]. CIOs in Singaporean organizations who have high education levels, high extraversion (which is related to TL), and high openness to experience have been shown to increase innovative use of IT [19]. These characteristics may continue to increase in importance for firms experiencing rapid technological change.

Reference [20] recognized the importance of TL behaviors in IT context and extended the model of TL by adding a fifth I: IT leadership. IT leadership in [20]'s model was comprised of developing the strategic IT plan, managing business process reengineering, understanding emerging technologies, establishing electronic communication flows throughout the organization, and the development and maintenance of highly skilled IT staff. It is clear how the model proposed by [20] was highly concerned with innovation, since the components of business process reengineering and understanding emerging technologies are both focused on identifying opportunities for improving organizational effectiveness.

The IT context results for middle managers have been supportive of findings elsewhere, showing that TL leads to affective commitment and performance [21]. LMX, which can be improved with TL, improves organizational commitment of the followers [22]. Reference [23] found identifying and articulating a vision and fostering group goals to increase IT personnel's intention to stay. Providing a model which, presumably, reduces autonomy, was negatively related to intention to stay. Burnout is related to turnover, and TL was found to be negatively related to burnout [24]. IT leadership is important for technology adoption as well. Reference [25] found idealized influence and inspirational motivation (often described together as charismatic leadership) to positively relate to both intentions to use and actual use of new technology. In other words, internal process and software innovation may require components of TL from IT leaders to gain business benefits from the changes.

Few recent studies have examined leadership in the developer and analyst context [26], but the importance of leaders for job satisfaction among programmers and analysts was demonstrated by [27]. Reference [28] found many differences in leader behavior when comparing successful and less successful project teams. More successful teams had leaders who acted as organizational catalysts, provided intellectual stimulation, were charismatic, and utilized contingent reward. Reference [26] found empowering leadership's relationship to team performance to be moderated by experience and task uncertainty, with high experience and high task uncertainty both contributing to the positive effects of empowering experience, suggesting that younger technical team members will need guidance before being given autonomy.

IMPLICATIONS FOR INNOVATION

As has been discussed above, TL holds the potential for improving innovation. It is important for change management, technology adoption, and ensuring that followers are performing environmental scanning behaviors. TL can lead to higher performance for work units, and support for innovation has been shown in one instance to partially moderate the impact of TL on performance, such that under workgroups who perceive support for innovation to be high, all four dimensions of TL contribute to performance, whereas with low support for innovation, only charismatic leadership (the combination of idealized influence and inspirational motivation) contributed to performance [29]. Similarly, [30] found that TL relates positively to innovation climate, and TL's relationship to employee creativity is partially mediated by the innovation climate.

Considering these findings, we can suggest that leadership is an important component of innovation process and employee creativity. Within IT, effective TL can be especially impactful when IT has expertise in technology, the business, and the industry. This confluence of understanding, contributed to by the fact that IT's work affects and is affected by every organizational unit, suggests that IT, when involved in decision-making and planning, can help identify innovative solutions for organizational improvement and problem-solving. Innovation provides competitive advantage if it creates rare resources that are not easily replicated by other organizations. Reference [31] suggested that IT leadership can aid the organization's development of competitive advantage when synergistic relationships are established between IT and the rest of the organization. To establish synergy, an IT asset must be compatible with an organizational resource, and management must take action to integrate the resource and asset to create an IT-enabled advantage [31].

It is important to note that it is not just IT resources that are capable of providing competitive advantage, and looking at IT resources as standalone solutions is going about things backwards in an unproductive manner. Rather than identifying technology and then seeking a problem to solve, the social capital built when relationships are established between IT and the rest of the organization must be utilized to identify opportunities for change and improvement. IT leaders have expertise in understanding how IT assets function, whereas non-IT managers have expertise regarding organizational resources, and only by effectively collaborating can the knowledge of both be combined to create value from IT-enabled change. This collaboration can also enable the organization to take off-the-shelf software that is available to other organizations and create workflows and processes that are unique, thereby providing a competitive advantage by adapting a generic solution to their specific, idiosyncratic situation, a form of innovation.

CONCLUSION

Effective IT leadership contributes to organizational success by supporting and enabling change efforts. Transformational IT leaders are constantly evaluating the current state of the organization to understand what changes must be made to progress toward the desired future state while encouraging their followers to do the same. Because IT is poorly understood by other organizational leaders, while IT leaders have insight into the functions of all major organizational units, IT leaders are invaluable partners in innovating for competitive advantage. The nature of IT is that the cutting-edge today will become obsolete tomorrow, making change and innovation the natural mindset of IT leaders. Transformational IT leaders help organizations innovate as long as they establish relationships with their fellow managers and executives, suggesting that technology alone cannot solve problems—rather, a well-crafted interplay of technology and people is required to establish competitive advantage.

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REMANUFACTURING INDUSTRY 4.0

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Abstract *− Internet of Things (IoT) can be used for maintaining the operations or mitigating the planning of warranty for remanufactured products. This is done by implementing sensors to capture the remaining useful life and the condition uncertainty in the end-of-use product (EOUP). These sensors are effective because they not only collect information, they also store significant quantities of information. This can be used to provide insight into the condition of the object for use in the reverse logistics. One of the best measures of reliability is the remaining useful life of a product. As a result, proper determination of the useful life remaining in a product can allow a firm to make the right recovery decisions that will ensure that the products recovered are guaranteed a minimum quality level. To that end, this paper studies and scrutinizes the impact of using IoT on offering warranties for remanufactured products. Specifically, the paper suggests a methodology which simultaneously minimizes the cost incurred by the remanufacturers and maximizes the confidence of the consumers towards buying remanufacturing products using IoT.*

Keywords − Reverse Supply Chain, Non-Renewable Warranty Policies, Remanufacturing, Sensor Embedded Products, Extended Product Life, Internet of Things, Sustainability

INTRODUCTION AND RELATED WORK

Many companies have become increasingly more responsible for the management of products that have reached the end-of-use (EOU). This is because of the decreasing number of landfills and the rising cost of natural resources causing commercial and environmental problems. The utilization of end-of-use product (EOUP) provides a way through which companies can reduce the need for natural resources by reusing some of the parts of the EOUPs. Furthermore, the cost of raw materials can be reduced using EOUPs. The proper management of the EOUPs requires cleaning, sorting, disassembling, component recovery, repair and material handling to ensure that all operations run smoothly. It is vital to highlight that the condition of the EOUPs determines the recovery option that can be used. EOUPs with minor problems can be refurbished using new parts in certain areas. However, those with significant damage need to be completely broken down and recycled or used as small components. The process of understanding the uncertainty that influences the recovery option used can be done using reverse logistics. Reverse logistics is important in remanufacturing which endures varies processes. The main reason for the varied processes is the varying condition of the EOUPs that are returned to the company. The condition determines whether the products can be remanufactured, recycled or whether the components can be harvested [1, 2].

The role of the IoT is to mitigate the complexity of the planning process that EOUPs require due to the uncertainty of the condition. One requirement of the IoT is the need for a network structure that allows unique identification of things. The network allows the remote tracking and monitoring of all objects in various segments of the supply chain including the reverse logistics. The IoT requires the use of RFID (radio frequency identification) tags as one of the vital components due to their ability to improve the tracking of these products. Sensors are effective because they not only collect information, they also store significant quantities of information. This can be used to provide insight into the condition of the object for use in the reverse logistics [3, 4].

An examination of the term “Industry 4.0” as noted from a reliable online platform called ‘Industry 4.0’ reveals that it is an industrial revolution in the fourth stage [4]. In this phase, managers are entrusted with the responsibility of controlling and organizing the activities of different supply chain industries. It is inclusive of re-organizing the products’ life cycle so that the customers’ needs can be met perfectly.

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Apparently, the product life cycle in supply chain starts with the generation of ideas, processing of the order while production managers develop and manufacture the goods. Finally, the end product as requested goods by the customer is delivered to the access points for the consumer. The delivery of the product to the consumer initiates the processes and services of post-delivery such as feedback about the consumer's experience. Therefore, the industry revolution applied through the "Industry 4.0" is based on the integration of all participants in the process of the supply chain. Most importantly is the observance of achieving the delivery of valuable information and quality product and service delivery. The application of the Industry 4.0 in a supply chain is a superb way of adding value optimally to the connection that exists between people, optimization of processes and products by supply chain companies in real time [5, 6].

Primarily, the use of mechanization, power generated from water and steams were used in the process of manufacturing during the first industrial revolution. In order to smoothly manage the mass production that existed in the second revolution, humans introduced assembly lines located within the production plants. In this case, humans had discovered electricity as the main source of power for all the operations of manufacturing. As the process of supply chain became complex, automation that involved the computerization of some processes of manufacturing through the technological inventions made the supply chain management more substantial. Therefore, in this fourth revolution of the supply chain industry, the cyber-physical systems have been initiated while adopting the technology and information used in the past three industry revolutions. However, the Industry 4.0 systems are sophisticated in that they create a complex boundary between the world of advanced information and communication technology (digital world) and the real world. In this case, the digital world is referred to as the cyber-physical production systems (CPPSs) [7, 8].

Sensors, are devices that monitor the product and provide measures of re-calibrated things such as vibration, temperature, and pressure. Products that have been built with sensors embedded in them are called Sensor Embedded Products (SEPs). They help in data collection and are useful during the use stage. Additionally, information on the amount of remaining life can be used to assess how close the product is to becoming an EOUP. The data on the remaining life can be used to ensure that the right recovery models are adopted so that the system criteria adopted optimizes the products. The adoption of specialized sensors can provide insight in the economic life of a product. The sensors can be used to monitor the main critical components of a product. The information can be used in providing information during the recovery phase. All the information stored in the RFID tags, like location, warranty terms, serial numbers, beginning-of-life and the middle-of-life information, can be accessed to provide insight on the best recovery process for the specific product. Additional sensors can be used to ascertain the environmental conditions, like the humidity, dust, and vibration, that the product has been subjected to. When combined with the service information, it can provide an empirical picture of the state of the product. If the product requires refurbishing only, it can be re-furbished to change the worn-out components. If the damage is too much, it can be disassembled for spare parts for use in other products. This information is quite important, but there is a need for a way of collecting this information using the least amount of manpower and without affecting the client satisfaction during the lifetime of the product. IoT offers a method of collecting this information. The design of the product can incorporate aspects like early detection of the beginning-of-life and middle-of-life information allowing the EOU operations department to ascertain the model that will be used in the individual product even before it has reached the factory at the product's end-of-life [9, 10].

The system that uses SEPs to ascertain the recovery options that a product should be placed in depending on the state of the product at end-of-life is the Remanufacturing 4.0 system. Remanufacturing 4.0 system uses the SEP information to ensure that the material and components demands of the recovered product satisfy the system goals. In an Remanufacturing 4.0 system, the IoT can allow time-based product lifetimes to be ascertained beforehand to ensure that the minimum quality requirements adhere. An additional benefit is that the remaining life of the components in the products can be clearly highlighted without the need for estimation. Considering most of the customer requirements and expectations are linked to the warranty costs, the use of sensors can ensure that the products will always exceed the quality requirements while reducing the number of warranty claims [11, 12].

The main role of this paper is to propose a Remanufacturing 4.0 model that can be used to ensure that the IoT in the EOUPs is properly implemented. The primary contribution offered by this paper is that it presents a quantitative assessment of the effect of offering warranties on remanufactured items from a remanufacturer's perspective by proposing an appealing price in the eyes of the buyer as well. While there are developmental studies on warranty policies for brand new products and a few on secondhand products, there exists no study that evaluates the potential benefits of warranties on remanufactured products in a quantitative and comprehensive manner. In these studies, the profit improvements achieved by the offering of warranties for different policies determine the range of how much money can be invested in a warranty while still keeping it profitable overall. To that end, this paper studies and scrutinizes the impact of offering renewing warranties on remanufactured products. Specifically, the paper suggests a methodology which simultaneously minimizes the cost incurred by the remanufacturers and maximizes the confidence of the consumers towards buying remanufacturing products.

SYSTEM DESCRIPTION

The Remanufacturing 4.0 system deliberated on in this study is a sort of product recovery system. A sensor embedded Gas Range (GR) is considered here as a product example. Based on the condition of EOL GR, it goes through a series of recovery operations. Refurbishing and repairing processes may require reusable components in order to meet the demand of the product. This requirement satisfies both the internal and the external component demands. Thus, both will be satisfied using disassembly of recovered components.

EOL GRs arrive at the Remanufacturing 4.0 system for information retrieval using a radio frequency data reader. The information retrieved is stored in the facility's database. The GRs then go through a six-station disassembly line. Complete disassembly is performed for the purpose of extracting every single component. There are nine components in a GR: the Metal Cover, Control panel, Surface burners, Pilot, Broiler oven burner, Ignition, Air Shutter, Shut-off valve, and Timer. For modeling purposes, exponential distributions are used to generate the station disassembly times, interarrival times of each component's demand, and interarrival times of EOL GR. All EOLPs after retrieval of the information are shipped either to station 1 for disassembly or, if EOLP only needs repair for a specific component, it is instead sent to its corresponding station. Two different types of disassembly operations, viz., destructive or nondestructive, are used depending on the component's condition. If the disassembled component is not functional (broken, zero percent of remaining life), then destructive disassembly is utilized in such a way that the other components' functionalities are not damaged. The unit disassembly cost for a functional component is higher than for a nonfunctional component. After disassembly, there is no need for component testing due to the availability of information regarding components' conditions from their sensors. It is assumed that the demands and life cycle information for EOLPs are known. It is also assumed that the retrieval of information from sensors costs less than the actual inspecting and testing.

Recovery operations differ for each SEP based on its overall condition and estimated remaining life. Recovered components are used to meet spare parts demands, while recovered or refurbished products are used for consumer product demands. Also, material demands are met using recycled products and components. Recovered products and components are characterized based on their remaining lifespans and are placed in different life-bins (e.g. one year, two years, etc.) where they wait to be retrieved via a customer demand. Underutilization of any product or component can happen when it is qualified for a higher life-bin but is placed in a lower life-bin because the higher life-bin is full. Any product, component, or material inventory that is greater than the maximum inventory allowed is assumed to be of excess and is used for material demand or is simply disposed of.

EOLP may have missing or nonfunctional (broken, zero remaining life) components that need to be replaced or replenished during the repairing or refurbishing process in order to meet certain remaining life requirements. EOLP may also consist of components having lesser remaining lives than desired, and, for that reason, might also have to be replaced.

According to a comprehensive study for the quantitative evaluation of the SEPs on the performance of a disassembly line conducted by Ilgin and Gupta [13], it was shown that SEPs are a favorable resolution in handling remanufacturing customer uncertainty. To test this claim on Remanufacturing 4.0, we built a simulation model to represent the full recovery system and observed its behavior under different experimental conditions. ARENA program, Version 14.5, was used to build the discrete-event simulation models.

Furthermore, for validation and verification purposes animations of the simulation models were built along with multiple dynamic and counters plots. 2,000 replications with six months (eight hours a shift, one shifts a day and 5 days a week) were used to run each experiment. ARENA models calculate the profit using the following equation:

$$Profit = SR + CR + SCR - HC - BC - DC - DPC - TC - RMC - TPC - WC \quad (1)$$

where SR is the total revenue generated by the products; components and materials sales during the simulated run time; CR is the total revenue generated by the collection of EOL GRs during the simulated run time; SCR is the total revenue generated by selling scrap components during the simulated run time; HC is the total holding cost of products, components, materials and EOL GRs during the simulated run time; BC is the total backorder cost of products, components and materials during the simulated run time; DC is the total disassembly cost during the simulated run time; DPC is the total disposal cost of components, materials and EOL GRs during the simulated run time. TC is the total testing cost during the simulated run time; RMC is the total remanufacturing cost of products during the simulated run time; TPC is the total transportation cost during the simulated run time; and WC is the total warranty cost.

In each nonfunctional EOL GR, there are three types of scraps that need to be recovered and sold. The Metal Cover and Ignition are sold as copper scrap, chassis and metal covers are sold as steel scraps and Surface burners, Air Shutter and Pilots are sold as fiberglass. All the other components are considered to be waste components. Scrap revenue from steel, copper, and fiberglass components is calculated by multiplying their weight in pounds by the units of scrap revenue produced by each metal type. Disposal cost as well is calculated by multiplying the waste weight by the unit disposal cost. The time of retrieving information from smart sensors is assumed to be 20 seconds per GR. The transportation cost is assumed to be $50 for each trip taken by the truck. There are different prices in the secondary market of recovery product due to different level of quality.

DESIGN-OF-EXPERIMENTS STUDY

According to a comprehensive study for the quantitative evaluation of the SEPs on the performance of a disassembly line done by (Ilgin and Gupta in ([14]), it is show that smart SEPs is a favorable resolve to handle remanufacturing uncertainty. To test this claim on Remanufacturing 4.0 we build a simulation model to represent the full recovery system and observe its behavior under different experimental conditions. Arena version 14.5 used to build the discrete-event simulation models. Three-level factorial design is used with 69 factors are considered each at 3 levels. These are stated as low, intermediate and high levels. The reason that the three-level designs were proposed is to model possible curvature in the response function and to handle the case of nominal factors at 3 levels. The parameters, factors and factor levels are given in Table 1 and Table 2. A full-factorial design with 69 factors at 3 levels requires an extensive number of experiments (viz., 8.34e+32). To reduce the number of experiments to a practical level, small set of all the possible combinations is picked. The selection method of experiments number called a partial fraction experiment, which yields to the most information possible of all the factors that affect the performance parameter with minimum number of experiments possible. For this type of experiments Taguchi made specific guidelines. A new method of conducting the design of experiments uses a special set of arrays called orthogonal arrays (OAs) was built by Taguchi. Orthogonal arrays provide the way of conducting the minimal number of experiments. In most cases orthogonal array is more efficient when compared to many other statistical designs. The minimum number of experiments that are required to conduct the Taguchi method can be calculated based on the degrees of freedom approach.

Table 1 Parameters used in the Remanufacturing 4.0 system

Parameters	**Unit**	**Value**	**Parameters**	**Unit**	**Value**
Backorder cost rate	%	40	Price for 3 Years Pilot	$	15
Holding cost rate	$/hour	10	Price for 3 Years oven burner	$	60
Remanufacturing cost	$	1.5	Price for 3 Years Ignition	$	25
Disassembly cost per minute	$	1	Price for 3 Years Air Shutter	$	20
Price for 1 Year Metal Cover	$	10	Price for 3 Years Shut-off valve	$	20
Price for 1 Year Control panel	$	20	Price for 3 Years Timer	$	65
Price for 1 Year Surface burners	$	5	Weight for Metal Cover	lbs.	8
Price for 1 Year Pilot	$	5	Weight for Control panel	lbs.	4
Price for 1 Year oven burner	$	45	Weight for Surface burners	lbs.	2
Price for 1 Year Ignition	$	15	Weight for Pilot	lbs.	2
Price for 1 Year Air Shutter	$	15	Weight for Broiler oven burner	lbs.	6
Price for 1 Year Shut-off valve	$	15	Weight for Ignition	lbs.	12
Price for 1 Year Timer	$	50	Weight for Air Shutter	lbs.	3
Price for 2 Years Metal Cover	$	15	Weight for Shut-off valve	lbs.	3
Price for 2 Years Control panel	$	30	Weight for Timer	lbs.	6
Price for 2 Years Surface burners	$	12	Unit copper scrap revenue	$/lbs	0.6
Price for 2 Years Pilot	$	12	Unit Fiberglass scrap revenue	$/lbs	0.9
Price for 2 Years oven burner	$	55	Unit steel scrap revenue	$/lbs	0.2
Price for 2 Years Ignition	$	18	Unit disposal cost	$/lbs	0.3
Price for 2 Years Air Shutter	$	18	Unit copper scrap Cost	$/lbs	0.3
Price for 2 Years Shut-off valve	$	20	Unit Fiberglass Scrap Cost	$/lbs	0.45
Price for 2 Years Timer	$	60	Unit steel scrap Cost	$/lbs	0.1
Price for 3 Years Metal Cover	$	20	Price of 1 Year GR	$	280
Price for 3 Years Control panel	$	35	Price of 2 Years GR	$	340
Price for 3 Years Surface burners	$	15	Price of 3 Years GR	$	375
Operation costs for Metal Cover	$	4	Operation costs for Ignition	$	1.66
Operation costs for Control panel	$	4	Operation costs for Air Shutter	$	2.34
Operation costs for Surface burners	$	2.8	Operation costs for Shut-off valve	$	0.6
Operation costs for Pilot	$	1.2	Operation costs for Timer	$	3.4
Operation costs for oven burner	$	4	Operation costs for GR	$	95

$$N_{Taguchi} = 1 + \sum_{i=1}^{\#\, variables} (\#\ of\ levels\ of\ variable\ i - 1) \quad (2)$$

So, number of experiments must be greater than or equal to system degrees-of-freedom. Precisely, $L_{139}(3^{54})$ Orthogonal Arrays was chosen since the degree of freedom Remanufacturing 4.0 system is 109 means it requires 109 experiments to accommodate 54 factors with three levels. Orthogonal array assumes that there is no interaction between any two factors.

Table 2 Factors and factor levels used in design-of-experiments study

No	Factor	Unit	Levels		
			1	2	3
1	Mean arrival rate of EOL GR	Products/hour	10	20	30
2	Probability of Repair EOLPs	%	5	10	15
3	Probability of a non-functional Surface Burner	%	10	20	30
4	Probability of a non-functional Ignition	%	10	20	30
5	Probability of a non-functional Air Shutter	%	10	20	30
6	Probability of a non-functional Timer	%	10	20	30
7	Probability of a missing Surface Burner	%	5	10	15
8	Probability of a missing Ignition	%	5	10	15
9	Probability of a missing Air Shutter	%	5	10	15
10	Probability of a missing Timer	%	5	10	15
11	Mean non-destructive disassembly time for station 1	Minutes	1	1	1
12	Mean non-destructive disassembly time for station 2	Minutes	1	1	1
13	Mean non-destructive disassembly time for station 3	Minutes	1	1	1
14	Mean non-destructive disassembly time for station 4	Minutes	1	1	1
15	Mean non-destructive disassembly time for station 5	Minutes	1	1	1
16	Mean non-destructive disassembly time for station 6	Minutes	1	2	2
17	Mean destructive disassembly time for station 1	Minutes	0	1	1
18	Mean destructive disassembly time for station 2	Minutes	0	1	1
19	Mean destructive disassembly time for station 3	Minutes	0	1	1
20	Mean destructive disassembly time for station 4	Minutes	0	1	1
21	Mean destructive disassembly time for station 5	Minutes	0	1	1
22	Mean destructive disassembly time for station 6	Minutes	1	1	1
23	Mean Assembly time for station 1	Minutes	1	1	2
24	Mean Assembly time for station 2	Minutes	1	1	2
25	Mean Assembly time for station 3	Minutes	1	1	2
26	Mean Assembly time for station 4	Minutes	1	1	1
27	Mean Assembly time for station 5	Minutes	1	1	2
28	Mean Assembly time for station 6	Minutes	1	2	2
29	Mean demand rate Metal Cover	Parts/hour	10	15	20
30	Mean demand rate for Surface Burner	Parts/hour	10	15	20
31	Mean demand rate for Control Panel	Parts/hour	10	15	20
32	Mean demand rate for Pilot	Parts/hour	10	15	20
33	Mean demand rate for Ignition	Parts/hour	10	15	20
34	Mean demand rate for Broiler oven burner	Parts/hour	10	15	20
35	Mean demand rate for Air Shutter	Parts/hour	10	15	20
36	Mean demand rate for Shut-off Valve	Parts/hour	10	15	20
37	Mean demand rate for Timer	Parts/hour	10	12	20
38	Mean demand rate for 1 Year GR	Products/hour	5	10	15
39	Mean demand rate for 2 Years GR	Products/hour	5	10	15
40	Mean demand rate for 3 Years GR	Products/hour	5	10	15
41	Mean demand rate for Refurbished GR	Products/hour	5	10	15
42	Mean demand rate for Material	Products/hour	5	10	15
43	Percentage of Good Parts to Recycling	%	95	90	80
44	Mean Metals Separation Process	Hour	1	1	2
45	Mean Copper Recycle Process	Minutes	1	1	2
46	Mean Steel Recycle Process	Minutes	1	1	2
47	Mean Fiberglass Recycle Process	Minutes	1	1	2
48	Mean Dispose Process	Minutes	1	1	1
49	Maximum inventory level for GR	Products/hour	10	15	20
50	Maximum inventory level for Refurbished GR	Products/hour	10	15	20
51	Maximum inventory level for GR Component	Products/hour	10	15	20
52	Level of Preventive Maintenance effort	-------	0.5	0.6	0.7
53	Number of Preventive Maintenance to perform	#	2	3	4
54	Time between each Preventive Maintenance	Months	1	2	3

Arena software version 14.0 used to build the discrete-event simulation model and calculate all the cost and revenue parameters corresponding to each 139 experiments. Furthermore, for validation and verification purposes animations of the simulation models were built along with multiple dynamic and counters plots. Ten replications with six months (eight hours a shift, one shift a day and 5 days a week) were used to run each experiment.

In each EOLP three types of scrap to recover and sold, surface burners and ignition are sold as copper scrap, surface burners and metal cover are sold as steel scrap and control panel, timer and air shutter sold as fiberglass. All the other components are considered as waste components. Scrap revenue from steel, copper and fiberglass components is calculated by multiplying the weight in pounds by the unit scrap revenue of each metal type. As well as disposal cost is calculated by multiplying the waste weight by the unit disposal cost. The time of retrieving information from smart sensors is assumed to be 20 second per GR. The transportation cost assumed to be $50 for each trip of the truck. There are different prices in the secondary market of recovery product due to different level of quality.

RESULTS

In order to have a quantitative assessment of the impact of SEPs on Remanufacturing 4.0 system performance, the design-of-experiments scheme presented in the previous section has been implementing. Table 3 shows the sample of the 139 experiments results.

Table 3 Performance measures of the Remanufacturing 4.0 system

Experiment #	Total Revenue	Total Cost	Profit
1	$1,452,500	$1,113,805	$338,694
2	$1,439,973	$999,220	$440,753
3	$1,319,731	$951,367	$368,364
:	:	:	:
137	$1,141,710	$1,031,339	$110,371
138	$1,246,454	$1,049,349	$197,105
139	$1,278,555	$944,146	$456,298
Average	**$1,278,555**	**$1,006,844**	**$271,711**

CONCLUSION

Environmental conscious manufacturing and product recovery has grown a lot of attention due to governments' regulations and customers' awareness. The main issue associated with recovery process is the uncertainty in quantity, quality, and frequency of EOLP returns that can be recovered prior to disassembly which has significant impact on the decision making due to missing or nonfunctional components. To overcome this issue SEPs with RFID tags used to mitigate EOL management and recovery processes by providing valid useful information about their conditions.

In this paper, a Remanufacturing 4.0 system was proposed. Remanufacturing 4.0 was designed to develop a use of information technology devices in a demand-driven environment to reach the optimum disassembly, repair, disposal, recycling, refurbish, remanufacturing and inventory plans.

A case example of gas range was considered to illustrate the application of the proposed approach and a discrete-event simulation model was build using ARENA 14.0 software package. Separate design-of-experiment studies based on OAs were carried out to assist and monitor the model behaviors and sensitivity of different parameters.

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PRICING DECISION FOR NEW AND REMANUFACTURED PRODUCTS WITH MULTIPLE GENERATIONS IN A DUAL-CHANNEL SUPPLY CHAIN

*Liangchuan Zhou, Surendra M. Gupta**

Abstract *– Companies are often eager to launch high technology products to meet the need of customers waiting to experience new products. Remanufacturing operations bring an opportunity for companies to gain more profit through selling remanufactured products. As such, new and remanufactured products belonging to different generations often co-exist in a competitive market place. This study focuses on a monopolistic environment with a manufacturer and a retailer. The flow path forms a dual-channel closed-loop supply chain system. Both players can decide on sales channel strategy. Customers are classified as quality-conscious and technology-savvy. They switch to a different segment according to the price, the value, and the sales channel for each product. In this paper, profit maximization linear models with time, price, and channel dependent demand function will be built for the manufacturer, the retailer, and the supply chain. Optimal rates for different types of products are obtained accordingly.*

Keywords – Close-loop supply chain, Dual-channel, Pricing, Remanufacturing, Multi-generation

1. INTRODUCTION

Driven by technological advancements and strong demand from customers, electronic products are spreading around of the world. On the manufacturer side, high technology companies release new products with the latest technologies and fashion designs at a high rate to maintain share in a competitive market. On the customers' side, many are eager to obtain the newest products and dispose of the old ones that are still workable. According to a survey on smartphone owners, they dispose of the old phones after twenty-five months on average [1]. Another report published by Slade shows that cell phones are getting retired after only eighteen months of use. He attributes this phenomenon to trailblazing consumers and following customers. The trend also changes the communication style with the birth of smartphone. Customers upgrade to new models belonging to later technology because of this social need of communication [2]. On account of these complicated interplay of communication method and technology advantage, the e-waste problem surfaces as a result of powerful drivers acting on both the technology companies and the customers. Governmental regulation is introduced to prevent e-waste from growing out of control. Companies are required to use recycled materials when they produce products or are responsible for the end-of-life products disposal. However, meeting governmental regulations does not need to be a complete burden to the manufacturers. Organizational regulators and academic researchers have made effort to explore ways to minimize the cost and gain additional revenue from recycling used products in the past decades in various areas.

Gungor and Gupta conducted a survey in the areas of environmentally conscious manufacturing and product recovery [3]. They discussed the previous contributions about life cycle analysis, environmental design, material recovery, disassembly process, and production planning. Most of the researchers in these areas report ways to protect the environment and minimize cost. Ilgin and Gupta extended the review of the state of the art [4]. They introduced more research fields including product design, reverse and closed-loop supply chains, remanufacturing, and disassembly. Scientists have begun to look for opportunity for companies to grow revenues while meeting the environmental regulations. Specialized in reverse and closed-loop supply chains, they classify the concept into nine sections, namely network design, network and product design integration, transportation optimization, used products selection, supplier selection, performance measurement, market-related issues, end-of-life alternative selection, and acquisition management.

This paper deals with pricing decisions in a closed-loop supply chain (CLSC) to address market-related issues. The focus of study is on high technology products, such as laptops and smartphones. Many researchers pay attention to the closed-loop supply chain of remanufactured electronic products. For example, Nowak and Lechner conducted an empirical study on laptops [5]. They pointed out that the researchers need to identify the drivers for market prices, consumers reaction to prices and original equipment manufacturer (OEM)'s reaction to changes in the return rate. Optimal price decisions for new and remanufactured products are driven

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by both the consumers and the manufacturers. Consumers' perceived value of various products influences price, and supply chain channel design influences OEM's operations process and customers' purchase methods as well.

Except for the aspect of remanufactured products, high technology products have another characteristic. As we described above, companies launch new products intensively. The phenomenon creates the co-existence of multiple production generations. In particular, companies give birth to a new generation when the earlier model is still available on the market. For high-end fashion followers, purchasing the latest one and disposing of the old one is the best choice. But for strategic consumers, they have options to choose a new product belonging to the earlier generation or to select a refurbished product belonging to the latest generation. They make decision by considering the perceived values of different products and the market prices. Therefore, price decisions are critical for the demand if the products are sold to strategic consumers.

In the following paragraphs, the literature review will be organized in two sections including customer purchasing behavior and pricing decision on dual channel supply chain. Then the problem statement is proposed to fill up the gap of previous research. Optimization models and numerical examples are shown in section 4 and section 5. Then the conclusion and future study are discussed in section 6.

2. LITERATURE REVIEW

The literature review is provided with a focus on customer purchase behavior and the price decision on a dual-channel supply chain. This paper is a study on pricing decision based on these two factors.

2.1 Customer Purchase Behavior

Customers have different consumption capacity and disparate perceived value on diverse types of products, are varied by several groups that we cannot look them as a whole. Customer segments should be defined before analyzing their purchase behavior. We have found different definition about customer segments. Atasu, Guide, and Wassenhove classify consumers in the group of newness-conscious and functionality-oriented, analyze the possibility of cannibalization between new and remanufactured products [6]. Newness-conscious customers never buy refurbished products unless the price is low enough, because newness is as important as quality. On the other hand, fashion ability and quality are not equal to functionality-oriented customers. To them, the value of remanufactured products is close to the new ones. Guide and Li also conduct a study on cannibalization analysis. They look at the spot of the brand. Customer segmentations are classified as the name brand and name brand premium. They believe there is little competition between new and refurbished products because consumers are segmented [7]. Besides, Andrew-Munot, Ibrahim, and Junaidi create new segmentation called "laggards" when they overview of used products remanufacturing, represents a group who do not want to switch to a new technology, which extends the technology life cycles [8]. Also, Mitra creates the groups of price-sensitive and quality-conscious, and talk a little about the group of environmental-friendly, when they analyze the optimal price and core acquisition strategy in a hybrid system [9]. Zhou, Zhang, Gou, and Liang propose period pricing model for new fashion style launching strategy, segment consumers as myopic and strategic [10]. Furthermore, depending on different sales channels, the customers can be divided into grocery shoppers and prior internet shoppers [11].

The most important customer purchase behavior is that the clients in each segment are switchable depending on particular conditions. In the paper written by Zhou, et al., customers purchase decisions for fashion products are changed by launching strategies, influenced by time-period and price-change, and no repeat purchase happens [10]. Mitra study the switching behavior with the assumption of one-way substitution that only customers in primary market may switch to the secondary market [9]. Hsiao and Chen suppose that shopping decisions are based on internet channels, pricing strategies, and the channel structure [11]. Gan, Pujawa, Suparno, and Widodo extend the model with the consideration of separate sales-cannel for new and remanufactured products in two periods. Customers switch to a different segmentation when the insight value of goods is close to the price [12].

2.2 Pricing Decision on Dual Channel Supply Chains

Products are always sold through retailers or online, along with retail service and e-service. Customers have different preferences especially for buying remanufactured products. Xu, Zeng, and He propose an empirical study on consumer online purchasing behavior based on e-service toward remanufactured electronic products [13]. They find that online information is the most influential on customers' willingness to pay for both auctions and fixed price transactions. With respect to the retail service, Zhang, Wang, and Liu demonstrate the price priority is influenced by the degree of customer loyalty and retail services by the two-stage optimization model and Nash game method [14].

Despite the research on single channel supply chain, Chen, Fang, and Wen propose a study on a system with one retailer and one manufacturer using Nash and Stackelberg games [15]. The Original Equipment Manufacturer (OEM) conducts a dual-channel policy, while the retailer also sells the product made by the manufacturer and a competing product. Ding, Dong, and Pan also explore the pricing decision on a dual-channel problem with one manufacturer and one retailer, but they use a hierarchical pricing decision process to find the optimal wholesale price, retail price and online sale price [16].

Except for the papers about pricing decisions on new products in a dual-channel supply chain, some researchers look at the window of pricing decisions for the new and remanufactured product in a closed-loop supply chain. Gao, Wang, Yang, and Zhong establish three models for Nash game, the Manufacturer-Stackelberg game, and the Retailer-Stackelberg game respectively. They study the customer preference of a direct channel. Optimal recycling transfer price and acquisition price are also analyzed [17]. Liu, Guo, Guo, and Lei find pricing strategy in CLSC in two cycles based on the diversity of consumers with a manufacturer, a retailer, and an e-tailer. They build an independent model for new products first, and then a joint profit model for both new and remanufactured products. Another paper is about channel distribution strategy for new and remanufactured products [18]. They implement equilibrium analysis and find that separate channel policy for new and remanufactured products brings more benefit to the manufacturer, no matter what types of products are sold via a retailer or sold online.

The papers mentioned above are focused on customer behavior, supply chain channels and competing for new and remanufactured products. As far as we know, no paper has investigated remanufactured products across generations in dual channels of CLSC. This study is to fill up the gap in this area.

3. PROBLEM STATEMENT

Gan, Pujawan, Suparno, and Widodo propose a study on pricing decision on new and remanufactured short lifecycle products in a two-period model [19]. Then they implement the model into a dual-channel closed-loop supply chain, considering the customers' purchase switch behavior [12]. Our previous work developed the model from [19] by considering a generation obsolescence [20]. İn this paper, we will extend the last problem to a dual-channel system.

İn the problem, three types of products are defined below.

Type1: New product belonging to the early generation
Type2: Remanufactured product belonging to the latest generation
Type3: New products belonging to the latest generation

Two players are in the system including one manufacturer and one retailer. The manufacturer produces new products and sells them to the retailer at a wholesale price. These products in this period are Type3 products. The retailer launches the new products to the market and sells them to the customers with a retailer price. Over time a new generation is released, the unsold Type3 products become Type1 products. The manufacturer does not manufacture Type1 products.

Meanwhile, some customers dispose of the old products; a portion of these customers return items to the manufacturer. The manufacturer processes remanufacturing operations, make the remanufacturing products available. These products are called Type 2 products. The manufacturer sells Type2 products via a direct channel without the retailer. They only provide the remanufactured items belonging to the latest technology. Figure 1 shows the relationship of each player in the system. In this closed-loop supply chain, the manufacturer has two sales channels, the indirect channel is for selling new products while the direct channel is for selling remanufactured products. The objective problem is to find the optimal prices for different types of products.

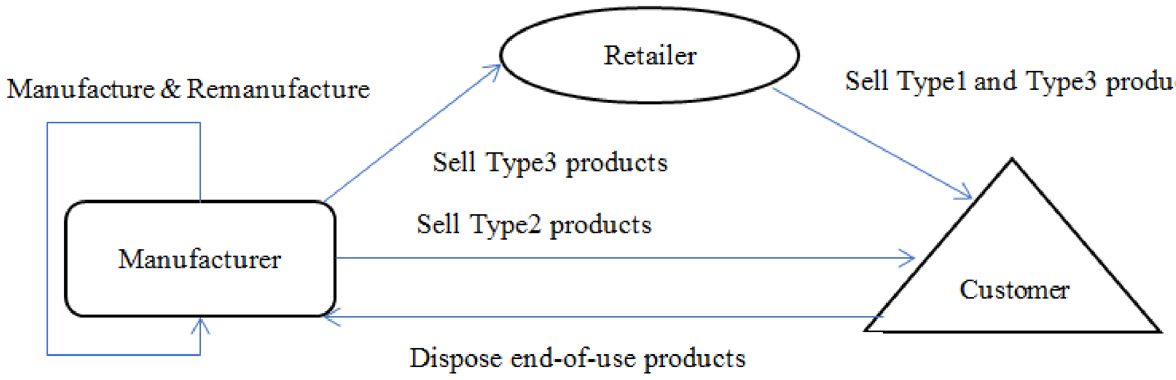

Figure1. Closed-loop supply chain system

The demand function curves are shown in Figure 2. The market for new products follows dual rollover strategy. That means early generation products (Type1) are still available when the new generation (Type3) is launched. However, the demand for Type1 products will go to the decline phase while that of Type3 products will occupant the increase phase.

The market for remanufactured products follows single rollover strategy. That means the old generation will be replaced by the new one. Therefore, the demand for remanufactured products always has an increasing curve. Zhou et al. described the two strategies in details [10]. The study will be focused on the period between t_2 and t_4. The demand curve functions for three types of products during the period [t_2, t_4] are the same with those in [20].

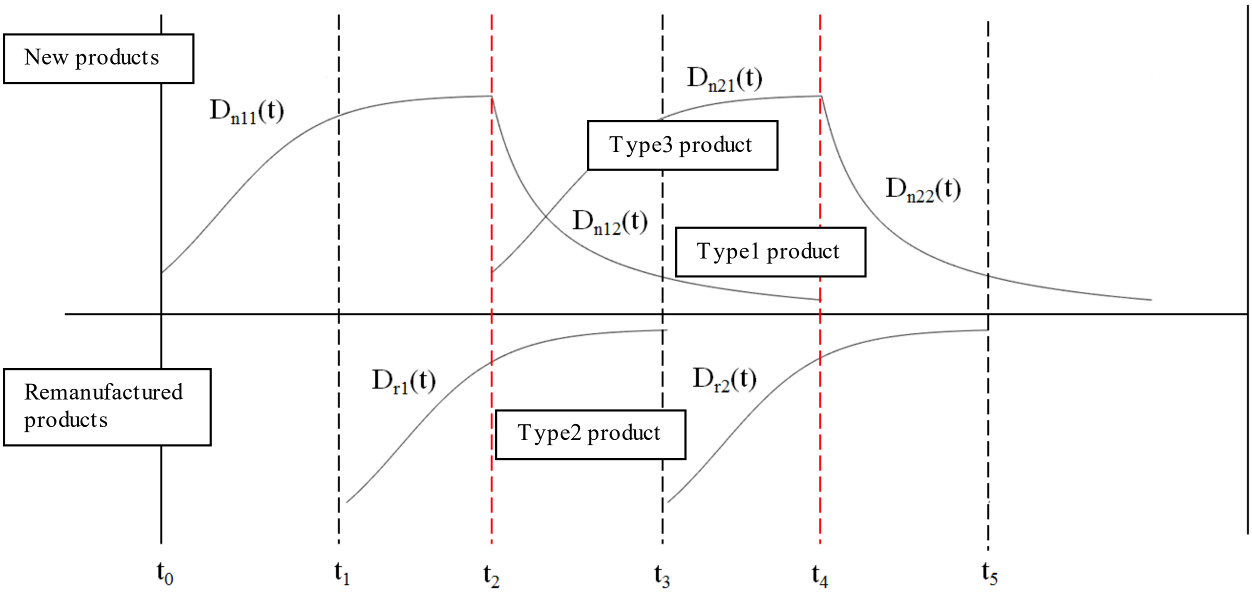

Figure2. Demand curve of different types of products

Customers are classified as high-end quality-conscious, price-sensitive quality-conscious, and price-sensitive technology-savvy. High-end quality-conscious customers only want Type3 products. Price-sensitive customers consider Type1 and Type2 products. Customers in quality-conscious and technology-savvy segmentations have different perceived value to Type1 and Type2 products. They are supposed to buy Type1 or Type2 products depending on their prices.

4. MODELS

Notations

- $D_{n12}(t)$: Cumulative demand potentia of Type1 product during $[t_2, t_4]$
- $D_{n21}(t)$: Cumulative demand potential of Type3 prpoduct during $[t_2, t_4]$
- $D_{r1}(t)$: Cumulative demand potentia of Type2 product $[t_2, t_3]$
- $D_{r2}(t)$: Cumulative demand potentia of Type2 product $[t_3, t_4]$
- P_{n12}: Price of Type1 product during $[t_2, t_4]$
- P_{n21}: Price of Type3 product during $[t_2, t_4]$
- P_{r1}: Price of Type2 product during $[t_2, t_3]$
- P_{r2}: Price of Type2 product during $[t_3, t_4]$
- P_{nw}: Wholesale price for new products
- C_n: Cost for producing new product
- C_r: Cost for producing remanufactured product
- α_1: Discount of generation obsolenscence in price-sensitive quality-conscious customer's view
- α_2: Discount of generation obsolenscence in price-sensitive technology-savvy customer's view
- β_1: Discount of remanufacturing inferiority in price-sensitive quality-conscious customer's view
- β_2: Discount of remanufacturing inferiority in price-sensitive technology-savvy customer's view
- γ: Direct channel preference rate

Demand functions are developed based on the models in [12]. İn the model, P_{n21} is the maximum price, which is known. Function (1)-(3) are the demand curves of Type1 product.

$$D_{n12}(t_2,t_3) = \frac{D_{n12}}{P_{n21}}[P_{n21} - \frac{P_{n12}-P_{r1}}{1-\beta_1}]; \quad P_{r1} < \alpha_1 \beta_1 P_{n21} \tag{1}$$

$$D_{n12}(t_3,t_4) = \frac{D_{n12}}{P_{n21}}[P_{n21} - \frac{P_{n12}-P_{r2}}{\alpha_1-\beta_1}]; \quad P_{r2} < \beta_1 P_{n21} \tag{2}$$

$$D_{n12}(t_2,t_3) = \frac{D_{n12}}{P_{n21}}[P_{n21} - P_{n12}]; \quad \alpha_1 \beta_1 P_{n21} <= P_{r1} <= \alpha_2 \beta_2 \gamma \bullet P_{n21} \tag{3}$$

$$D_{n12}(t_3,t_4) = \frac{D_{n12}}{P_{n21}}[P_{n21} - P_{n12}]; \quad \beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \bullet P_{n21} \tag{4}$$

Function (1) and (2) represent the demand of Type1 products during $[t_2,t_3]$ and $[t_3,t_4]$ respectively. When the price of Type2 product is lower than quality-conscious customers' value. Some customers in this segment will switch to buy Type2 products. Function (3) presents the demand when the rate of Type2 product is higher than quality-conscious customers' value but still lower than technology-savvy's perceived value.

Function (5)-(8) are the demand functions during $[t_2,t_4]$ for Type2 product.

$$\text{Dr1}\ (t_2,t_3) = \frac{1}{P_{n21}}\left[D_{r1}\left(P_{n21-}\frac{Pr1}{\gamma}\right) + D_{n12}\left(\frac{P_{n12}-P_{r1}}{1-\beta_1} - \frac{P_{r1}}{\alpha_2\beta_2}\right)\right]; \quad P_{r1} < \alpha_1 \beta_1 P_{n21} \tag{5}$$

$$\text{Dr2}\ (t_3,t_4) = \frac{1}{P_{n21}}\left[D_{r2}\left(P_{n21-}\frac{Pr2}{\gamma}\right) + D_{n12}\left(\frac{P_{n12}-P_{r2}}{\alpha_1-\beta_1} - \frac{P_{r2}}{\alpha_2\beta_2}\right)\right]; \quad P_{r2} < \beta_1 P_{n21} \tag{6}$$

$$D_{r1}(t_2,t_3) = \frac{D_{r1}}{P_{n21}}[P_{n21} - \frac{P_{r1}}{\gamma}]; \quad \alpha_1 \beta_1 P_{n21} <= P_{r1} <= \alpha_2 \beta_2 \gamma \bullet P_{n21} \tag{7}$$

$$D_{r2}(t_3,t_4) = \frac{D_{r2}}{P_{n21}}[P_{n21} - \frac{P_{r2}}{\gamma}]; \quad \beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \bullet P_{n21} \tag{8}$$

4.1 Retailer's Optimization

Retailers only sell Type 1 and Type 3 products. The maximum revenue function is generated based on the income and cost for the new products. The demand trend is price and customer perceived discount dependent.

The function is piece-wise dependent on customer's combined perceived value deduction on quality and technology obsolescence.

$$\text{Max } \Pi_R = \left(\frac{D_{n12}}{P_{n21}}\left[P_{n21} - \frac{P_{n12}-P_{r1}}{1-\beta_1}\right] + \frac{D_{n12}}{P_{n21}}\left[P_{n21} - \frac{P_{n12}-P_{r2}}{\alpha_1-\beta_1}\right]\right)*(P_{n12}-P_{nw}); \quad \text{When } P_{r1}, P_{r2} < \alpha_1\beta_1 P_{n21}$$

$$= \left(\frac{D_{n12}}{P_{n21}}\left[P_{n21} - P_{n12}\right]\right) * (P_{n12}-P_{nw}); \quad \text{When } \alpha_1\beta_1 P_{n21} <= P_{r1}, P_{r2} <= \alpha_2\beta_2\gamma \bullet P_{n21} \qquad (9)$$

Decision variable: P_{n12}, P_{r1}, P_{r2}
Parameters: P_{n21}, P_{nw}, α_1, α_2, β_1, β_2, γ
Constraints: $P_{r1} \leq P_{n12}$, $P_{r2} \leq P_{n21}$, $P_{n12} \leq P_{n21}$, $\alpha_1 > \alpha_2$; $\beta_1 < \beta_2$; $\alpha_1 > \beta_1$

4.2 Manufacturer's Optimization

Manufacturer's model also depends on two different conditions of customers' perceived value discount on the depreciated quality and outdated generation. The profit is generated by manufacturing and remanufacturing products, selling Type 3 products to the retailer and Type 2 products to the customers. During the period [t_2, t_3], Type 2 products decrease in value because of the older generation and the lower qualtiy. While during [t_3, t_4], the value of the goods is only deducted by the inferior quality.

When P_{r1} , $P_{r2} < \alpha_1 \beta_1 P_{n21}$;

$$\text{Max } \Pi_M = \left(\frac{1}{P_{n21}}\left[D_{r1}\left(P_{n21} - \frac{Pr1}{\gamma}\right) + D_{n12}\left(\frac{P_{n12}-P_{r1}}{1-\beta_1} - \frac{P_{r1}}{\alpha_2\beta_2}\right)\right]\right) * (Pr1 - Cr) + \left(\frac{1}{P_{n21}}\left[D_{r2}\left(P_{n21} - \frac{Pr2}{\gamma}\right) + D_{n12}\left(\frac{P_{n12}-P_{r2}}{\alpha_1-\beta_1} - \frac{P_{r2}}{\beta_2}\right)\right]\right) * (P_{r2}-C_r) + \left(\frac{D_{n12}}{P_{n21}}\left[P_{n21} - \frac{P_{n12}-P_{r1}}{1-\beta_1}\right] + \frac{D_{n12}}{P_{n21}}\left[P_{n21} - \frac{P_{n12}-P_{r2}}{\alpha_1-\beta_1}\right]\right)*(P_{nw}-C_n) \qquad (10)$$

When $\alpha_1 \beta_1 P_{n21} <= P_{r1}$, $P_{r2} <= \alpha_2 \beta_2 \gamma \bullet P_{n21}$; (11)

$$\text{Max } \Pi_M = \frac{D_{r1}}{P_{n21}}\left[P_{n21} - \frac{P_{r1}}{\gamma}\right] * (P_{r1}-C_r) + \frac{D_{r2}}{P_{n21}}\left[P_{n21} - \frac{P_{r2}}{\gamma}\right] * (P_{r2}-C_r) + \left(\frac{D_{n12}}{P_{n21}}\left[P_{n21} - P_{n12}\right]\right) * (P_{nw}-C_n)$$

4.3 Closed-loop Supply Chain Optimization

The closed-loop supply chain model is to maximize the total profit of the manufacturer and the retailer in the two different conditions mentions above.

$$\text{Max } \Pi_{clsc} = \Pi_R + \Pi_M \qquad (12)$$

5. NUMERICAL EXAMPLE

The values of parameters in the two phases diffusion demand curves in Figure 2 are the same as the values in paper [20]. The cumulative demand of Type1 and Type2 products in different periods are in Table 1.

Table 1. Cumulative demand potential of Type1 and Type2 products

Dn12 (t2, t3)	Dn12 (t3, t4)	Dr1	Dr2
240	64	438	270

We assume that Cn=\$200, Cr=\$50, Pn21=\$650, Pnw=\$370, $\alpha 1=0.8$, $\alpha 2=0.7$, $\beta 1=0.7$, $\beta 2=0.8$, $\gamma=0.9$. Table 2-4 shows the results of the retailer, the manufacturer, and the supply chain profit maximization model. The results are varied by different values of α_1, α_2, β_1, β_2, for showing the expected different discount rates of generation outdated and remanufacturing inferior between the two segmentations.

Table 2. The result of retailer's model

Value of α & β	**α1=0.8; α2=0.7; β1=0.7; β2=0.8**		**α1=0.8; α2=0.6; β1=0.7; β2=0.8**		**α1=0.8; α2=0.7; β1=0.6; β2=0.8**	
Condition	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$\alpha_1 \beta_1 P_{n21} <= P_{r1} <= \alpha_2 \beta_2 \gamma \cdot P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$
Pn12	456	468	455	468	462	511
Pr1	364	364	364	364	312	312
Pr2	455	455	364	455	390	390
ΠR	**16,321**	12,732	12,512	**12,732**	**11,968**	9,291
Max. Profit *	*			*	*	

Table 3. The result of manufacturer's model

Value of α & β	**α1=0.8; α2=0.7; β1=0.7; β2=0.8**		**α1=0.8; α2=0.6; β1=0.7; β2=0.8**		**α1=0.8; α2=0.7; β1=0.6; β2=0.8**	
Condition	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$\alpha_1 \beta_1 P_{n21} <= P_{r1} <= \alpha_2 \beta_2 \gamma \cdot P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$
Pn12	650	650	650	650	650	312
Pr1	299	299	288	288	281	312
Pr2	357	455	351	455	323	390
ΠM	**142,598**	103,459	**131,577**	95,594	**116,327**	111,026
Max. Profit	*		*		*	

Table 4. The result of joint supply chain model

Value of α & β	**α1=0.8; α2=0.7; β1=0.7; β2=0.8**		**α1=0.8; α2=0.6; β1=0.7; β2=0.8**		**α1=0.8; α2=0.7; β1=0.6; β2=0.8**	
Condition	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$	$P_{r1} < \alpha_1 \beta_1 P_{n21}$ $P_{r2} < \beta_1 P_{n21}$	$\alpha_1 \beta_1 P_{n21} <= P_{r1} <= \alpha_2 \beta_2 \gamma \cdot P_{n21}$ $\beta_1 P_{n21} <= P_{r2} <= \beta_2 \gamma \cdot P_{n21}$
Pn12	422	437	407	422	456	510
Pr1	258	265	242	249	260	318
Pr2	304	455	290	455	300	390
Πc	**103,287**	95,439	**95,649**	89,613	**103,838**	93,342
Max. Profit *	*		*		*	

We can see that in most cases when the price of Type2 products is lower than the quality-conscious customers' perceived value, the profit will be optimized in all of the three models. The only exception is in the retailer's model when the difference between generation discount level in the two consumer groups is larger than that of the remanufacturing discount level (α_1-α_2>β_2-β_1). The profit will be optimized if Type2 products are sold at a price less than the quality-conscious customers' perceived value in [t_2, t_3] and higher than the perceived value at [t_3,t_4]. In the manufacturer's model, the difference between generation discount level in the two segmentations is the same with that of the remanufacturing discount level (α_1-α_2=β_2-β_1), and the Type2 products' price is lower than quality-conscious customers' perceived value, the profit is maximum. In the joint profit model above, when α_1-α_2<β_2-β_1, and the discount level of Type2 products is high enough to attract some of the quality-level consumers in all the studied period, the total profit is maximum.

6. CONCLUSION

This paper proposes a study on pricing decision on new and remanufactured products in multiple periods with the consideration of remanufacturing inferior discount and technology diffusion rate and different launch strategies. The contribution of this research was to develop price models by considering production generations and sales channels. For new products, dual rollover strategy was applied. For remanufactured products, single rollover strategy was implemented. In addition, customer switch behavior was considered in the model. Technology-savvy and quality-conscious customers select the product depending on the price and the perceived value. Furthermore, the study did not focus on the two products with a huge difference; two types of the products have different merit and demerit. Type1 is new but belonging to the early generation, while Type2 is refurbished but belonging to the latest generation. However, Type2 products do not always have a prior technology. The most recent generation of Type2 products is based on the availability of returned cores. All of the possible conditions were considered in the model.

We understand that the number of used cores is uncertain. İn the future study, acquisition strategy and inventory fluctuation could be integrated into the model. Also, high-end and environment-conscious customers could be analyzed in the model.

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A HYBRID FUZZY MULTI CRITERIA DECISION MAKING APPROACH FOR MULTI OBJECTIVE SUPPLIER SELECTION

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Abstract − *Suppliers that constitute the first step of the supply chain play an important role in achieving the objectives of companies. Supplier selection decision is very important for a company to be successful. Choosing the right suppliers working towards the objectives of the company with quality, cost and speed performance will increase the company's customer satisfaction and improve its competitiveness. In terms of companies, supplier selection is a multi-criteria decision-making problem that requires consideration of many qualitative and quantitative factors. This study presents a novel hybrid fuzzy multi criteria approach for selecting the appropriate suppliers in a supply chain that aims to minimize the total cost of procurement, late delivered product, defected product, and amount of carbon emissions and maximize value of purchasing using fuzzy AHP-fuzzy TOPSIS and fuzzy multi-objective linear programming.*

Keywords − *Fuzzy AHP, fuzzy TOPSIS, fuzzy multi-objective linear programming, hybrid approach, supplier selection*

INTRODUCTION

Supplier selection is the choosing the best supplier that will provide itself competitive advantage among alternative suppliers considering the short and long term plans of the company [1]. Supplier selection plays an important role of purchasing as its results have a great impact on the cost, quality and delivery of goods and performance of organizations and supply chains [2]-[5]. Recently, companies have implemented a variety of regulatory controls to ensure that suppliers can provide materials and services that are both high quality and meet environmental standards and also suggested that climate change risk should be addressed correctly in order to gain competitive advantage [3, 6].

Selecting the right suppliers will reduce purchasing costs, decrease production lead time, increase customer satisfaction, profitability and quality of products and competitiveness in the market. For this reason, choosing the right suppliers requires far more than scanning a set of price lists, and depends on a wide variety of factors, both quantitative and qualitative [7]-[9].

In fact, two types of supplier selection are evident. In the first type (single supplier), one supplier meets the needs of all buyers, so the buyer only decides the best supplier. In the second and more common type (multiple supplier), more than one supplier are selected. For this reason, companies should choose both the best suppliers and how much should be allocated between them to create a stable competitive environment [6]. According to the situation, supplier selection may require looking for new suppliers or choosing suppliers from the available suppliers pool. Supplier selection requires multiple goals and criteria to be considered [4]-[5]. In a real situation, many inputs are not fully known. When deciding, the values of many criteria and constraints are expressed in uncertain terms for a supplier selection problem. The fuzzy set theory combined with multi criteria decision making methods has been widely used to deal with the uncertainty in the supplier selection decision process [2, 4]. Such as the analytic hierarchy process (AHP), analytic network process (ANP), case-based reasoning (CBR), data envelopment analysis (DEA), genetic algorithm (GA), mathematical programming, simple multi-attribute rating technique (SMART), and their hybrids [8].

Amid et al. [2] developed a fuzzy multi objective linear model applying an asymmetric fuzzy-decision making technique to assign different weights to various criteria. Kumar et al. [10] treated a fuzzy multi-objective integer programming vendor selection problem formulation that provides facilitates the vendor selection and their quota allocation under different degrees of information vagueness in the decision parameters.

Jadidi et al. [11] proposed a single objective function and used TOPSIS to solve the fuzzy multi-item multi-objective model in order to calculate the optimum order quantities to each supplier. Amid et al. [12] developed a fuzzy multi objective model for supplier selection in order to assign different fuzzy weights to various

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criteria considering vagueness of input data and varying importance of criteria. For soliton, they transformed the fuzzy multi objective supplier selection problem into a convex (weighted additive) fuzzy programming model and single objective linear programming. Ng [13] proposed a weighted linear program for the multi-criteria supplier selection problem and studied a transformation technique for proposed model to be solved without an optimizer.

Wang and Yang [7] introduced the AHP and fuzzy compromise programming for allocating order quantities among suppliers with their quantity discount rate offered. Thakre et al. [14] proposed a method to the solution of fuzzy linear programming problem with the aid of multi objective constrained linear programming problem where the constraint matrix and the cost coefficients are fuzzy.
Amid et al. [15] developed a weighted max–min fuzzy model which help the decision maker to find out the appropriate order to each supplier, and manage supply chain performance on cost, quality and service .they used AHP to determine the weights of criteria. Shaw et al. [3] presented an integrated approach for selecting the appropriate supplier in the supply chain, addressing the carbon emission issue, using fuzzy AHP(FAHP) and fuzzy multi-objective linear programming. Lin et al. [16] used the fuzzy ANP (FANP) approach first to identify top suppliers and then integrated FANP with fuzzy multi-objective linear programming in selecting the best suppliers for achieving optimal order allocation under fuzzy conditions.

Kannan et al. [6] presented an integrated approach for selecting the best green suppliers and allocating the optimum order quantities among them. They used FAHP to determine the best green suppliers and then used multi-objective linear programming to consider various constraints and objectives. Arıkan [17] transformed a typical multi objective supplier selection model into convex fuzzy programming models with a single objective function for reduces the dimension of the system and computational complexity.

Mavi et al. [9] evaluated spare parts suppliers in the context of supply chain risk management. They applied fuzzy TOPSIS (FTOPSIS) with considering nine criteria for evaluating suppliers. Kumar et al. [18] used integrated FAHP and fuzzy multi-objective linear programming approach for order allocation among suppliers. They applied proposed model in an Indian automobile supply chain to verify efficiency and used seven sustainability dimensions to optimize sustainability outcomes.

PROBLEM DEFINITION

The supplier selection problem is a difficult decision-making problem that requires a large number of criteria to be taken into consideration. The solution of the problem correctly with this structure is made possible by the use of scientific methods in the decision process. Problem is related to the decision of supplier selection for a firm that manufactures a single type of product. This firm has several suppliers to supply the materials required for production. The firm wants to minimize cost of procurement, late delivered, defected, carbon emissions per product and maximize value of purchasing for supplier selection. Firm management chose the criteria of cost, quality, delivery, flexibility, environmental policy that are widely discussed in the current literature to create an efficient supplier selection process. This information is generally available from suppliers. Five suppliers were selected by the committee for sourcing the material. The aim of the committee is to find out the best suppliers.

This study proposes a two-stage mathematical model to evaluate suppliers, given a number of quantitative and qualitative criteria. In the first stage, FAHP is used to calculate the relative weights of supplier selection criteria and FTOPSIS is used for ranking (weights) of suppliers. Then, formulation of multi objective linear programming of supplier selection is constructed using fuzzy linear programming. In the second stage, the weights of the criteria and suppliers were incorporated into the multi-objective linear programming model to determine the optimal order quantity from each supplier with some resource constraints. The weights of supplier are used as coefficients of last objective function to allocate order quantities between suppliers so that the sum of the purchasing value is maximized.

Some assumptions made for developed multi-objective supplier selection model are as follows:
(i) Only one type of product is purchased from each supplier.
(ii) There is no provision for quantity discount in this model.
(iii) There aren't stock and stock out.
(iv) Demand, capacity, lead time, quality, amount of CO_2 emission, all costs and ratios are fixed and known.

Methodologies

In this section, fuzzy set theory, FAHP, FTOPSIS and fuzzy linear programming that we used in our study are mentioned.

Fuzzy set theory: Fuzzy sets were interpreted by Lotfi A. Zadeh who noted that human thinking is mostly fuzzy in 1965. Fuzzy set theory has been used for modeling decision making processes based on uncertain and vague information such as judgment of decision makers. Fuzzy set theory removes uncertainty in decision making through quantification to qualitative values [4, 18].

A fuzzy set is defined with a membership function and it's all elements have membership degrees that vary between 0 and 1 [19]. In this study, triangular fuzzy numbers have been used as well as the possibility of different fuzzy numbers. A triangular fuzzy number is shown in Figure 1. A triangular fuzzy number is shown as (l, m, u) with l < m< u [4, 20].

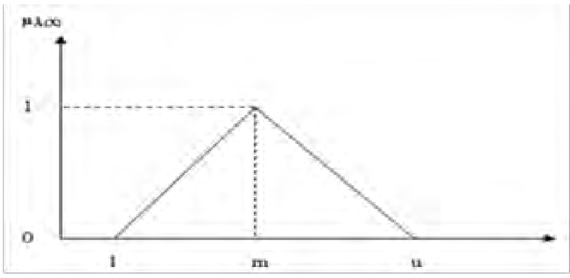

Figure 1. Triangular Membership Function.

A triangular membership function and its elements are represented as follows:

$$\mu_A(x) = \begin{cases} 0 & for\ x < l, \\ \frac{x-l}{m-l} & for\ l \leq x \leq m, \\ \frac{u-x}{u-m} & for\ m \leq x \leq u, \\ 0 & for\ x > u, \end{cases} \tag{1}$$

Fuzzy AHP: In this study, Buckley's method was used to determine the relative importance weights for the criteria. Buckley [21] used the geometric mean method to obtain fuzzy weights and performance scores. This method can be easily generalized to fuzzy situations and obtains a single solution from comparison matrices. It consists of the following steps [22];

1. A matrix of comparison to the opinion of the decision maker is obtained. If the fuzzy positive comparison matrix is given as follows;

$$A = \begin{bmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{bmatrix} \tag{2}$$

2. In order to calculate w_i fuzzy weights, geometric averages are calculated for each row first.

$$Z_i = \left[\prod_{j=1}^{n} a_{ij}\right]^{1/n} \tag{3}$$

3. After finding the geometric mean of each row, w_i is calculated using (4).

$$w_i = \frac{z_i}{z_i + \cdots + z_n}, \quad \forall i. \tag{4}$$

Fuzzy TOPSIS: The FTOPSIS proposed by Chen [23] was developed to solve group decision problems under fuzzy environment. In this method, linguistic expressions are used instead of numerical values in order to reflect the environment more realistically. Linguistic variables are used by the decision makers, D_r (r=1, ..., k), to assess the weights of the criteria and the ratings of the alternatives. Thus, $\widetilde{W}_r^j$ describes the weight of the jth criterion, C_j (j=1, ..., m), given by the rth decision maker. Similarly, $\tilde{X}_{ij}^r$ describes the reating of the ith alternative, A_i (i=1, ..., n), with respect to criterion j, given by the rth decision maker. Given that, the method comprises the following steps [4, 6, 20]:

1. Aggregate the weights of criteria and ratings of alternatives given by k decision makers, as expressed in (5) and (6) respectively:

$$\widetilde{w}_j = 1/k\left[\widetilde{w}_j^1 + \widetilde{w}_j^2 + \cdots + \widetilde{w}_j^k\right] \quad (5)$$

$$\tilde{x}_{ij} = 1/k\left[\tilde{x}_{ij}^1 + \tilde{x}_{ij}^2 + \cdots + \tilde{x}_{ij}^k\right] \quad (6)$$

2. Assemble the fuzzy decision matrix of the alternatives ($\widetilde{D}$) and the criteria ($\widetilde{W}$), according to (7) and (8):

$$\widetilde{D} = \begin{matrix} & C_1 & C_2 & C_j & C_m \\ A_1 & \tilde{x}_{11} & \tilde{x}_{12} & \tilde{x}_{1j} & \tilde{x}_{1m} \\ A_i & \vdots & \vdots & \vdots & \vdots \\ A_n & \tilde{x}_{n1} & \tilde{x}_{n2} & \tilde{x}_{nj} & \tilde{x}_{nm} \end{matrix} \quad (7)$$

$$\widetilde{W} = [\widetilde{w}_1 + \widetilde{w}_2 + \cdots + \widetilde{w}_m] \quad (8)$$

3. Normalize the fuzzy decision matrix of the alternatives ($\widetilde{D}$) using linear scale transformation. The normalized fuzzy decision matrix $\tilde{R}$ is given by:

$$\tilde{R} = \left[\tilde{r}_{ij}\right]_{m\times n} \quad (9)$$

$$\tilde{r}_{ij} = \left(\frac{l_{ij}}{u_j^+}, \frac{m_{ij}}{u_j^+}, \frac{u_{ij}}{u_j^+}\right) \text{ and } u_j^+ = max_i u_{ij} (benefit\ criteria) \quad (10)$$

$$\tilde{r}_{ij} = \left(\frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}}\right) \text{ and } l_j^- = min_i l_{ij} (cost\ criteria) \quad (11)$$

4. Compute the weighted normalized decision matrix, $\tilde{V}$ by multiplying the weights of the evaluation criteria, $\widetilde{w}_j$, by the elements $\tilde{r}_{ij}$ of the normalized fuzzy decision matrix.

$$\tilde{V} = \left[\tilde{v}_{ij}\right]_{m\times n} \quad (12)$$

Where $\tilde{v}_{ij}$ is given by (13)

$$\tilde{v}_{ij} = \tilde{x}_{ij} \times \widetilde{w}_j \quad (13)$$

5. Define the Fuzzy Positive Ideal Solution (FPIS, A^+) and the Fuzzy Negative Ideal Solution (FNIS, A^-), according to (14) and (15).

$$A^+ = \{\tilde{v}_1^+, \tilde{v}_j^+, \dots, \tilde{v}_m^+\} \quad (14)$$

$$A^- = \{\tilde{v}_1^-, \tilde{v}_j^-, \dots, \tilde{v}_m^-\} \quad (15)$$

Where $\tilde{v}_j^+ = (1, 1, 1)$ and $\tilde{v}_j^- = (0, 0, 0)$.

6. Compute the distances d_i^+ and d_i^- of each alternative from respectively $\tilde{v}_j^+$ and $\tilde{v}_j^-$ according to (16), (17).

$$d_i^+ = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^+) \quad (16)$$

$$d_i^- = \sum_{j=1}^n d_v(\tilde{v}_{ij}, \tilde{v}_j^-) \quad (17)$$

Where $d(.,.)$ represents the distance between two fuzzy numbers according to the vertex method. For triangular fuzzy numbers, this is expressed as in (18).

$$d(\tilde{x}, \tilde{z}) = \sqrt{\frac{1}{3}[(l_x - l_z)^2 + (m_x - m_z)^2 + (u_x - u_z)^2]} \quad (18)$$

7. Compute the closeness coefficient, CC_i, according to (19).

$$CC_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (19)$$

8. Define the ranking of the alternatives according to the closeness coefficient, CC_i, in decreasing order. The best alternative is closest to the FPIS and farthest to the FNIS.

Fuzzy linear programming: Zimmermann [24] proposed fuzzy linear programming by using Bellman and Zadeh (1970) approach. After fuzzification, the fuzzy linear program that included fuzzy goals and fuzzy constraints can be solved as a linear programming problem. Zimmermann [24] proposed a conventional linear programming problem as fallows (20–22):

Minimize $Z = Cx$ (20)

Subject to,

$Ax \leq b$ (21)

$x \geq 0$ (22)

After fuzzification the equation can be represented as (23–25),

$\tilde{C}x \lesssim Z$ (23)

$\tilde{A}x \lesssim b$ (24)

$x \geq 0$ (25)

The symbol $\lesssim$ in the constraint set denotes 'smaller than or equal to' and allows one to reach some aspiration level where $\tilde{C}$ and $\tilde{A}$ represent the fuzzy values. According to Bellman and Zadeh [25] approach, the fuzzy set A in X is defined as: $A = \{x, \mu_A(x)/x \in X\}$.Where $\mu_A(x): x \rightarrow [0, 1]$ is called the membership function of A and $\mu_A(x)$ is the degree of membership to which x belongs to A.

A fuzzy objective $\tilde{Z} \in X$ is a fuzzy subset of X characterized by its membership function $\mu_Z(x): x \rightarrow [0, 1]$. In this approach, Zimmermann formulated the membership function of objectives by separating every objective function into its maximum and minimum values. The linear membership functions for minimization and maximization objectives are given as:

$$\mu_{Zj}(x) = \begin{cases} 1 & if\ Z_j(x) \leq Z_j^{min} \\ \frac{Z_j^{max} - Z_j(x)}{Z_j^{max} - Z_j^{min}} & if\ Z_j^{min} \leq Z_j(x) \leq Z_j^{max}, where\ j = 1, 2, \ldots, j \\ 0 & if\ Z_j(x) \geq Z_j^{max} \end{cases} \quad \text{(for minimization)} \quad (26)$$

$$\mu_{Zj}(x) = \begin{cases} 0 & if\ Z_j(x) \leq Z_j^{min} \\ \frac{Z_j(x) - Z_j^{min}}{Z_j^{max} - Z_j^{min}} & if\ Z_j^{min} \leq Z_j(x) \leq Z_j^{max}, where\ j = 1, 2, \ldots, j \\ 1 & if\ Z_j(x) \geq Z_j^{max} \end{cases} \quad \text{(for maximization)} \quad (27)$$

In Equation (26)-(27), Z_j^{min} is $min_j\ Z_j$ (x*) and Z_j^{max} is $max_j\ Z_j$ (x*) and x* is the optimum solution.

A fuzzy constraint $\tilde{C} \in X$ is a fuzzy subset of X characterised by its membership function $\mu_C(x): x \rightarrow [0, 1]$. The linear membership function for the fuzzy constraints is given by (28):

$$\mu_{ck}(x) = \begin{cases} 1 & if\ g_k(x) \leq b_k \\ [1 - \{g_k(x) - b_k\}/d_k] & if\ \ b_k \leq g_k(x) \leq b_k + d_k \\ 0 & if\ b_k + d_k \geq g_k(x) \end{cases} \quad (28)$$

Crisp formulation: The fuzzy programming model for j objectives and k constraints are transformed into the crisp formulation as fallows [3, 10, 18]:

Maximize λ (29)

Subject to,

$\lambda(Z_j^{max} - Z_j^{min}) + Z_j(x) \leq Z_j^{max} \quad for\ all\ j, j = 1, 2, \ldots, J,$ (30)

$\lambda(d_x) + g_k(x) \leq b_k + d_k \quad for\ all\ k, k = 1, 2, \ldots, K,$ (31)

$Ax \leq b \quad for\ all\ the\ deterministic\ constant,$ (32)

$x \geq 0$ and integer, (33)

$0 \leq \lambda \leq 1.$ (34)

According to Zimmermann [24] each objective function should be solved for maximization and minimization for calculating the lower bound (Z_j^{min}) and upper bound (Z_j^{max}) values. The lower bound of the optimal values (Z_j^{min}) is obtained by solving the multi objective supplier selection problem as a linear programming problem using each time only one of the objectives. The upper bound of the optimal values (Z_j^{max}) is obtained by solving a similar multi objective supplier selection problem as a linear programming problem.

Mathematical Model

Based on the above assumptions, a multi-objective linear programming model was developed. The model decides most appropriate suppliers to maximize the efficiency of the supply. The indices, decision variable, parameters and enriched multi-objective model are presented as follows [2, 3, 6, 7, 10, 12, 13, 16, 17, 18]:

Indices:

i: *Set of suppliers* $(i = 1, 2, \ldots, I)$

j: *Set of objectives* $(j = 1, 2, \ldots, J)$

k: *Set of fuzzy constraints* $(k = 1, 2, \ldots, K)$

Parameters:

$\boldsymbol{D}$ **:** *Total demand of the product*

$\boldsymbol{N}$ **:** *Number of suppliers*

$\boldsymbol{Q}$ **:** *Maximum acceptable ratio (percent) of the defect products*

$\boldsymbol{B}$ **:** *Total budget allocated to suppliers*

$\boldsymbol{O}$ **:** *Total carbon emission limit for supply*

$\boldsymbol{P_i}$ **:** *Unit purchasing cost of product from supplier i*

$\boldsymbol{R_i}$ **:** *The ratio (percent) of the defect products delivered by the supplier i*

$\boldsymbol{L_i}$ **:** *The ratio (percent) of the late delivered products by the supplier i*

$\boldsymbol{C_i}$ **:** *The capacity of the supplier i.*

$\boldsymbol{G_i}$ **:** *The carbon emission for product supplied by supplier i*

$\boldsymbol{W_i}$ **:** *The weight (priority value) of the supplier i*

Decision Variables:

$\boldsymbol{X_i}$ **:** *The amount of product ordered from supplier i*

Objective Functions:

$$Min\ Z_1 = \sum_i^N P_i X_i \qquad (35)$$

$$Min\ Z_2 = \sum_i^N L_i X_i \qquad (36)$$

$$Min\ Z_3 = \sum_i^N R_i X_i \qquad (37)$$

$$Min\ Z_4 = \sum_i^N G_i X_i \qquad (38)$$

$$Max\ Z_5 = \sum_i^N W_i X_i \qquad (39)$$

Constraints:

$$\sum_i^N X_i \geq D \qquad (40)$$

$$X_i \leq C_i \qquad \forall i \qquad (41)$$

$$\sum_i^N R_i X_i \leq QD \qquad (42)$$

$$\sum_i^N G_i X_i \leq O \qquad (43)$$

$$\sum_i^N P_i X_i \leq B \qquad (44)$$

$$X_i \geq 0 \ and\ integer \qquad \forall i \qquad (45)$$

Objective function (35) minimizes the total cost of ordering. Objective function (36) minimizes the late delivered products of the suppliers. Objective function (37) minimizes the defected products due to the quality problem of the suppliers. Objective function (38) minimizes the total carbon gas emissions for procurement. Objective function (39) maximizes the total value of purchasing. Constraint (40) is the demand constraint ensures that the total demand is satisfied. Constraint (41) is the capacity constraint of suppliers, means that the amount of product ordered from each supplier cannot exceed its capacity. Constraint (42) is the quality control constraint, means that the total defect products cannot exceed maximum total acceptable defect products. Constraint (43) is the carbon footprint constraint, means that the amount of carbon emission released by each supplier cannot exceed maximum total carbon emission limit. Constraint (44) is the budget constraint means that total purchasing cost of products cannot exceed budget amount allocated to the suppliers. Constraint (45) is the non-negativity and integrity constraint.

In a real case supplier selection problem, decision makers do not have certain and complete information related to decision criteria, sources and constraints. For example, capacity, demand, budget, etc. the vagueness in this information cannot be obtained in deterministic problems. For this reason the best result of these deterministic models may not serve the real purpose. Fuzzy multi objective modeling is applied to deal with such problems [10, 12].

Fuzzy mathematical programming has the ability to handle both multi-objective problems and vagueness [24].

Application of Fuzzy Linear Programming for Supplier Selection

A fuzzy multi objective linear programming model is proposed for supplier selection. Fuzzy set theory is used for modelling and solving the multi objective linear programming due to the vagueness of the model parameters. The cost of procurement, late delivered products, defected products, carbon emissions, weights of suppliers and budget are considered fuzzy numbers because of their inherent uncertainty and vague structure. After fuzzification, the equations can represented as follows (46)–(56).

$\sum_i^N P_i X_i \lesssim \tilde{Z}_1$ (46)
$\sum_i^N L_i X_i \lesssim \tilde{Z}_2$ (47)
$\sum_i^N R_i X_i \lesssim \tilde{Z}_3$ (48)
$\sum_i^N G_i X_i \lesssim \tilde{Z}_4$ (49)
$\sum_i^N W_i X_i \gtrsim \tilde{Z}_5$ (50)
$\sum_i^N X_i \geq D$ (51)
$X_i \leq C_i \quad \forall i$ (52)
$\sum_i^N R_i X_i \leq QD$ (53)
$\sum_i^N G_i X_i \leq O$ (54)
$\sum_i^N P_i X_i \lesssim \tilde{B}$ (55)
$X_i \geq 0$ *and integer* $\forall i$ (56)

Where ~ denotes the fuzzy number.

Illustrative Example

In tackled numerical examples, for supplying a product to a firm assume that five suppliers will be managed using five main criteria. The purchasing criteria are Cost, Quality, Delivery, Flexibility and Environmental Policy. The fuzzy pair wise comparisons among the criteria are shown in Table 1. Weights of the criteria are found by the FAHP method using the pair wise comparison matrix. Table 2 presents the parameters of the triangular fuzzy numbers determined by the decision maker as fuzzy decision matrix. Weights of the suppliers are found by the FTOPSIS method using fuzzy decision matrix and fuzzy weights of criteria (as shown in Table 3). To perform optimal allocation of order quantity, the weights of the suppliers based on the results of FTOPSIS are used as coefficients in the fifth objective function of the fuzzy multi objective linear programing model.

Table 1. The Fuzzy Pair Wise Comparisons among the Criteria.

	Cost	**Quality**	**Delivery**	**Flexibility**	**Environmental Policy**
Cost	(1, 1, 1)	(0.30, 0.50, 0.70)	(0.50, 0.70, 0.90)	(0.90, 1, 1)	(0.70, 0.90, 1)
Quality	(1.43, 2, 3.33)	(1, 1, 1)	(0.70, 0.90, 1)	(0.70, 0.90, 1)	(0.90, 1, 1)
Delivery	(1.11, 1.43, 2)	(1, 1.11, 1.43)	(1, 1, 1)	(0.30, 0.50, 0.70)	(0.10, 0.30, 0.50)
Flexibility	(1, 1, 1.11)	(1, 1.11, 1.43)	(1.43, 2, 3.33)	(1, 1, 1)	(0.10, 0.30, 0.50)
Environmental Policy	(1, 1.11, 1.43)	(1, 1, 1.11)	(2, 3.33, 10)	(2, 3.33, 10)	(1, 1, 1)

After FAHP analysis for determining criteria weights, it is observed that the weights of Cost: (0.17, 0.19, 0.20), Quality: (0.18, 0.20, 0.22), Delivery: (0.17, 0.19, 0.21), Flexibility: (0.18, 0.20, 0.22) and Environmental Policy: (0.19, 0.22, 0.28).

Table 2. Fuzzy Decision Matrix and Fuzzy Weights of Criteria.

Suppliers	**Cost**	**Quality**	**Delivery**	**Flexibility**	**Environmental Policy**
1	(0, 0, 1)	(3, 5, 7)	(9, 9, 10)	(7, 9, 10)	(5, 7, 9)
2	(1, 3, 5)	(0, 0, 1)	(7, 9, 10)	(9, 9, 10)	(0, 1, 3)
3	(7, 9, 10)	(5, 7, 9)	(1, 3, 5)	(0, 1, 3)	(1, 3, 5)
4	(9, 9, 10)	(1, 3, 5)	(0, 0, 1)	(5, 7, 9)	(0, 0, 1)
5	(3, 5, 7)	(7, 9, 10)	(0, 1, 3)	(0, 0, 1)	(9, 9, 10)
Weights of criteria	(0.17, 0.19, 0.20)	(0.18, 0.20, 0.22)	(0.17, 0.19, 0.21)	(0.18, 0.20, 0.22)	(0.19, 0.22, 0.28)

Table 3. Outranking of Alternative Suppliers.

Suppliers	d_j^+	d_j^-	CC_j	Normal weights	Rank
1	4.37	0.66	0.131	0.250	1
2	4.55	0.49	0.097	0.185	4
3	4.54	0.51	0.102	0.194	3
4	4.61	0.43	0.084	0.161	5
5	4.48	0.55	0.110	0.210	2

Table 4. Supplier's Quantitative Information.

Suppliers	P_i($)	L_i(%)	R_i(%)	G_i(kg)	C_i(kg)
1	10	0.03	0.02	1.5	11500
2	7.5	0.04	0.05	2.1	7000
3	9	0.02	0.03	1.7	10000
4	8.5	0.06	0.04	2.3	13500
5	8	0.04	0.04	1.9	6000

It is assumed that the input data from supplier's performance on these criteria are not known precisely. The budget is predicted to be about 170000 and it is assumed that it can vary from 165000 to 178000. The total demand value (D) is taken 20600, maximum acceptable ratio of the defect products value (Q) is taken 0.041 and the total carbon emission limit value (O) is taken 40000 in this model. Supplier quantitative information is given in Table 4. The multi objective linear formulation of illustrative example is presented as:

$Z_1 = 10x_1 + 7.5x_2 + 9x_3 + 8.5x_4 + 8x_5$
$Z_2 = 0.03x_1 + 0.04x_2 + 0.02x_3 + 0.06x_4 + 0.04x_5$
$Z_3 = 0.02x_1 + 0.05x_2 + 0.03x_3 + 0.04x_4 + 0.04x_5$
$Z_4 = 1.5x_1 + 2.1x_2 + 1.7x_3 + 2.3x_4 + 1.9x_5$
$Z_5 = 0.250x_1 + 0.185x_2 + 0.194x_3 + 0.161x_4 + 0.210x_5$
Subject to;
$x_1 + x_2 + x_3 + x_4 + x_5 \geq 20600$
$x_1 \leq 11500$
$x_2 \leq 7000$
$x_3 \leq 10000$
$x_4 \leq 13500$
$x_5 \leq 6000$
$0.02x_1 + 0.05x_2 + 0.03x_3 + 0.04x_4 + 0.04x_5 \leq 0.041 * 20600$
$1.5x_1 + 2.1x_2 + 1.7x_3 + 2.3x_4 + 1.9x_5 \leq 40000$
$10x_1 + 7.5x_2 + 9x_3 + 8.5x_4 + 8x_5 \leq 170000$
$x_1 \geq 0, x_2 \geq 0, x_3 \geq 0, x_4 \geq 0, x_5 \geq 0$
x_1, x_2, x_3, x_4, x_5 are integer

The multi objective supplier selection problem is solved as a single-objective supplier selection problem using each time only one objective. Firstly the objective function Z_1 is minimized using all constraints for getting the lower-bound of the objective function -this value is the best value for this objective as other objectives are absent -and then similarly maximized for getting its upper bound. This procedure is repeated for rest four objective functions (Z_2, Z_3, Z_4 and Z_5) for getting the lower and upper bound of these objective functions. The data set for the values of the lower bounds and upper bounds of the objective functions are given in Table 5.

Table 5. The Data Set for Membership Functions.

Objective functions	*Lower bounds* $\mu = 1$	*Upper bounds* $\mu = 0$
Z_1	168083.333333	170000
Z_2	650	791
Z_3	803.333333	834.333333
Z_4	38726.666667	40000
Z_5	3913.4	4091

In Zimmermann approach, all factors are assigned the same weight, and λ is the overall objective function. Hence, λ is maximized in this case. The crisp formulation of the illustrative example is presented as:
Maximize λ
Subject to

$$\lambda \leq \frac{170000-(10x_1+7.5x_2+9x_3+8.5x_4+8x_5)}{1916.666667}$$

$$\lambda \leq \frac{791-(0.03x_1+0.04x_2+0.02x_3+0.06x_4+0.04x_5)}{141}$$

$$\lambda \leq \frac{834.333333-(0.02x_1+0.05x_2+0.03x_3+0.04x_4+0.04x_5)}{31}$$

$$\lambda \leq \frac{40000-(1.5x_1+2.1x_2+1.7x_3+2.3x_4+1.9x_5)}{1273.333333}$$

$$\lambda \leq \frac{(0.250x_1+0.185x_2+0.194x_3+0.161x_4+0.210x_5)- 3913.4}{177.6}$$

$$x_1 + x_2 + x_3 + x_4 + x_5 \geq 20600$$
$$x_1 \leq 11500$$
$$x_2 \leq 7000$$
$$x_3 \leq 10000$$
$$x_4 \leq 13500$$
$$x_5 \leq 6000$$
$$0.02x_1 + 0.05x_2 + 0.03x_3 + 0.04x_4 + 0.04x_5 \leq 0.041 * 20600$$
$$1.5x_1 + 2.1x_2 + 1.7x_3 + 2.3x_4 + 1.9x_5 \leq 40000$$

$$\lambda \leq \frac{178000-(10x_1+7.5x_2+9x_3+8.5x_4+8x_5)}{8000}$$

$$\lambda \leq \frac{(10x_1+7.5x_2+9x_3+8.5x_4+8x_5)- 165000}{5000}$$

$$x_1 \geq 0,\ x_2 \geq 0,\ x_3 \geq 0,\ x_4 \geq 0,\ x_5 \geq 0$$
x_1, x_2, x_3, x_4, x_5 are integer

Fuzzy multi objective linear programming model developed in accordance with these data was solved in GAMS/CPLEX 24.0 software package.
The optimal solution for the above formulation is as follows:

Objective value λ is 0.548, and the value of $x_1 = 0,\ x_2 = 6967,\ x_3 = 7633,\ x_4 = 0,\ x_5 = 6000$.
$Z_1 = 168949.50,\ Z_2 = 671.34,\ Z_3 = 817.34,\ Z_4 = 39006.80,\ Z_5 = 4029.70$

In this solution, No products were purchased from suppliers 1and 4, because the supplier 1 has the highest purchasing cost and supplier 4 is not environment friendly. 6000 (maximum capacity) products were purchased from supplier 5, and the remaining products are ordered from supplier 2 and 3. So, the company will work towards its goals with suppliers 2, 3 and 5.

CONCLUSIONS

Supplier selection is a critical decision for long term survival of the firm. The supplier selection problem includes both selecting suppliers and allocating optimal order quantity among the selected suppliers. Supplier selection is based on a supplier's ability to meet economic and also environmental criteria. But in real cases, many input data are not known precisely for decision making. So, FAHP-FTOPSIS methods and fuzzy multi-objective linear programming was used to deal effectively with vagueness and imprecision in this study.

In this study, a new fuzzy multi objective linear programing model was considered for supplier selection. The problem includes the five objective functions: minimizing the total cost of procurement, late delivered product, defected product, amount of carbon emissions and maximize value of purchasing for supplier selection while satisfying demand, capacity, quality, carbon emission limit and budget requirement constraints. At first, FAHP was used to obtain the relative weights of quantitative and qualitative criteria. Next, FTOPSIS method was used for evaluating the selected suppliers. Finally, fuzzy multi objective linear programming model was developed to find out the optimum solution of the problem. The proposed model was verified with the aid of a numerical example by solving in GAMS/CPLEX 24.0 software package.

In practice, all objective functions may not have the same important; thus, for future researches, weighted methods can be employed and the weights of the objective functions can be changed according to the needs of the manager. Also, in the proposed model other constraints such as demand and capacity can be considered fuzzy as well as budget constraint. Additionally, Other than the FTOPSIS method used in this study, other multi-criteria decision making methods can be used in a fuzzy environment and compared in terms of suitability.

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BUSINESS PROCESS REENGINERING FOR THE CENTRAL STERILIZATION UNIT AND ITS APPLICATION

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Abstract – *Many healthcare systems are forced to survive in a rapidly changing environment with rising costs and the need for proper resource utilization. It is inevitable that the healthcare systems will seek for business process reengineering (BPR) to address the growing requirements for effective strategic planning in order to exist. Business process reengineering (BPR) concerns the fundamental rethinking and radical redesign of business processes to obtain dramatic and sustaining improvements in quality, cost, service, lead time, outcomes, flexibility and innovation. Recently, BPR has become an important function in a healthcare system. This paper presents a BPR method for modelling the system in healthcare sector- specifically the central sterilization unit-, As-Is and To-Be processes are modeled and compared by ARIS tools.*

Keywords – BPR, Healthcare, Business processes, ARIS.

INTRODUCTION

The companies should regularly upgrade their operations to stay competing in the business. To do so, it is indispensable to transform its daily basis business processes. The major causes for business transformation are the worldwide integration of business operations, the fast formation of new technologies and the constantly altering customer needs. Because of the rising costs, the urgency for proper resources, and the global transformations, the healthcare systems will eventually look up for reengineering projects in order to survive. Business process reengineering concerns significant improvements in many aspects in an organization. That is why business process reengineering has recently turned into an important role in a healthcare system.

Business Process Management

Business Process Management (BPM) is an organized procedure to analyze and consistently ameliorate main activities and other major components of a company's operation. The units and operational activities are reorganized by well-organized approach in order to obtain improvements of quality in operations [10] [16]. BPM makes a more holistic concept possible for the organization because it gathers standard procedures from numerous different domains, such as IT, engineering, management, and sociology as well [13].

One of the BPM tool among many others is Business Process Reengineering (BPR). Business process reengineering is a useful technique for analyzing the existing enterprise processes with a process-oriented approach, defining relations between activities and processes, redesigning processes within and between enterprises, estimating time, cost and resources of the changed processes and then improving and optimizing the processes. One of the principal strategies to initiate change over process performance developments is BPR [19]. The aim of BPR is to accomplish the best performance possible in regard of operational and organizational solutions [33].

The Architecture of Information Systems

The Architecture of Information Systems (ARIS) can be used as a keystone for Business Process Reengineering and Business Process Management (Scheer, 1992 and 1998). ARIS, along with ARIS toolset, is an engineering tool based on a modeling language, using a process view. It ensures representing the different views of an enterprise (functional, informational, organizational and control) based on different levels (conceptual, technical and implementation). The user guidance is maintained for the modeling process. ARIS is often used to do reengineering of information systems [11].

Enterprise Resource Planning

ERP applications are known as one of the most preferred Business Process Management Software (BPMS) product among others. ERP is a business process management software that permits a company to adopt an integrated operation system to control the organization and automate various business operations. It is an operating system tailored to be benefited from many organizations. ERP software represents and links a plenty of business processes and allows the data stream between them.

The Central Sterilization Unit

Healthcare services have always been an important area for applications of Business Process Reengineering. The central sterilization unit is basically where the hospital items such as surgical and medical items, both nonsterile and sterile, are cleaned, packed, sterilized, stored, and issued when needed. The departments are generally separated into four primary fields to fulfill respectively the activities of decontamination, assembly and cleaning sterilization, sterile storage and distribution. These units work in coordination with other units of a hospital, and they are a central place in fighting and destroying pathogens and microorganisms, which is important to maintain the unit's safety.

The sterilization process includes basic steps such as washing, packaging and cleaning, sterilization, quality control, sterile storage and distribution. The used instruments are freed of microorganisms by sterilization. After this process, these instruments are reused for the patients; therefore, all activities should be certainly conducted in this unit because of its importance to all patients and hospital staff [9].

The healthcare sector is one of the major field of the business process reengineering study. Because of the importance of the sterilization processes in hospital institutions and the intention of preventing the healthcare related infections, the application part will be done in this area. As the amount and diversity of surgical procedures expanded and the variety of equipment, MDs and supplies multiplied, it becomes more and more important that a centralized sterilization process is necessary for finance, efficiency and patient care. A framework is required to describe the current working system and also to lead the needed changes. In the literature there are different methods/methodologies and they have the same approach: initially, the actual working system is analyzed and modeled to illustrate the current on-going processes (in other words AS-IS situation); secondly, the targeted system is developed to form the suitable planning and control system (in other words TO-BE situation). Finally, the expected performance is evaluated after the implementation of the proposed solutions. In this case, the proposed solution will be an information technology to enable the improvements.

In the AS-IS process analysis step, the current way of working in the central sterilization unit will be summarized and documented. Data collection such as observation records, interviews and its analysis will be applied during this phase. In the TO-BE process-modeling phase, the future workflows will be remodeled and the workflows of each phases will be modeled and compared by using ARIS tool. In this process-modeling step, the data collection will be collected automatically by the information system. After the implementation, the results will be compared and the areas that will be automated by the proposed solution - using an Enterprise Resource Planning - will be observed.

LITERATURE REVIEW

For the first part of the study, the existing literature is searched for the investigation of various methodological tools in the field. According to the literature survey, the studies in the field can be grouped under a few categories and most of the studies are solved by using business process reengineering method. That is why in this study business process reengineering will be used as a methodology in healthcare sector.

Main studies that use literature review as a tool are as follows. Al Mashari (2001) provided an overall research study in the ERP field related to process management, organizational change and knowledge management [1]. Ranganathan and Dhaliwal (2001) presented the results of the business process reengineering practices survey accompanied by firms in Singapore [30]. Gunasekaran and Kobu (2002) studied a survey for searching the analysis, modelling and tools/techniques used for modelling of BPR [16]. Silvestro and Westley (2002) stated the outcomes of case-study research that was handled for investigating the functional developments appearing from organizations' process re-engineering [34]. Vanwersch et al. (2016) investigated the research procedures of the studies that were used to create the framework [37]. Leijen-Zeelenberg et al (2016) evaluated the present knowledge about the influence of process redesign on the healthcare quality.

Studies that use Business Process Redesign approach are as follows. Jansen-Vullers and Reijers (2005) defined a redesign method established on a set of current redesign heuristics and applied this method in a mental healthcare case [20]. Noumeir (2006) involved in modeling the process of radiology interpretation that outcomes in generating a diagnostic radiology report [27]. Mansar and Reijers (2005) presented a structure for helping the process designer in selection of the convenient best practice(s) [25]. Mansar et al. (2009) proposed a strategy for the implementation of business process redesign [26]. Pourshahid et al. (2009) proposed a methodology that will examine the effect of business processes changes with what-if scenarios based on the most convenient process remodeling motifs among many possibilities [28].

Studies that use Business Process Reengineering approach are as follows. Crowe et al. (2002) addressed a developed tool to guess the potential risk level of a BPR effort before an organization allocates its resources [8]. Wu (2002) proposed a unifying approach established on a strategic vision and examined the plan by an empirical study [39]. Cheng and Tsai (2003) precised the process reengineering definition and description and developed Construction Management Process Reengineering Method to improve the efficiency of construction management [6]. Attaran (2004) examined a series of connection between business process reengineering and information technology. Attaran addressed possible obstacles to successful reengineering implementations and described important factors for its achievement [2]. Rahmati and Cao (2005) examined the impact of different organizational and national factors on the reengineering of the business processes to adopt ERP [29]. Huq and Martin (2006) made a comparison between the concepts towards BPR implementation and prepared some proof to state which concept proposes bigger success [19]. Vergidis et al. (2008) discussed business workflows by proposing a new categorization pattern for business process models and by displaying the present analyzing trends and optimization methods [38]. Samaranayake (2009) proposed an integrated method to process implementation, automation, and optimization through upgraded business process models [32]. Lesselroth et al. (2011) described a self-service patient kiosk implementation engaged patients for a clinic appointment check in and gathered a medication attachment history that is accessible from the electronic health record. They showed how business process design and simulation modeling were used for infrastructure impact estimation, and proposed strategies for kiosk deployment in an ambulatory care clinic [23]. Leu and Huang (2011) applied the main ARIS approach for optimizing an emergency department's clinical processes in a mid-size hospital with 300 clinical beds and studied the essence of a healthcare organization at the same time [24]. Bahramnejad et al. (2015) presented BPR method that adopts Enterprise Ontology for modelling the on-going system and its purpose was to enhance current system analyze and to reduce the failure rate of BPR, the process performing time and the cost [3]. Rasheed and Khan (2015) showed how workflow can be optimized through re-engineering methodology in Tele Cardiac system [31]. Leggat et al. (2016) explored the perceptions of hospital staff on the effect of a process remodel initiative on healthcare quality [14]. Hakim et al. (2016) presented a methodology to assist enterprise decision makers (DMs) to select from a number of processes during Business Process Reengineering according to organizational objectives [17].

Studies that use Business Process Simulation/ Simulation Modeling approach are as follows. Greasley (2003) introduced a business process simulation case study based on a BPR framework for change [15]. Mascolo et al. (2006) proposed a simulation model of a real sterilization service [12]. Kolker (2008) matured a simulation process model of Emergency Department patient flow considering a time of stay difference between allocations of patients dismissed home and patients allowed into the hospital [21]. Han et al. (2009) proposed a two-stage process analysis for redesigning a process that integrates BPS (business process simulation) and PPMF (process-based performance measurement framework) [18]. Smits (2010) developed a system design to maintain the intake and treatment process management in a mental healthcare [35]. Lesselroth et al. (2011) described a self-service patient kiosk implementation engaged patients for a clinic appointment check in and gathered a medication attachment history that is accessible from the electronic health record [23]. Bisogno at al. (2016) provided a method for analyzing and improving the operational performance of business processes (BPs) [4].

Besides, there are many other studies in the field, such as, Scheer and Nüttgens (2000) presented a common business process structure which is founded on ARIS and which is collected of the four levels of process engineering, process planning and control, workflow control and application systems [33]. Kwak and Lee (2002) presented a MCMP application (multicriteria mathematical programming) for supporting strategic planning for an organization's business process infrastructure advancement [22]. Aguilar-Saven (2004) inspected business process-modelling literature, explained the principal process modelling methods, and suggested a framework for categorizing business process-modelling methods. Tan et al. (2008) displayed a vision and methodology set throught a business process intelligence using an evaluation of the dynamic process performance, along with the measurement models established on ABM (Activity Based Management) and a dynamic enterprise process performance evaluation methodology [36]. Martinelly (2009) developed a modeling framework that permits decision makers to reengineer and evaluate their hospital supply chain [11]. Combi et al. (2014) proposed a new process modeling language (TNest), that permits to deliberate the time constraints and the data dependencies with ease throughout the process design [7]. Buttigieg (2016) investigated how BPM standards can aid to obtain better health care management and considered the BPM principle application in health care sector [5].

BUSINESS PROCESS REENGINEERING

Most of the BPR methodologies have general aspects and phases. All the business process-reengineering projects should have general phases such as the envision phase, the initiation phase, the diagnosis phase, the redesign phase, the reconstruction phase and the evaluation phase. To do so, in every business process-reengineering project, these fundamental steps must be followed in order to succeed the project : Step 0 - Preparation and Coordination of the Project, Step 1 - Business Diagnosis and Measurements, Step 2 - Selection of Processes for Change and Modeling, Step 3 - Technical Design of the Solution, Step 4 - Personnel Adaption and Training, Step 5 - Management of Change and Employee Empowerment, Step 6 - Introduction of New Processes into Business Operations and Step 7 - Continuous Improvement. There are many bottlenecks and inefficiencies (such as delays on the reception and delivery of equipment, human resources and schedule problems etc.) in the current sterilization cycle of surgical equipment that needs to be optimized and automated. Therefore, some radical changes are required with a BPR application. In this study the primary motivation to apply BPR to the health care sector, specifically into a central sterilization unit, is to improve the productivity of the sterilization unit process.

For the application phase, we benefited from a large hospital in Turkey for the case study to get the challenges of a central sterilization unit in a health care organization. The current core and sub-processes (AS-IS situation) of the central sterilization unit are shown in Figure 1- Figure 7. Since this is an ongoing project the TO-BE processes are on redesign stage. The core and sub-processes of the new central sterilization unit process are shown in Figure 8. In this study, a process redesign with ERP is proposed for the operation of the sterilization to automate the work processes. In the technical design of the solution phase, an ERP will be selected as an IT solution and reengineered in order to meet the requirements for better information flow and for reduced inventory costs. The future processes will be operated through the ERP system. With that, the business efficiency will be enhanced and the overall ability will be improved to fit the needs of the central sterilization unit. Problems will be diagnosed earlier and the error rate will be reduced. Also, with the well resource allocation and effective use of resources, the waiting times of the hospital departments will be reduced.

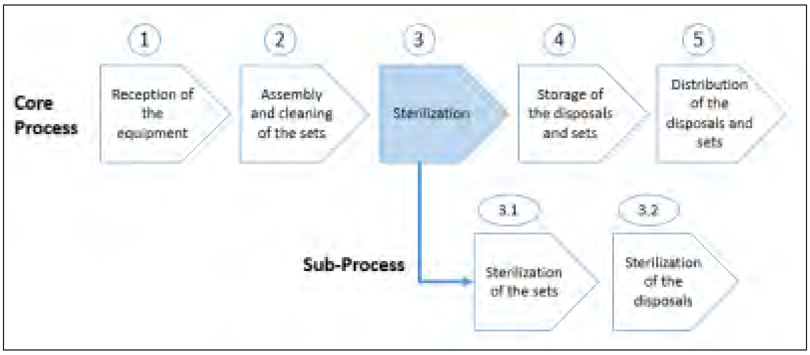

Figure 1. Current Core and Sub-Processes of the Sterilization Process

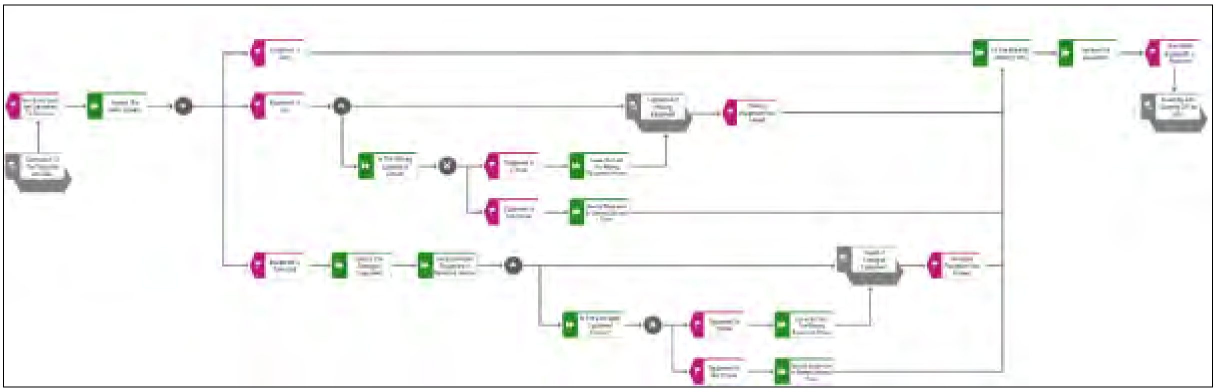
Figure 2. Reception of the Equipment

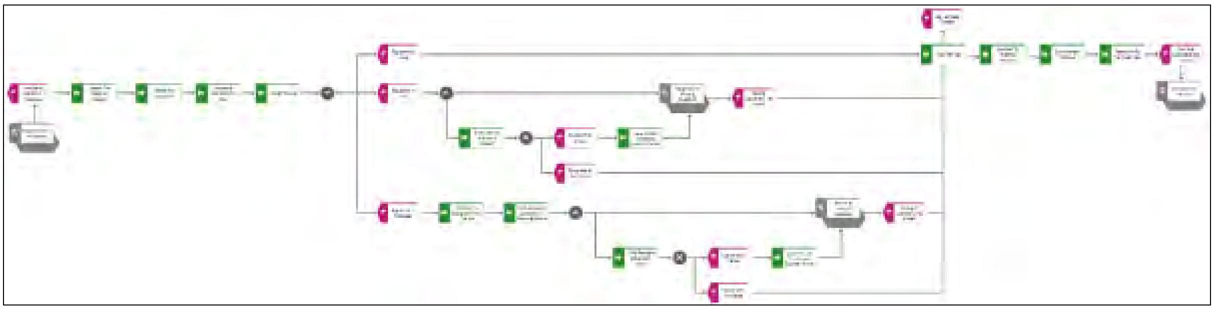
Figure 3. Assembly And Cleaning Of The Sets

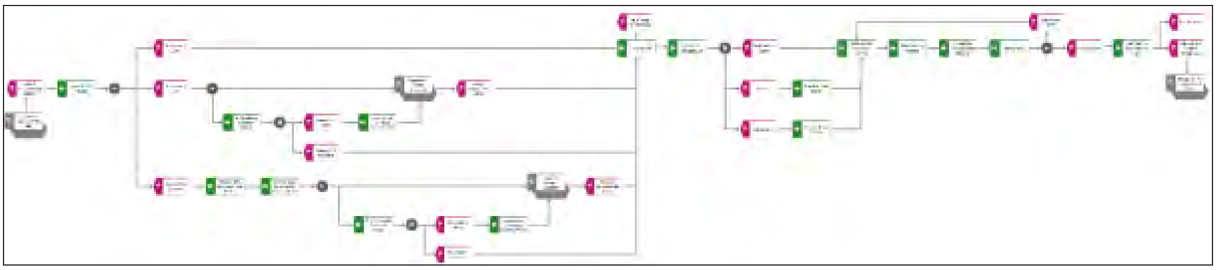
Figure 4. Sterilization of The Sets

Figure 5. Sterilization of The Disposals

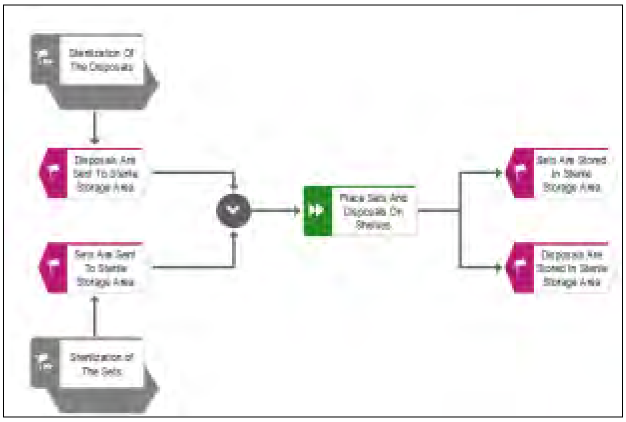

Figure 6. Storage of The Disposals and Sets

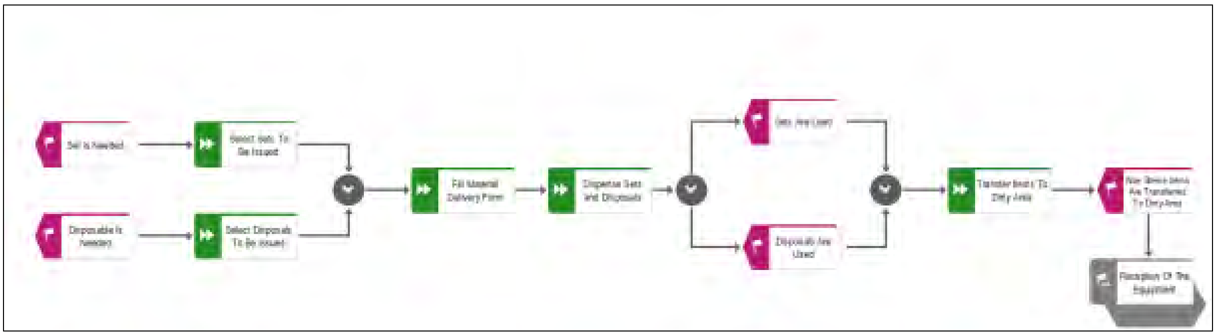

Figure 7. Distribution of The Disposals and Sets

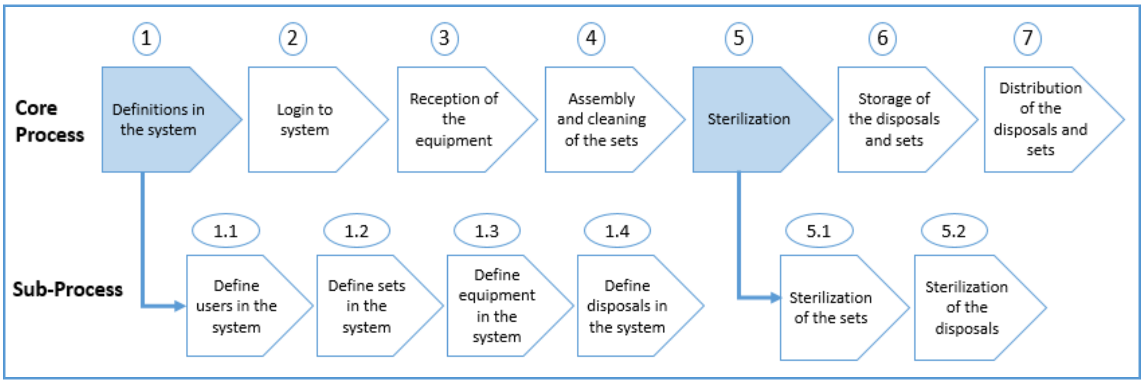

Figure 8. Core and Sub-Processes of the Sterilization Process

As a solution method, ERP-driven BPR will be used to reengineer its processes. Within this framework, the requirements of the current system will be analyzed, AS-IS and TO-BE processes will be modeled by using EPC notation in ARIS tool and then the performance of the reengineering processes will be held after the implementation of the proposed solution in order to compare the results and the automated areas. All the processes will be standardized and documented throughout the central sterilization unit.

CONCLUSION

In conclusion, the health care sector is increasingly confronting challenges that it is necessary to react by adapting new processes into the organization of health care. By supporting integrated systems for business performance management as well as current process management, BPM can give solutions to problems and treats that health care sector confronts today. In this paper, we presented a BPR method for modelling the system in healthcare sector- specifically the central sterilization unit-, As-Is and To-Be processes modeled and compared by ARIS tools and then the performance of the study is examined. This study seeks for the potential gains of the project about the implementation of ERP in hospitals. As a result of this project, improvements in productivity, cost and quality are expected in sterilization processes since the new process design will bring automation, human related error reduction and equipment tracking system. This project is still undergoing today because of the lack of resources, human and financial.

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REVERSE LOGISTICS NETWORK DESIGN OF WASTE BATTERIES IN TURKEY

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Abstract — *The inadequacy of the environmental resources that comes with the overpopulation reveals the need for protection of the natural resources and for recovery of the used resources in order to obtain new raw materials as well as minimizing their damage to the environment. Reverse logistics concept, which deals with the reverse product flow from the end user to the origin point, is emerged as a consequence of this quest. In this study, waste battery reverse logistics is handled. The waste batteries embody different heavy metals, so that they are classified in the hazardous wastes category and batteries are the richest sources in terms of the metal contents. Hence, recycling of the reusable waste battery parts to provide economic benefits and disposing the hazardous parts properly to minimize its damage to the environment and human health becomes a very significant issue. In this study, the literature review about reverse logistics network design is made and the existing situation of the waste batteries in Turkey is examined. A mixed integer linear programming model for the waste batteries is proposed. The mathematical model is applied for Turkey case under three different scenarios. The results of the mathematical model are analysed and future directions are provided finally.*

Keywords — *Network design, reverse logistics, recycling, waste batteries*

1. INTRODUCTION

The environment has a limited resource capacity. In the world, overpopulation naturally leads to faster depletion of these limited resources. Wasting raw materials at critical levels, creates the need of seeking some methods and techniques to obtain new raw materials and resources. Reverse logistics term has emerged as a consequence of the cycle of these events. Within this context, reverse logistics includes the recovery of the end-products by gaining value step by step.

Growing awareness in a limited resource environment generates the demand of proper disposal of the non-reusable and hazardous materials. Hence, consumers and authorities put a burden on manufacturers about the recycling or disposal of the wastes resulting from the consumption. Reverse logistics concept involves both the recycling and properly disposal of the end-products by planning, implementing and managing the flow of the parts. Recycling of the products and materials, which are worth for a particular value recovery, provides financial gains to institutions, considerably.

In the world, many countries have begun to realize the importance of reverse logistics applications. Recovery of the materials becomes very significant in minimizing the harmful influence on the environment and to meet the requirement of raw material usage. Due to these reasons, the European Union wants to create an added value by revaluating the used or wasted materials with using one or more of the recycling, recovering or burying and burning options that are mentioned in the 2008/98/EC up-to-date directive [1].

In Turkey, there are approximately 35 megatons of industrial wastes collected each year. Annual turnover of Turkey's recycling industry is nearly 5 billion dollars. The recyclable waste generated only from residential areas is about 6 megatons. Unfortunately, due to the lack of proper organizational and economical structure in Turkey, nearly 5 megatons of these wastes are buried without entering any recycling or recovering process. The deficiency of having the proper structure for recycling costs 2.25 billion TL to Turkey, without including the impact of environmental damage of buried wastes [2].

In this study, it is focused on the recycling of the waste batteries. Since the batteries contain both environmentally hazardous substances (Pb, Cd, Hg etc.) and recyclable substances (Zn, Cd, Pb, C, Mn etc.), after valuable metal parts of the batteries are recovered, remaining parts should be disposed in a way that is not harmful to the human health and environment [3]. Establishment of the first waste battery recycling facility in Turkey creates the need of making researches about the reverse logistics of waste batteries. In this study, after investigating the existing collection and recycling systems in the world, a network model for the waste batteries in Turkey is proposed. The purpose of the model is to provide an optimal flow for waste

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batteries from the collection point to the secondary material market or final processing plants by minimizing the related costs.

The remainder of this paper is mapped as follows. Section 2 provides the literature review about reverse logistics. Section 3 gives information about waste battery recycling and situation in Turkey. The proposed mathematical model is explained in Section 4. Section 5 presents the application of the case in Turkey. Finally, conclusion is provided in Section 6.

2. LITERATURE REVIEW

Rogers and Tibben-Lembke (2001) defined reverse logistics as: "*The process of planning, implementing, and controlling the efficient, cost effective flow of raw materials, in-process inventory, finished goods and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal.*" [4]

In reverse logistics processes, proper backflow of the used materials to be collected from consumers has an important place. Besides the uncertainty in the amount of products that will enter the backflow, it is also uncertain when the recycling processes will be completed. For these reasons, characteristics of the reverse logistics should be well defined. Some of the unique characteristics of the reverse logistics can be listed as below [5]:

- Uncertainty in the quality, quantity and timing of the backflow
- Difficulties in locating the recovered products or materials in the market
- Structural problems
- Difficulties in collecting and recycling of the used products

Reverse logistics has emerged to draw attention to the recovery potentials of used products. Based on the literature survey, the reasons of firms to incorporate the reverse logistics can be divided into 5 main categories such as economic factors, legislation, environmental and green issues, corporate citizenship and asset protection [6]. Moreover, there are five product recovery processes to recover the used or end-of-life products and materials: repair, refurbishing, remanufacturing, cannibalization and recycling [7].

There are many studies in the literature about reverse logistics network design. Some of these studies are summarized as follows:

Alidi (1992) studied about hazardous waste treatment and disposal. He constructed an integer goal programming model in order to minimize the cost and determine the optimal locations of treatment transfer stations, landfill and incineration plant sites, and the sites of potential markets for recyclable materials. A presumptive example was used to examine the practicality of the constructed model and the results show that the model is very useful for planning and cost minimization of the hazardous waste systems [8].

Bloemhof-Ruwaard et al. (1996) studied about an environmental life-cycle optimization model for the European pulp and paper industry. They used a linear programming network flow model to find optimal configurations such as a distribution of pulp and paper production, and a level of recycling with the lowest environmental impact. Different scenarios with different recycling strategies were used to examine the results of the model [9].

Le Blanc et al. (2002) studied about redesign of a recycling system for LPG-tanks. In this study, a vehicle routing model with mathematical programming model was designed as an alternative solution approach. Because the system has many uncertain outputs, a sensitivity analysis was also conducted for the different behaviors of the model [10].

Pati et al. (2008) studied on a goal programming model for paper recycling system in India. For this purpose, a mixed integer goal programming (MIGP) model was used to construct a recycled paper distribution network by using multiple objectives with different priorities. The goal was to minimize the cost, increase the recovery of wastepaper and product quality, and determine the optimal flow and locations [11].

Demirel et al. (2011) worked on a hybrid genetic algorithm for multistage integrated logistics network optimization problem. The aim was to decide the necessary number and the locations of the plants with the minimum cost. They generated a multi-product mixed integer linear programming model for the logistics network design based on a heuristic approach with LP (Linear Programming). The results of the different scenarios were obtained by using GAMS-CPLEX [12].

Kannan et al. (2012) presented an article about a carbon footprint based reverse logistics network design model. The objective was to minimize the overall cost and carbon emissions. A mixed integer linear programming model was developed and the location and transportation decision problems were combined for solving the problem. A case study from the plastic sector was used to examine the results of the model [13].
Budak (2013) worked on reverse logistics and network design for waste disposal in health institutions of Turkey. For the next five years, the expected waste quantities, the required number and location of facilities were determined. The aim was to minimize the overall cost and find the optimal collection and disposal system for wastes by using mixed integer linear programming. Also, a sensitivity analysis was performed for the different waste quantities [14].

Dönmez (2013) developed a MILP to design reverse logistics network for waste batteries and implemented the model to the Turkey. The objective was to maximize the profit and to design the reverse network of waste batteries. All models were programmed and implemented in GAMS optimization package and solved using the CPLEX solver. They also conducted a sensitivity analysis for the changes of different parameters [15].
Cingöz (2014) studied on the analysis and design of reverse logistics networks on waste collection in Mersin. The aim was to improve waste collection processes by using simulation and vehicle routing methods. For that purpose Arena Simulation Software was used to compare the two different scenarios. Furthermore, the vehicle routing problems were solved with the shortest path method to find the optimal routes for the vehicles. OpenJump and gvSIG programs were used to determine the shortest path [16].

Nabaee (2014) studied about reverse logistics network design with centralized return center. An integrated forward and reverse logistics network were constructed by using an optimization modeling approach. Two different models were presented which were CRC (centralized return center) model and the DRC (decentralized return center) model. Additionally, a sensitivity analysis was conducted to analyze the results of the different scenarios [17].

Yu and Solvang (2016) presented an article about a general reverse logistics network design model for product reuse and recycling with environmental considerations. The presented multi-objective mixed integer programming had three objectives: minimizing the operation costs, minimizing the carbon emissions caused from transportation and processing of the products and minimizing the waste of resources. Finally, sensitivity analysis was applied to examine the model outputs [18].

In addition to the explained articles, there are various studies focusing on different product groups such as end-of-life vehicles, used frying oils, papers, batteries and electric and electronic equipment (Merkisz-Guranowska, 2011; Köse, 2009; Bloemhof-Ruwaard et al., 1996; Kannan et al., 2010; Kilic et al., 2015). In most of those studies, reverse logistics network models were formulated by using mixed integer linear programming with the aim of minimizing the related costs. Constructed models were solved with different scenarios to make some inferences about the optimum solutions. However, in this study, waste batteries are chosen which has a quite a few number of studies in Turkey and in the light of literature review, mixed integer linear programming is used to minimize the overall cost.

3. WASTE BATTERY RECYCLING AND SITUATION IN TURKEY

As waste batteries contain harmful materials as well as valuable and reusable ones, their recycling process is important and quite different from other types of wastes. Current recycling technology in Turkey is capable to recycle every type of collected waste batteries. Recovery of precious metals in the waste batteries consist of two separate processes as physical and chemical [19].

Within the physical process of the waste batteries, sorting, crushing, sieving, grinding, magnetic separation, and pneumatic separation according to density difference and filtration operations are performed. However, within the chemical process, waste battery powder which is obtained by physical process and less than the size of 250 µm, is subjected to the processes such as washing, acid/alkali dissolving, electrolysis, crystallization, solvent extraction and precipitation. On the other hand, wastes with precious metal contents are processed in the same processes [19].

The first battery recycling facility was opened in May 2016 in Turkey. This is supposed to increase the demand for the collection of waste batteries. Having legal obligations in the collection and recycling of waste batteries in Turkey, The Portable Battery Manufacturers and Importers Association (TAP) educates consumers on the harms and collection of waste batteries and provides their participation and contributions about this issue. For this reason, it is predicted that battery collection rates will increase in Turkey thanks to TAP which will continue to work on awareness in the coming years [3].

The Turkish Ministry of Environment and Urban Planning imposed a quota application for collecting and properly disposing of the waste batteries in order to protect the ecological balance and provide environmentally-friendly management of the waste batteries. These regulations require more collection and proper management of the waste batteries [20].

As it is seen, increasing demand for the waste batteries and directives have emphasized the importance of the waste battery recovery in Turkey and newly structured recycling technologies and methods make it necessary to study about reverse logistics processes. With this aim, reverse logistics network design of the waste batteries in Turkey is tried to be modeled by constructing a systematic structure for collecting, transporting, storage, recycling and disposal operations of the waste batteries.

4. MATHEMATICAL MODEL

After reviewing the reverse network flow models in the literature, a mixed integer linear programming model is developed. While developing the model, it is benefited from the study of Kilic et al. (2015). The proposed mathematical model provides the suitable answers to the following questions [5]:

- The types, numbers and locations of storage sites
- The types, numbers and locations of recycling facilities
- The quantity of batteries to be allocated to the storage sites
- The quantity of battery categories to be allocated to the recycling facilities
- The network flow of batteries through storage sites, recycling facilities, secondary material markets and landfill areas
- The total cost of the reverse logistics system

Model construction consists of three stages. In the first stage, model parameters are determined and the required data for preparing the substructure of the model are obtained. Mathematical model is constructed in the next stage. Finally, in the third stage, model-oriented three different scenarios are solved by using the LINGO optimization software and related results are evaluated.

Determination of the model parameters is very significant to obtain correct results from the model to be constructed. Since the exact amounts and related transportation and disposal costs of the waste batteries in Turkey were not recorded accurately, the provincial environment status reports and special waste statistics of the Ministry of Environment and Urban Planning as well as the reports of the TAP, which is the only responsible for collection of the waste batteries, have been used in this study. In other respect, there is no information about the waste battery recycling facilities in Turkey, since the first battery recycling facility was established in 2016. Therefore, the necessary information is obtained either directly from different studies and articles or by making reasonable assumptions.

Basically, the model parameters are as follows:

- The amount of waste batteries
- Determination of the waste battery categories and their properties
    - Determination of the waste battery categories
    - Determination of the unit transportation costs of the waste battery categories

Determination of the waste battery material compositions
Determination of the incomes of useful materials
Determination of the transportation costs of the useful materials
Determination of the disposal costs of hazardous materials
Determination of the transportation costs of the hazardous materials

- Specifications of the storage sites
  Specifying the storage site capacities
  Specifying the annual fixed costs of the storage sites
  Specifying the storage site location sets
- Specifications of the recycling facilities
  Specifying the recycling facility capacities
  Specifying the annual fixed costs of the recycling facilities and unit sorting and operation costs of the waste battery categories
  Specifying the recycling facility location sets
- Determination of the locations and capacities of secondary material markets
- Determination of the locations and capacities of the landfill areas

All the values of the parameters are determined and used in the mathematical model whose aim is to minimize the total cost subtracting the revenue from secondary material markets. The nomenclatures used in the objective function are as follows:

Subscript	Description
c	: waste battery categories
i	: collection points
j	: storage sites
k	: recycling facilities
m	: secondary material markets
l	: landfill areas for the hazardous materials
u	: useful materials which bring revenue
h	: hazardous materials which cause cost

Variables	Description
$q1_{ij}$	: quantity of waste battery transported from the collection point "i" to the storage site "j" (kg)
$q2_{jk}$	: quantity of waste batteries transported from the storage site "j" to the recycling facility "k" (kg)
$q3_{kmu}$	: quantity of useful material "u" transported from recycling facility "k" to the secondary material market "m" (kg)
$q4_{klh}$	: quantity of hazardous material "h" transported from recycling facility "k" to the landfill area "l" (kg)
b_j	: quantity of waste battery at the storage site "j" (kg)
$qq2_{kc}$	: quantity of waste battery category "c" at the recycling facility "k" (kg)
sb_j	: selection of the storage site "j" (1 or 0)
rb_k	: selection of the recycling facility "k" (1 or 0)
$rawm1_{ku}$	: quantity of useful material "u" at the recycling facility "k" (kg)
$rawm2_{kh}$	: quantity of hazardous material "h" at the recycling facility "k" (kg)
$srawm1_{mu}$	: quantity of the useful material "u" at the secondary material market "m" (kg)
$srawm2_{lh}$	: quantity of the hazardous material "h" at the landfill area "l" (kg)

Parameters	Description
a_i	: quantity of waste battery at the collection point "i" (kg)
$d1_{ij}$	: distance from the collection point "i" to the storage site "j" (km)
$d2_{jk}$	: distance from the storage sites "j" to the recycling facility "k" (km)
$d3_{km}$	: distance from the recycling facility "k" to the secondary material market "m" (km)
$d4_{kl}$	: distance from the recycling facility "k" to the landfill area "l" (km)
tc	: waste battery per km transportation cost (TL/kg)
$tc2_u$	: "u" useful material transportation cost (TL/kg*km)
$tc3_h$	: "h" hazardous material transportation cost (TL/kg*km)
sc_{kc}	: sorting cost of the waste battery category "c" at the recycling facility "k" (TL/kg)
oc_{kc}	: kg operation cost of waste battery category "c" at the recycling facility "k"(TL/kg)

$mat1_{cu}$: Weight percentage of the useful material "u" in the waste battery category "c"
$mat2_{ch}$: Weight percentage of the hazardous material "h" in the waste battery category "c"
rev_u : revenue of the useful material "u" (TL/kg)
exp_h : cost of the hazardous material "h" (TL /kg)
sfc_j : annual fixed cost of the storage site "j" (TL)
rfc_k : annual fixed cost of the recycling facility "k" (TL)
$minsca_j$: Minimum capacity of the storage site "j" (kg)
$maxsca_j$: Maximum capacity of the storage site "j" (kg)
$minrca_k$: Minimum capacity of the recycling facility "k" (kg)
$maxrca_k$: Maximum capacity of the recycling facility "k" (kg)
$recu_{ku}$: The recycling rate of the useful material "u" at the recycling facility "k"
$maxsec_{mu}$: Capacity of the secondary material market "m" (kg)
$maxland_{lh}$: Capacity of the the landfill area "l" (kg)
x : Maximum number of the storage sites
y : Maximum number of the recycling facilities
$percentage_{kc}$: Waste battery category percentages at the recycling facility "k"

Objective Function

$$Min\ z = \sum_i \sum_j (q1_{ij} * d1_{ij} * tc) + \sum_j \sum_k (q2_{jk} * d2_{jk} * tc) + \sum_k \sum_m \sum_u (q3_{kmu} * d3_{km} * tc2_u) + \sum_k \sum_l \sum_h (q4_{klh} * d4_{kl} * tc3_h) \text{ (Transportation cost)} + \sum_k \sum_c (qq2_{kc} * sc_{kc})(Sorting\ cost\ at\ the\ recycling\ facility)" + \sum_k \sum_c (qq2_{kc} * oc_{kc})\text{(Operation cost at the recycling facilities)} + \sum_j (sfc_j * sb_j) + \sum_k (rfc_k * rb_k) \text{ (Fixed costs of the storage sites, recycling facilities)} + \sum_k \sum_h (rawm2_{kh} * exp_h)\text{(hazardous materials disposal cost)} - \sum_k \sum_u (rawm1_{ku} * rev_u) \text{ (Revenue from secondary markets)} \quad (1)$$

Flow Constraints

$\sum_j q1_{ij} = a_i \quad \forall i$ (2)
$\sum_i q1_{ij} = b_j \quad \forall j$ (3)
$\sum_k q2_{jk} = b_j \quad \forall j$ (4)
$\sum_j (q2_{jk} * percentage_{kc}) = qq2_{kc} \quad \forall c, \forall k$ (5)
$\sum_c (qq2_{kc} * mat1_{cu} * rec_{ku}) = rawm1_{ku} \quad \forall k, \forall u$ (6)
$\sum_m q3_{kmu} = rawm1_{ku} \quad \forall k, \forall u$ (7)
$\sum_c (qq2_{kc} * mat2_{ch}) = rawm2_{kh} \quad \forall k, \forall h$ (8)
$\sum_l q4_{klh} = rawm2_{kh} \quad \forall k, \forall h$ (9)
$\sum_k q3_{kmu} = srawm1_{mu} \quad \forall m, \forall u$ (10)
$\sum_k q4_{klh} = srawm2_{lh} \quad \forall l, \forall h$ (11)

Capacity Constraints

$b_j \geq minsca_j * sb_j \ \forall j$ (12)
$b_j \leq maxsca_j * sb_j \ \forall j$ (13)
$\sum_c qq2_{kc} \geq minrca_k * rb_k \ \forall k$ (14)
$\sum_c qq2_{kc} \leq maxrca_k * rb_k \ \forall k$ (15)
$srawm1_{mu} \leq maxsec_{mu} \quad \forall m, \forall u$ (16)
$srawm2_{lh} \leq maxland_{lh} \quad \forall l, \forall h$ (17)

Maximum Number Limit of Storage Sites and Recycling Facilities

$\sum_j sb_j \leq x$ (18)

$\sum_k rb_k \leq y$ (19)

0/1 binary variables

$sb, rb \in \{0, 1\}$ (20)

Non negative decision variables
$Others \geq 0$ (21)

Objective Function and Constraint Explanations:

Equation (1) is the objective function that includes all the costs and revenue.
Equation (2) is the flow conservation at the collection points.
Equation (3) and Equation (4) are the flow conservation at the storage sites.
Equation (5) is the flow conservation at the recycling facilities.
Equation (6) and Equation (7) are the useful material conservation at the recycling facilities.
Equation (8) and Equation (9) are the hazardous material conservation at the recycling facilities.
Equation (10) is the flow conservation at the secondary material markets.
Equation (11) is the flow conservation at the landfill areas.
Equation (12) and Equation (13) are the minimum and maximum storage site capacities.
Equation (14) and Equation (15) are the minimum and maximum recycling facility capacities.
Equation (16) is the capacity constraints for the secondary material markets.
Equation (17) is the capacity constraints for the landfill areas.
Equation (18) is the maximum number limit of the storage sites.
Equation (19) is the maximum number limit of the recycling facilities.
Equation (20) is the binary variable constraint.
Equation (21) is the non-negative decision variables constraint.

5. APPLICATION IN TURKEY

It is assumed that each of Turkey's 81 provinces has one waste battery collection point. It is considered that the expected amount of waste batteries to be collected is closely related with the socio-economic development and population of each province. The model is executed for 3 scenarios considering the forecasted amount of waste batteries to be collected today and in the future as shown in Table 1. These three scenarios are selected by starting from 2017 and taking five-year breaks.

Table 1. Forecasted Total Waste Battery Collection Amounts in Turkey, 2016 to 2029

Year	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Forecast	696	750	803	857	911	965	1018	1072	1126	1180	1233	1287	1341	1394

Storage site and recycling facility locations, waste battery amounts that are sent from which collection points to which storage sites and from which storage sites to which recycling facilities are determined after running the mathematical model. The results of the scenarios are partially shared.

Scenario 1

Scenario 1 is created by considering the forecasted amount of waste battery collection in 2017 which is 750 tons. The global optimum solution was obtained for Scenario 1. Optimum result and total cost of the system are as follows:

Storage site locations are selected as large type storage sites (800 m2) in Bursa, Kocaeli, Ankara and Gaziantep. Recycling facility locations are selected as Bursa (small), Kocaeli, Ankara (medium) and Gaziantep (small). Total cost of the system is 1 286 526 TL. The waste battery quantities and capacity usage rates of the storage sites are shown in Table 2. Moreover, data about the quantities and network flows are provided in Tables 3-5 and Figures 1-3.

Table 2. The Waste Battery Quantities and Capacity Usage Rates of the Storage Sites for Scenario 1

Storage Site Location	**Waste Battery Amount (kg)**	**Storage Site Max Capacity (kg)**	**Capacity Usage Rate**
Bursa	200000	200000	100%
Kocaeli	200000	200000	100%
Ankara	200000	200000	100%
Gaziantep	150000	200000	75%

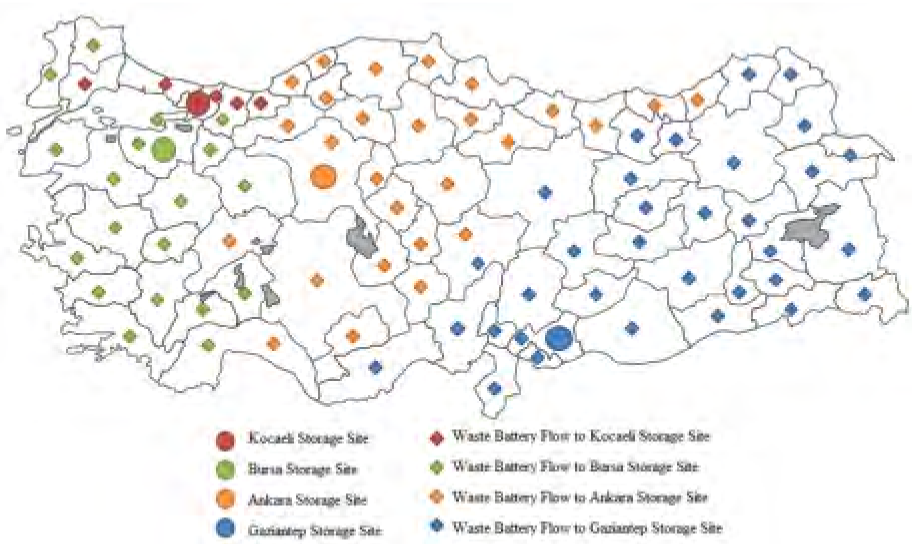

Figure 1. The Network Flow from Collection Points to the Related Storage Sites for Scenario 1

Table 3. The Waste Battery Category Amounts to be Processed in Recycling Facilities and Capacity Usage Rates of the Recycling Facilities for Scenario 1

Recycling Facility Location	ZnC (kg)	Alkali (kg)	NiCd (kg)	NiMh (kg)	Li-ion (kg)	Lithium (kg)	Button cell (kg)	Recycling Facility Max Capacity (kg)	Capacity Usage Rate
Bursa	17500	46000	7500	10500	6000	7000	5500	100000	100%
Kocaeli	52500	138000	22500	31500	18000	21000	16500	300000	100%
Ankara	43750	115000	18750	26250	15000	17500	13750	300000	83,3%
Gaziantep	17500	46000	7500	10500	6000	7000	5500	100000	100%

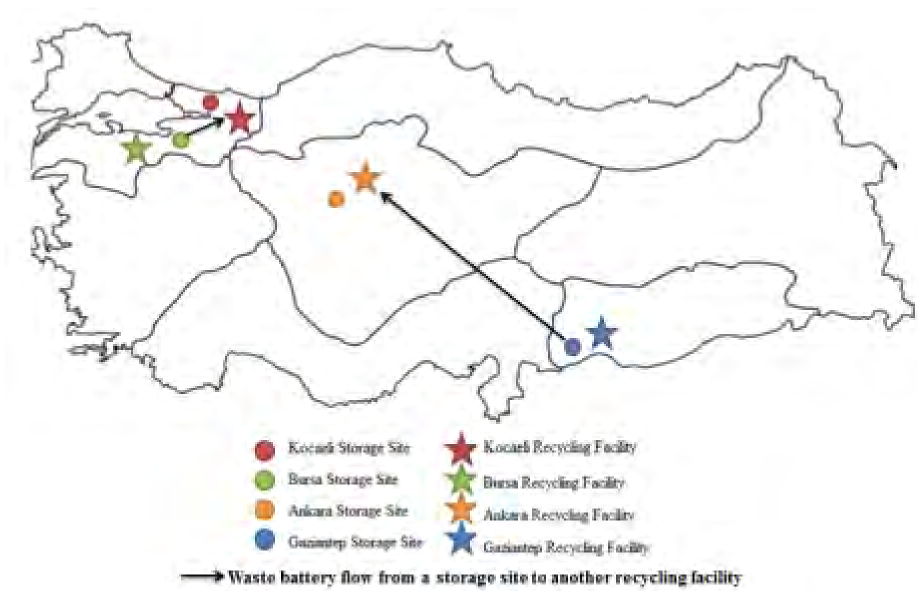

Figure 2. The Network Flow from Storage Sites to the Related Recycling Facilities for Scenario 1

Table 4. The Useful Material Amounts in Secondary Material Markets for Scenario 1

Secondary Material Market	Mn (kg)	Fe (kg)	Cu (kg)	Al (kg)	Zn (kg)	Cd (kg)	Co (kg)	Li (kg)	Ni (kg)	Brass (kg)	Paper (kg)	Plastic (kg)
Hatay	19292	9588	18808									
Zonguldak	125398	62322	122252									
Karabük				6750	9000	1320						
Artvin												
Diyarbakır							240	312	4460	736	5086	5510
Samsun												
Konya							600	780	11150	1840	12715	13775
Bursa							240	312	4460	736	5086	5510
İstanbul												
Tekirdağ												
İzmir												
Kocaeli							720	936	13380	2208	15258	16330

Table 5. The Hazardous Material Amounts in Landfill Areas for Scenario 1

Landfill Area (l)	Waste Solution (kg)	Solid Waste (kg)
Bursa	7125	7125
Kocaeli	46312,5	46312,5

Figure 3. The Network Flow from Recycling Facilities to the Secondary Material Markets and Landfill Areas for Scenario 1

Scenario 2

Scenario 2 is created by considering the forecasted amount of waste battery collection in 2023 which is 1072,6 tons. The global optimum solution was obtained for Scenario 2. Optimum result and total cost of the system are as follows:

Storage site locations are selected as large type storage sites (800 m2) in İstanbul, Bursa, Kocaeli, Ankara, Gaziantep and a medium type storage site (400 m2) in Tokat. Recycling facility locations are selected as Kocaeli, Bursa (medium), Ankara (medium) and Gaziantep (medium). Total cost of the system is 1.751.895 TL. The waste battery quantities and capacity usage rates of the storage sites are shown in Table 6. Moreover, data about the quantities and network flows are provided in Tables 7-9 and Figures 4-6.

Table 6. The Waste Battery Quantities and Capacity Usage Rates of the Storage Sites for Scenario 2

Storage Site Location	Waste Battery Amount (kg)	Storage Site Max Capacity (kg)	Capacity Usage Rate
İstanbul	200000	200000	100%
Bursa	200000	200000	100%
Kocaeli	192600	200000	96%
Ankara	200000	200000	100%
Tokat	80000	80000	100%
Gaziantep	200000	200000	100%

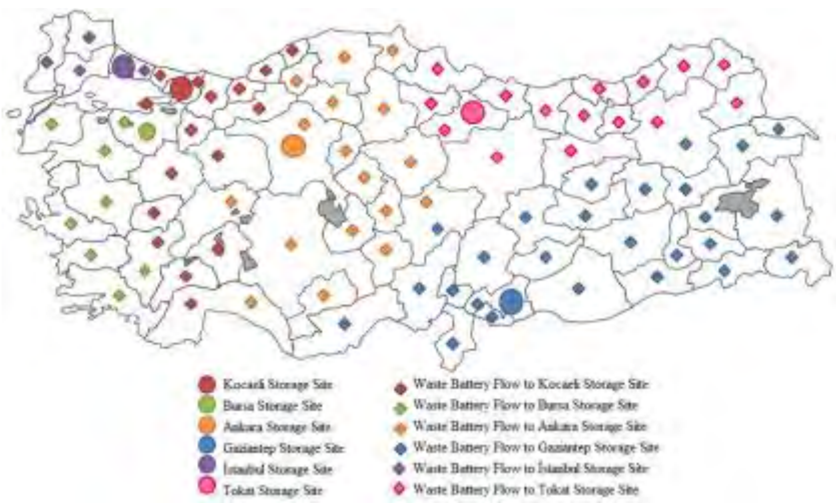

Figure 4. The Network Flow from Collection Points to the Related Storage Sites for Scenario 2

Table 7. The Waste Battery Category Amounts to be Processed in Recycling Facilities and Capacity Usage Rates of the Recycling Facilities for Scenario 2

Recycling Facility Location	ZnC (kg)	Alkali (kg)	NiCd (kg)	NiMh (kg)	Li-ion (kg)	Lithium (kg)	Button cell (kg)	Recycling Facility Max Capacity (kg)	Capacity Usage Rate
Bursa	51205	134596	21945	30723	17556	20482	16093	300000	98%
Kocaeli	52500	138000	22500	31500	18000	21000	16500	300000	100%
Ankara	42000	110400	18000	25200	14400	16800	13200	300000	80%
Gaziantep	42000	110400	18000	25200	14400	16800	13200	300000	80%

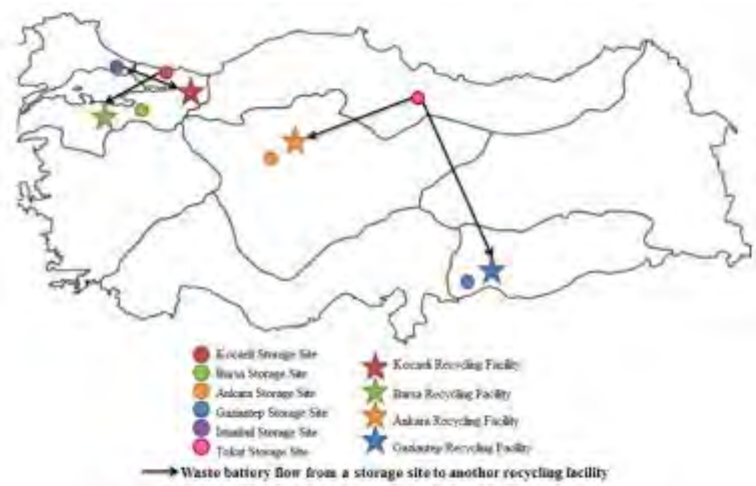

Figure 5. The Network Flow from Storage Sites to the Related Recycling Facilities for Scenario 2

Table 8. The Useful Material Amounts in Secondary Material Markets for Scenario 2

Secondary Material Market	Mn (kg)	Fe (kg)	Cu (kg)	Al (kg)	Zn (kg)	Cd (kg)	Co (kg)	Li (kg)	Ni (kg)	Brass (kg)	Paper (kg)	Plastic (kg)
Hatay	46300,8	23011,2	45139,2									
Zonguldak	160625,2	79829,69	156595,4									
Karabük				9653,4	12871,2	1887,776						
Artvin												
Diyarbakır							576	748,8	10704	1766,4	12206,4	13224
Samsun												
Konya							576	748,8	10704	1766,4	12206,4	13224
Bursa							702,24	912,912	13049,96	2153,536	14881,64	16122,26
İstanbul												
Tekirdağ												
İzmir												
Kocaeli							720	936	13380	2208	15258	16530

Table 9. The Hazardous Material Amounts in Landfill Areas for Scenario 2

Landfill Area (l)	Waste Solution (kg)	Solid Waste (kg)
Bursa	20847,75	20847,75
Kocaeli	55575	55575

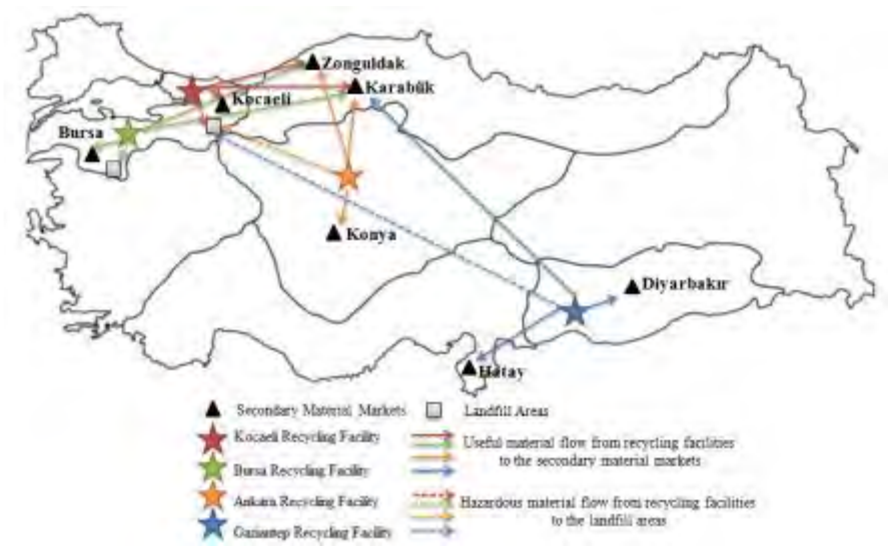

Figure 6. The Network Flow from Recycling Facilities to the Secondary Material Markets and Landfill Areas for Scenario 2

Scenario 3

Scenario 3 is created by considering the forecasted amount of waste battery collection in 2029 which is 1395 tons. The global optimum solution was obtained for Scenario 3. Optimum result and total cost of the system are as follows:

Storage site locations are selected as large type storage sites (800 m2) in İstanbul, Bursa, Kocaeli, Eskişehir, Ankara, Kayseri, Gaziantep. Recycling facility locations are selected as Kocaeli, Bursa (large), Ankara (medium) and Gaziantep (medium). Total cost of the system is 2.187.027 TL. The waste battery quantities and capacity usage rates of the storage sites are shown in Table 10. Moreover, data about the quantities and network flows are provided in Tables 11-13 and Figures 7-9.

Table 10. The Waste Battery Quantities and Capacity Usage Rates of the Storage Sites for Scenario 3

Storage Site Location	Waste Battery Amount (kg)	Storage Site Max Capacity (kg)	Capacity Usage Rate
İstanbul	200000	200000	100%
Bursa	200000	200000	100%
Kocaeli	200000	200000	100%
Eskişehir	200000	200000	100%
Ankara	200000	200000	100%
Kayseri	195000	200000	97,5%
Gaziantep	200000	200000	100%

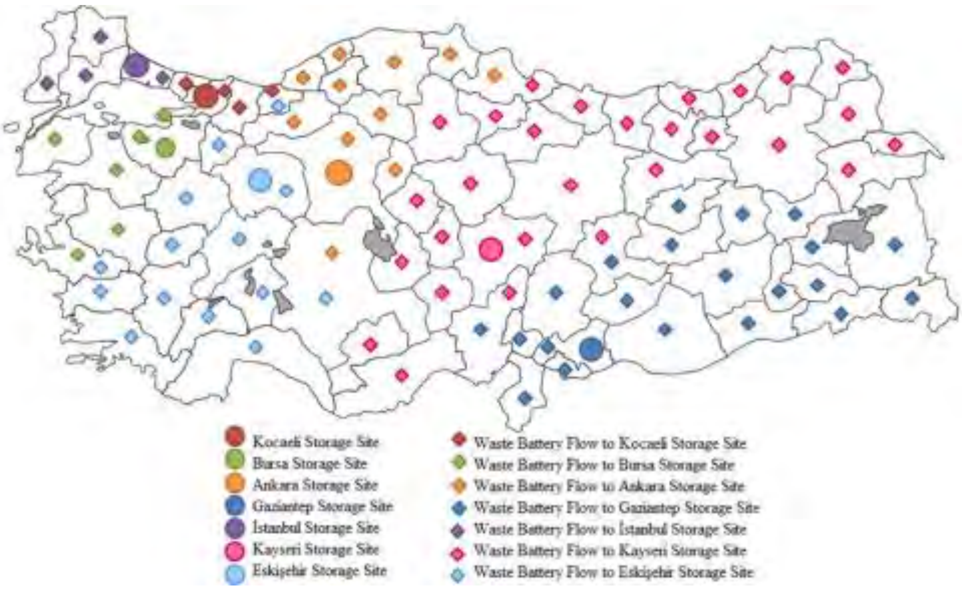

Figure 7. The Network Flow from Collection Points to the Related Storage Sites for Scenario 3

Table 11. The Waste Battery Category Amounts to be Processed in Recycling Facilities and Capacity Usage Rates of the Recycling Facilities for Scenario 3

Recycling Facility Location	ZnC (kg)	Alkali (kg)	NiCd (kg)	NiMh (kg)	Li-ion (kg)	Lithium (kg)	Button cell (kg)	Recycling Facility Max Capacity (kg)	Capacity Usage Rate
Kocaeli	52500	138000	22500	31500	18000	21000	16500	300000	100%
Bursa	87500	230000	37500	52500	30000	35000	27500	600000	83,3%
Ankara	52500	138000	22500	31500	18000	21000	16500	300000	100%
Gaziantep	51625	135700	22125	30975	17700	20650	16225	300000	98,3%

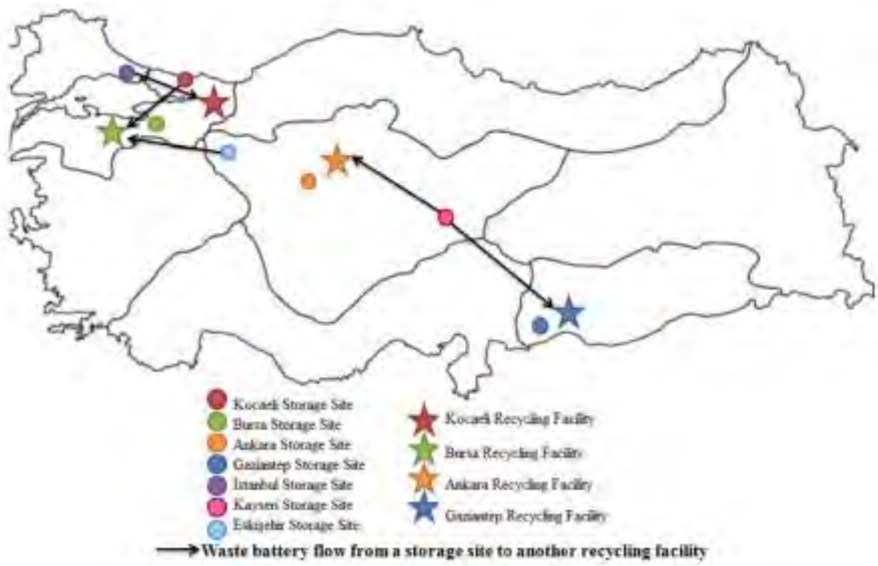

Figure 8. The Network Flow from Storage Sites to the Related Recycling Facilities for Scenario

Table 12. The Useful Material Amounts in Secondary Material Markets for Scenario 3

Secondary Material Market	Mn (kg)	Fe (kg)	Cu (kg)	Al (kg)	Zn (kg)	Cd (kg)	Co (kg)	Li (kg)	Ni (kg)	Brass (kg)	Paper (kg)	Plastic (kg)
Hatay	56911,4	28284,6	55483,6									
Zonguldak	212212	105468	206888									
Karabük				12555	16740	2455,2						
Artvin												
Diyarbakır							708	920,4	13157	2171,2	15003,7	16254,5
Samsun												
Konya							720	936	13380	2208	15258	16530
Bursa							1200	1560	22300	3680	25430	27550
İstanbul												
Tekirdağ												
İzmir												
Kocaeli							720	936	13380	2208	15258	16530

Table 13. The Hazardous Material Amounts in Landfill Areas for Scenario 3

Landfill Area (l)	Waste Solution (kg)	Solid Waste (kg)
Bursa	35625	35625
Kocaeli	63768,75	63768,75

Figure 9. The Network Flow from Recycling Facilities to the Secondary Material Markets and Landfill Areas for Scenario 3

Summary of the Model Outputs

The model is solved by the LINGO optimization software and the storage site and recycling facility locations which provide the minimum cost are determined. In Scenario 1, large type storage sites in Kocaeli, Bursa, Ankara and Gaziantep are selected. Capacity usage rate of the Gaziantep storage site is predicted to be 75%, while capacity usage rates of the other storage sites are 100%. In Scenario 2, large type storage sites in İstanbul, Kocaeli, Bursa, Ankara and Gaziantep and medium type storage site in Tokat are selected. Capacity usage rate of the Kocaeli storage site is predicted to be 96%, while capacity usage rates of the other storage sites are 100%. In Scenario 3, large type storage sites in İstanbul, Kocaeli, Bursa, Ankara, Eskişehir, Kayseri and Gaziantep are selected. Capacity usage rate of the Kayseri storage site is predicted to be 97,5%, while capacity usage rates of the other storage sites are 100%.

For the recycling facilities, medium type recycling facilities in Kocaeli and Ankara and small type recycling facilities in Bursa and Gaziantep are selected in Scenario 1. Capacity usage rate of the Ankara recycling facility is predicted to be 83,3%, while capacity usage rates of the other recycling facilities are 100%. In Scenario 2, Bursa and Gaziantep recycling facility types transform from small to medium as different from Scenario 1. Capacity usage rates of the Ankara, Gaziantep and Bursa recycling facilities are predicted to be 80%, 80% and 98% respectively, while capacity usage rate of the Kocaeli recycling facility is 100%. As different from Scenario 2, Bursa recycling facility type transforms from medium to large in Scenario 3. Capacity usage rates of the Bursa and Gaziantep recycling facilities are predicted to be 83,3% and 98,3%, while capacity usage rates of the Ankara and Kocaeli recycling facilities are 100%.

The total cost of the system is found as 1.286.526 TL for Scenario 1, 1.751.895 TL for Scenario 2 and 2.187.027 TL for Scenario 3. In terms of per kg cost, the cost of the Scenario 1 is 1,72 TL, the cost of the Scenario 2 is 1,63 TL, the cost of the Scenario 3 is 1,56 TL, approximately. As the amount of collected waste batteries increases, the per kg costs decrease. As can be seen, the per kg cost is decreasing even if the forecasts are based on the ongoing development levels. Increasing the development levels by giving importance of raising the awareness may lead to collect more amounts in less time and decrease the total cost of the system.

6. CONCLUSION

As a result of the environmental concerns, economical issues, institutional and social responsibilities formalized through the laws have encouraged to work on reverse logistics concept. Reverse logistics network design constitutes an important part of the reverse logistics concept. In this study, regardless to any company, reverse logistics network design model of waste batteries is made by considering the newly structure in Turkey.

The recovery system of the waste batteries is considered in this study. Collected waste batteries are transformed into valuable raw materials that is metal blooms, after they have undergone the physical and chemical processes. However, since the recycling of the waste batteries in Turkey started in 2016, the benefits to be gained cannot be understood exactly and systematic deficiencies pose an obstacle on these. In accordance with this situation, “what”, “why” and “how” questions of the waste battery reverse logistics in Turkey are tried to be answered. The existing situation is investigated by making interviews and the new system is built in the direction of the more comprehensive recycling abilities which exist but not implemented yet.

In reverse logistics network design, important decisions are included such as the most appropriate storage sites, recycling facilities, secondary material markets, landfill areas and specification of the waste battery amounts that are sent from which collection points to which storage sites and from which storage sites to which recycling facilities. In this sense, the reverse logistics network design includes both location choices and assignments.

In this study, mixed integer linear programming model which is a basic model for reverse logistics network design is used. With this model, the above-mentioned decisions are tried to be made for recovery of the waste batteries. The aim of the proposed model is to provide an optimal flow while costs of the processes from collection points to the secondary material market and final processing plants are minimized and revenue of the obtained materials from recycling is maximized. For this purpose, appropriate storage site and recycling facility locations are selected from possible locations. The costs mentioned on the above are transportation costs, sorting costs, operation costs, and fixed costs about the new facilities, final processing and disposal costs.

The model is solved by the LINGO optimization software and the storage site and recycling facility locations which provide the minimum cost are determined. However, there is not enough accurate and historical data available in Turkey since recycling of the waste batteries has newly started. Therefore, obtained data contain uncertainties. During the other studies that will be done in this area, stochastic models can be built so that uncertainties can be reflected in the model. On the other hand, the model can be improved by adding holding cost and market demand.

In conclusion, this study is one of the first studies on reverse logistics network design model of waste batteries in Turkey, so there may be some shortcomings in determining some parameters. In the future, it may be possible to make network designs that give better results to actual conditions with more reliable data and clarification of parameters. Moreover, the proposed model may be re-written as a multiobjective one for cost minimization and minimization of hazardous waste contamination.

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GREEN PACKAGING: A LITERATURE REVIEW

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Abstract – *Environmental pollution and its effects on the Earth is becoming a matter of discussion in every area of human activity. Today, green innovations take a place in every business and are considered as an indicator of success. In parallel, there is great demand for environment-friendly solutions in logistics, also. However, logistics is a process consisting of many and various stages. Thus, every stage should be taken into consideration for better and efficient solutions. In accordance with this idea, this study aims to discuss environmental solutions for packaging whose high contribution to pollution has been demonstrated with various analysis. State of a tendency to green packaging and its examples from various is presented, also.*

Keywords – *Green Logistics, Green Supply Chain Management, Green Packaging, Sustainability*

INTRODUCTION

Climate change, air pollution, spreading viruses… These words are uttered by research committees, luminary people of societies and global leaders in many areas over past decades. However, there is still a huge environmental pollution problem and its impact continues on all living creatures. Together with the accelerated increase in damage to the Earth, there are attempts to make human activities to be more environment-friendly and sustainable. Economic activities and supply chain management, which is an underlying factor of economic activities in today's continuously globalizing world, comprise a significant part of human activities. Thus, green orientation in supply chain management has become an important issue for maintenance and success of global businesses, today. Supply chain management covers all steps of planning, production of a product or service from a primary source, processing it, manufacturing it, and then delivering it to the end consumer (WBG, n.d.). Because it spreads to such a large area, environmental damage during the processes of supply chain management also becomes greater. According to data, UK wasted almost 540 million tons of materials each year in the late 90s (Jones, 1996). Global transportation systems, on the other hand, are reported to being responsible for 23% of CO_2 emissions and 15% of greenhouse gas emissions (International Transport Forum, 2010). In term of these effects, a more sustainable supply chain management is required not because of its detrimental effect on the environment but also for reducing expenses of business with more efficient systems. Considering all these consequences, stakeholders, consumers, and governmental agencies make pressure on firms to be more sustainable and sensitive to the environment (Lamming and Hampson, 1996; Guide et al., 2000). The term of "green supply chain management" and its practices stem from these developments and involve diverse environmental innovations in all steps of supply chain management.

GREEN SUPPLY CHAIN MANAGEMENT AND GREEN LOGISTICS

Green supply chain management (GSCM) practices aim to decrease waste of energy, emission, chemical substances, and solid materials by innovative product designs, elaborative material selection, and resourcing, redesigned manufacturing and delivery processes (Rao, 2006; Srivastava, 2007). To develop and implement green innovations in these steps, there is a need for a huge body of literature and research in the area. However, GSCM is found to be having greatest attention only in between 2007-2011 by scholars according to Luthra and his colleagues' study (Luthra, Garag and Haleem, 2014). Again according to this study, green logistics take lesser attention among researchers on GSCM (Luthra, Garag and Haleem, 2014). On the other hand, logistics is the framework that supply chain builds upon (Christopher, 2011). It defines the transportation, storage, and handling of products or information during their flow from raw material source to end consumer (McKinnon et al., 2015). Thus, green innovations in logistics area are essential for efficient green supply chain management. According to the reports of The World Economic Forum and Accenture in 2009, logistic activities are responsible for 5,5% of greenhouse gas emissions. International Transport Forum report, on the other hand, indicates that trade-related freight transportation in all logistic activities responsible for 30% of CO_2 emission (ITF, 2017) which forms the 93-95% of the total greenhouse gasses (Cefic-ECTA, 2011). Furthermore, it is expected to rise by 60% until 2050. This rise is caused by continuous expansion of production, consumption and transportation routes due to growing demand in the global market (World Business Council for Sustainable Development, 2004). Therefore, a more efficient use of transportation activities should be addressed in terms of green logistics. This could be provided by innovative packaging and handling systems that could allow usage of spaces more efficiently, rearrangement of order cycles that allows fixation of distribution into particular times and places, and usage of larger vehicles that could transport more freight in one time. Among these options, packaging systems carry an importance not because as being a waste of space during transportation, but as being a solid waste after their use (Rodrigue, Slack and Comtois, 2001). Therefore, usage of biodegradable or recyclable materials and space-saving designs in packaging systems are becoming outstanding issues in green logistics. The current study aims to briefly review the literature of the green packaging and to exhibit the new innovative examples of this developing field and possible directions for future research.

GREEN PACKAGING

Different types of wastes emerge during and after logistic activities. Among those wastes, packaging materials are stated as accounting for approximately 30% of all solid wastes even in 90's (Auguston, Staples and Weston, 1990). Today, diverse kinds of materials such as plastics, papers, glass, metals, and wood are used to packaging products. Furthermore, one product is not generally packaged with one material during its transportation; there are levels of packaging. The first level refers to packaging that contacts with the product directly. The second level, however, refers to packaging of the product that has already been packaged. Secondary packaging is used to transportation, storage, loading and unloading of the product (Zhang and Zhao, 2012). When all of these packaging levels are considered, it is indicated that packaging creates an economical cost for business, also. It also causes waste of space and weight during transportation. According to TATA Strategic Management Group's report, packaging costs cover 5-12% of all costs in logistics and is estimated to being responsible for 4-8% of carbon emissions created during logistic activities (TSMG, 2014). More importantly, packaging wastes increase environmental pollution which causes more serious problems. Commonly, three types of packaging wastes are defined. These are solid waste pollution, liquid, and gaseous pollution, and spreading bacteria and pests (Zhang and Zhao, 2012). The majority of solid wastes on the earth composed of packaging wastes. The annual amount of solid wastes is estimated as 10 million tons in a year and packaging wastes accounted for 1/3 of this total waste. This amount of solid packaging wastes also causes waste of manpower and financial resources for their collection and cleaning. On the other hand, liquid and gaseous pollution imply a more serious pollution due to its wider impact area. These kinds of wastes spread to a wider area by water and air. It may cause life threatening health risk for living creatures. Similarly, bacteria and pests that are carried by packaged products, especially foods, pose harm to the ecological environment and human health. When all these effects of packaging wastes are considered, the necessity of innovative green packaging systems becomes more significant. In green logistics, green packaging systems defined with 3R strategies. These strategies are described in detail in Table 1.

Table 1. 3R strategy of packaging systems (TSMG, 2014)

	Strategy	*Definition*
3R	• Reduce	Usage of less toxic, light and thin material in packaging, and elimination of excess or unnecessary packaging while maintaining product safety.
	• Reuse	Repeated usage of packaging materials after simple treatment
	• Recycle	Usage of recyclable materials like biopolymers, cartons and glass for packaging.

3R strategy has many benefits in terms of decreased amount of packaging wastes and associated reduced financial and energy costs. Reduction of packaging provides a reduction in financial costs for packaging and transportation, and decrease in manpower and energy supply for disposal of packaging wastes. Reuse and recycling, also, decrease the amount of packaging waste while reducing the use of raw materials at the same time. On the other hand, reuse and recycling processes require reverse logistics. Reverse logistics refers all logistic activities for collection, inspection, sorting, and recovery of wasted products including packages (Dekker, Bloemhof and Mallidis, 2012). However, despite its lots of benefits, there are some limitations and possible problems for transportation of packaging wastes and their quality due to cleaning processes in reverse logistics processes. Thus, both business sector and governmental agencies should take necessary preventions and apply legislations to ensuring efficiency of 3R strategies and environmental-friendly green packaging applications. As global market demands for green solutions, green packaging becomes an issue for governmental agencies increasingly. In terms of regulations on packaging wastes, Germany is one of the leading countries. The first policy of Germany on packaging wastes was determined in 1991 as "Waste Packaging Ordinance Law" (Lamming and Hampson, 1996). In 1994, Germany declared "The Closed Substance Cycle and Waste Management Act" to implement sustainable development into the broader area (German Law Archive, 2013). This policy aims to achieve an economic advantage by recycling of packaging and other waste materials, and so, reducing the usage raw materials and removing the residual waste from the environment permanently. After implementation of this policy, Germany gains approximately €40 billion financial turnover annually (UN, n.d.). After the success of Germany, other European nations started to apply similar policies for recycling (Rembert, 1997). Today, many countries have laws or policies for green packaging practices in different degrees. Some of the examples of policies for green packaging that are implemented in different countries are shown in Table 2.

Table 2. Green Packaging Policies, Agreements, and Acts

Policy & Agreements & Acts	*Content*
Singapore Packaging Agreement	"Singapore Green Plan 2012" was conducted in 2005. Based on this plan "The Singapore Packaging Agreement" was declared in 2007. In two years after the agreement, the amount of packaging wastes decreased by 2,500 tones and this decrease was estimated to worth $4.4 M saving.
The European Packaging Directive	The Directive was adopted in 2004 and revised in 2005, 2013 and 2015. This directive defines recycling and recovery targets and deadlines for the EU Member States. It also designates the essential requirements for packaging.
CONEG Model Legislation	This legislation brings strict limitations for use of heavy metals in packaging. This legislation is implemented in 19 states in the United States.
The California Rigid Plastic Packaging Container (RPPC) Act	This act is declared in 1991 and lastly updated in 2013. It aims to decrease the use of raw material and increasing the usage of recycled material. It also prohibits reduction of the amount of resin in rigid plastic packaging containers as a way to reduced use of raw material.

Although governments realize the importance of green innovations and take actions to imply new policies rapidly, their attempts alone are not sufficient. Thus, both governmental and non-governmental organizations and agencies publish new standards and guidelines for implementation green packaging. Most of these standards are expected to meet by firms and manufacturers. Some of these standards are presented in Table 3. Increase in awareness for environmental issues and for financial benefits of sustainability cause consumers, governments and stakeholders to make pressure on and oblige firms and manufacturers to adopt these standards, today.

Table 3. Green Packaging Standards and Guidelines (Misko, 2013)

Guidelines and Standards	Content
Guides for the Use of Environmental Marketing Claims (or Green Guides)	• Announced by U.S. Federal Trade Commission • Addresses: carbon offsets, certifications and seals of approval, compostable, degradable, free-of, non-toxic, ozone-safe and ozone-friendly, recyclable, recycled content, refillable, renewable energy, renewable materials and source reduction.
The European Committee for Standardization (or CEN Standards)	• EN 13427:2004, Packaging – Requirements for the use of European Standards in the field of packaging and packaging waste; • EN 13428:2004, Packaging – Requirements specific to manufacturing and composition – Prevention by source reduction; • EN 13429:2004, Packaging – Reuse; • EN 13430:2004, Packaging – Requirements for packaging recoverable by material recycling • EN 13431:2004, Packaging – Requirements for packaging recoverable in the form of energy recovery, including specification of minimum inferior calorific value • EN 13432:2000, Packaging – Requirements for packaging recoverable through composting and biodegradation – Test scheme and evaluation criteria for the final acceptance of packaging
International Chamber of Commerce's (ICC) Framework for Responsible Environmental Marketing Communication	• Provide a checklist for compatibility of product, component, and package that will be advertised to the "green" claims.
The GCF Global Protocol on Packaging Sustainability	• Provides metrics, indicators and measurement framework for sustainable packaging
ISO Standards	• ISO 18601:2013 Packaging and the environment – General requirements for the use of ISO standards in the field of packaging and the environment • ISO 18602:2013 Packaging and the environment – Optimization of the packaging system • ISO 18603:2012 Packaging and the environment – Reuse • ISO 18604:2013 Packaging and the environment – Material recycling • ISO 18605:2013 Packaging and the environment – Energy recovery • ISO 18606:2013 Packaging and the environment – Organic recycling

These standards and regulations are implied by many firms. Their attempts at reduction of waste by green packaging solutions help to decrease the annual amount of packaging wastes and bring economic advantages to those firms. Some of the green innovations to reduce packaging wastes and financial costs that are practiced by global firms are presented in Table 4.

Table 4. Green Innovation Examples of Companies

Company	Green Innovation
PepsiCo	PepsiCo reduced packaging waste and reduced plastic consumption by 135 million pounds between 2002 and 2010. This amount raised to 350 million pounds in later years. Additionally, PepsiCo recycled 196 million beverage containers since 2010 (TSMG, 2014).
Henkel	Henkel made an agreement with Chep who creates environmental solutions for pallet pooling. With pallet pooling solutions, Henkel expects to gain the benefit of reduced carbon emission by 895MT, annually. Waste wood is also estimated to be reduced by 76 MT annually (TSMG, 2014).
Tetra Pak	TetraPak has started an initiative to recovering polyethylene plastic that is used in packaging. By this initiative, it expects to reduce plastic waste by 380 tons for one machine per year (Peck and Tay, 2010).
KFC	KFC shrunk its thrift and dinner boxes 36mm and 50mm respectively. It reduced paper waste by approximately 20 tons and saved $21.000, annually. KFC also reduced the thickness of its bags and boxes and reduced plastic waste by 2,9 tons and paper waste by approximately 29 tons, annually (Peck and Tay, 2010).
Boncafé International Pte Ltd	Boncafé reduced the thickness of its packaging material from 140 microns to 120 microns. By this way, it reduced 1516 kg of packaging waste and saved $6160 per year (Peck and Tay, 2010).
Dell	Dell uses organic materials such as bamboo and mushroom cushions to replace foam for packaging. It also uses cubic packaging in three different sizes for transportation to better placement and reduces waste (Dell, 2017).

Innovative packaging materials are investigated by researchers to increase life of the package and decrease contamination, and also to satisfy the demand for longer shelf life of the product (Nakazato et al., 2017). While plastic, paper, board, wood, metal and glass were the most used packaging materials in 2003 in the world, in 2014 flexible plastic was the most common material used in packaging and it is expectd to be the most used material up to 2019 (euromonitor, 2015). Deng et al. (2017) propose to add inorganic nanoparticles like antimicrobial peptides and chitosan to food packaging materials to improve them in regard of antibacterial performance. ITENE, a pioneer packaging company located in Spain, makes considerable efforts to develop biodegradable polymers, nanocomposites and new functionalities in materials via additives in order to replace current packages based on oil (ITENE, n.d.). Another big company that is in search of innovative green packaging materials is Dell. The company is investing in agricultural waste to produce green house gas emissions free packages and grows cushions consisting of mushrooms which is to be used instead of polyethylene cushioning. In the official website of the comppany it is expressed that (Dell, 2016): "The mushrooms are grown in engineered molds to create the cushions, so the process is by nature less automated than that of creating plastic cushioning. This presented some hurdles in terms of continuity in supply and material cost, but developments in manufacturing combined with recent testing have put us on track for a FY16 re-introduction of mushroom-based server cushioning". In addition to mushroom cushions, the company also conducts researches to use bamboo and wheat waste as environmental friendly green packaging material. Tetra Pak introduced its first carton in 2014, which consists of renewable and plant-based materials. The innovative carton, called as the Tetra Rex® carton, is the first packaging carton material which has bio-based low-density polyethylene (LDPE) films and bio-based high-density polyethylene (HDPE) caps, both produced from sugar cane. The company has been already utilizing 70% of renewable resources in its cartons and this percentage is increased by 4% after utilizing bio-based caps (Hower, 2014).

Cinelli et al. (2013) propose to use fish-industry waste in producing food packaging material with low wast. The nano-Chitopack project investigates possible usage of chitin waste from the fish industry because of its bacteriostatic, high biodegradability and increased resistance to UV and heat properties. As one of the two most common natural polysaccharides, chitin is a low-cost, biocompatible, compostable, natural biodegradable, and non-toxic building block to produce food packaging material with reduced environmental negative impacts.

It is also important to use packaging containers repeatedly in order to protect environment. Kroon et al. (1994) investigate reusable containers as an practical application of reverse logistics and outlines a quantitative model to support planning of returnable containers. Duhaim et al. (2001) analyzed and optimized the use and sharing of a logistics package, which is a returnable container and often out of stock, between Canada Post and its large mailing customers utilizing value analysis.

GREEN PACKAGING IN TURKEY

Turkey is one of the countries in the world whose constitutional law has articles about environmental concerns. In addition, the regulation on the control of packaging waste declared in Turkey on 24th August 2011 states that the organizations dispatching products with packaging need to collect or organize the gathering of a specific amount of that packaging. In this regard, the quantity was determined as 48% in 2015, 52% in 2016 and will be 60% in 2020.

Although green logistics is not a new topic for Turkey literature, its applications have started to be finding a place in the business sector in recent years. Thus, there are a few examples of it. Some of the large-scaled firms make attempts to reduce their carbon emission by reducing and recycling of organic and inorganic wastes. On the other hand, green packaging is a very new concept for firms in Turkey. Therefore, among these attempts to reduce carbon emissions, green packaging practices and innovations take a small place. Most of the green packaging practices are based on the usage of recyclable materials such as paper (İnce, n.d.). One of the biggest producer in Turkey, Anadolu Cam makes considerable efforts to use resources efficiently and protect environment. While it tries to increase steadily the amount of recycled glass consumed in its production processes, it leads many glass recycling projects as a social responsibility, for instance, the company produced and donated 3750 bottle tanks to municipalities during 2015. As non-hazardous waste recovery rate was 94% in 2014, it is increased to 96 % in 2015. The company participates in “resource efficiency” initiative which aims to improve sustainable growth in the European union 2020 strategy. In this respect, the organization tries to increase quantity and quality of recycled glass (cullet). The company has utilized 156052 tons of recycled glass in its manufacturing and gathered and reused 48% of packaging materials, which it introduced to his costumers in 2014, during 2015 (Sustainability Report of Anadolu Cam,2015).

The green dot sign application in industry, which makes compulsory to obey some rules related with packaging, is finding increasing usage among many Turkish products. Moreover, according to a research conducted by ÇEVKO (Environmental Protection and Packaging Waste Recovery and Recycling Trust) in 2017, 70% of people in Turkey know the green dot application, and one third of these people prefer to buy products with green dot (http://www.cevko.org.tr).

Per capita packaging consumption is increased considerably in recent years in Turkey. As indicated by the research of WPO (World Packaging Organization), Turkey is very likely to be the fastest growing market for package consumption in the world in coming years. According to the research, package market of Turkey expanded by 101% between years 2005 and 2009 (Kırgız, 2016). Nonetheless, Turkey is expected to achieve only €7-8 billion recycling capacity in later years. These insufficient recycling practices in Turkey cause undermining of recyclable packaging attempts, also.

Yıldız-Geyhan et al. (2016) analyzed different source-seperated packaging waste collection systems for Istanbul using life cycle assessment methodology, which is the first study investigating this issue in literature. Acoording to the study, the existing collection system in Istanbul is found to be the most environmentally optimum source-separated packaging waste collection system applicable in Istanbul. In the existing system, recyclable packaging waste is grouped into mixed packaging wastes (paper-cardboard, plastic, metal, glass) gathered by door-to-door system and glass wastes gathered in drop-off points while unsorted waste is collected by curbside containers. In another study, Yıldız-Geyhan et al. (2017) investigated the social impacts of different packaging recycling systems using life cycle assessment methodology. The considered impact categories in the study are socio-economic repercussions, health and safety, working conditions, cultural heritage, governance and human rights. According to the study, the formal scenarios have socially bigger score than informal collection scenarios and existing system in almost all impacts and an improved informal collection system would be socially more useful than informal and formal collection systems.

CONCLUSION

Increased environmental pollution and its observable effects on living creatures alert governments and non-governmental agencies to take immediate precautions. These attempts particularly interest business sector due to their role in this environmental pollution. In recent years, many global firms look for innovative solutions for reducing the number of wastes and greenhouse gas emissions occurred in logistics and supply chain. Green logistic applications become significant solutions for this purpose. However, every step of logistics should be approached in detail to increase the efficiency of green practices. Considering green logistic activities, green packaging seems to have less attention. Thus this study aims to identify green packaging practices both in the world and Turkey.

As it is discussed in this study, there are some legislations and standards for packaging to being more sustainable and environment-friendly. Many global firms try to adapt these standards to reduce their footprint on greenhouse gas emissions and environmental pollution. However, these attempts are still yet to be sufficient. Increased demand for consumption due to globalization and developing marketing cause disposal of huge amounts of packaging materials every day. Not only methods for using recyclable packaging is not insufficient, but also substructure of governments and firms to recycle those materials are imbalanced across countries. However, effects of environmental pollution caused by different countries cannot be separable from each other. Thus, the cooperation between countries is essential for creating green solutions for packaging systems and reducing their contribution to pollution.

Furthermore, better technological innovations should be taken into consideration. Today, there are lots of scientific and technological developments in terms of creation of environment-friendly materials (e.g. Xie et al., 2014). However, most of these studies have a limited area of usage due to competitive structure of today' market environment. Hence, governments should provide better incentives to induce usage of green packaging systems and place more severe sanctions.

There are too few studies investigating reusable container systems in the literature. In the future, the topic of returnable container and package systems should be studied in more detail and these systems should find more application in daily life in order to reduce amount of packaging waste in the world.

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A MATHEMATICAL MODEL FOR SPACE UTILIZATION IMPROVEMENT IN WAREHOUSES

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Abstract – *Depending on the intensely competitive environment, firms focus on the improvement of any single part of their systems. At this point, warehouse management is one of the key parts of supply chain management and has evolved as a distinct area of expertise. There are various activities within warehouse management such as receiving, storing, picking and shipping. The layout of the warehouses directly affects these activities and hence has an important role regarding the elimination of wastes. The layout design including the location and arrangement of departments and business centers for reducing the costs and improving the performance of operations plays an important role in managing the stores efficiently. In this study, it is specifically focused on the utilization of the space in the warehouse of a white goods company. After providing the related literature about the topic, a mixed integer linear programming model is developed for the aim of increasing the space utilization rate. The optimum dimensions of the blocks (addresses) that the goods will be stored in are obtained and alternative scenarios are handled in the proposed model. Finally, the results are analyzed and savings for each scenario are presented.*

Keywords *— Warehouse management, layout design, space utilization rate*

1. INTRODUCTION

Storage management, one of the key rings of the supply chain, has evolved as a distinct area of expertise and has become an integral part of logistics activities. Timely and healthy logistics movements must be safely stacked, stored and computerized according to the quality and quantity of the goods. Logistics firms have undertaken a major role in providing warehousing services, reducing the inventory of commercial enterprises, reducing inventory costs and delivering the goods to target markets on time.

Storage services are at the forefront of increasingly important issues in today's logistics manner of rule. Storing the goods and products that need to be moved in certain centers increases the efficiency and efficiency of logistics activities.

Basic business processes in warehouse management can be listed as:

- Inbound of goods
- Warehousing
- Order picking
- Packaging
- Outbound of orders

In this study, it is focused on warehousing and effective use of the space. Warehouses are the intermediate points that play a strategic role in the actualization of an entire sequence of operations from the raw material phase to the production environment and then to distribution to the consumption centers. Bartholdi and Hackman define warehouses as "points in the supply chain where product pauses, however briefly, and is touched". Warehouses are important for suppliers, producers, distributors and retailers. [1]

Warehousing has a great importance as a result of contemporary competition environment including cost reduction, logistics management bureaucracy and customer satisfaction [2]. It is important that raw materials, semi-finished products or products are stored for efficient warehouse management in the most appropriate way and prepared at the required time in case of demand.

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Warehouse layouts have some reasons to be the most appropriate way such as regardless of the material being stored: maximize the use of space, maximize the use of equipment, maximize the use of labor, maximize accessibility to all items and maximize protection of all items [3].

It has become imperative to redesign the warehouse to correspond with changing the role of warehouses, such as increased demand for the storage area, increased importance of inventory control, and increased labor costs etc. [1].

Regarding the importance of warehouse layouts, the aim of this study is to analyze and improve logistics processes of finished goods warehouse by designing the layout in a white goods manufacturer's plant. Factories (such as cooling, cooking, freezing and etc.) send finished goods to the central warehouse and as a result of the ineffective use of space, there occur problems. There are various types of products having different dimensions. Each product type has an address to be located in. Hence, it is important to determine the optimum size and quantity of addresses to minimize the loss of area and provide effective warehouse management. A mathematical model is proposed to determine the address sizes and a comparison is provided between the layouts having a different number of addresses having a range between 5 and 10. The comparison is based on indicators such as space saving percentage, the percentage of addresses and space utilization rate.

The rest of the paper is organized as follows: Literature review about the methodologies in warehouse layout design is provided in the second part. The third part includes the case and the proposed mathematical model. The results of the mathematical model are provided in the fourth part and in the last part, a conclusion is given with the references following.

2. LITERATURE REVIEW

The problem of warehouse layout design has been studied for a long time and consists of two sub-problems. The first problem, known as facility layout planning, involves determining how the warehouse layout should be designed with various departments. The most frequently used aim in the problem is the reduction of total transport and transit costs [4].

The second sub-problem, known as the internal layout design or corridor configuration problem involves determining how many blocks of storage space that make up the order collection system should be made up and how many corridors these blocks must have with respect to the height and length. In the solution of this problem, it is important to obtain the best settlement plan in accordance with the given constraints and requirements. As a performance criterion, it is often taken into account that the total travel distance is reduced [5].

Different design and integration models have been developed in the literature including mathematical models and heuristic procedures. There are a number of studies related to the design and integration of the different warehousing processes. The methods will be analyzed under mathematical models, simulation based models and heuristics.

Mathematical Programming

There are various studies including mathematical models. Some of them are explained as follows:

Alfred et al. used linear programming algorithms for optimizing the routing of shipments in multi-plant, multi-destination systems [6]. Karasawa et al. presented a nonlinear mixed integer formulation with decision variables being the number of cranes and the height and length of storage racks and costs including construction and equipment costs while satisfying service and storage capacity requirements [7]. Cormier and Gunn developed a nonlinear programming formulation for the optimal warehouse expansion over consecutive time periods [8]. Michael et al. used mathematical programming approach for addressing the problem of allocating items of material in a given two or three-dimensional space [9]. Anjos et al. used mathematical-programming models to find good starting points for the iterative algorithm and find different competitive layouts with relatively little computational effort [10]. Horta et al. proposed a mathematical programming approach, based on a min-max formulation that returns the optimized layout of a cross-docking warehouse that feeds a just-in-time distribution operation [11].

Simulation

Besides mathematical models, simulation-based studies have also been carried out for the effectiveness of in-store operations.

Marsh used simulation to evaluate the effect on space utilization of alternate lane depths and the rules for assigning incoming shipments to lanes [12]. Chew and Tang proposed a method of analyzing order grouping and repository allocation strategies [13]. In this method, orders are grouped by customer and a simulation model is used for collection. Lin and Lu developed a simulation-based method to determine order collection strategies [14]. After the orders are divided into groups by an analytical method, the appropriate collection strategy for each order group is realized by simulation. Petersen and Aase developed a simulation-based model to compare different collection, storage, and puncture strategies affecting order picking distances [15]. It has been found that the group-based collection strategy provides better results in this study. Hsieh and Tsai proposed a simulation-based method of evaluating different policies related to assignment, collection route, and order merges affecting order collection [16].

Heuristic Approach

Depending on the combinatorial structure of the warehouse layout problems, heuristic approaches are frequently developed.

A genetic algorithm with a special crossover operator was proposed by Poulos et al. finding the Pareto-optimal solutions in the warehouse replenishment problem [17]. Lee and Elsayed considered the storage sizing problem for productive warehouses under a dedicated storage policy [18]. Since the problem was formulated as a nonlinear optimization model, a repetitive search procedure was developed to solve the model optimally. It is a popular case that plant sites are formulated as Quadratic Assignment Problem (QAP) even in the presence of various formulations. It is easy to determine the potential locations occupied by departments if all sections are equally spaced in the facility settlement problem, or if the physical locations of the sections can be changed without changing the proximity or distance relationships between the remaining sections. Gülsün et al. used Genetic Algorithms (GA) and as a result 41% decrease in the transportation costs is expected with the redesign of the facility [19]. Rodoslu used heuristic approach since the problem is formulated as an objective vehicle routing problem with time windows in which the objective is the minimization of the total route distance [20]. Unequal Area Facility Problem (UA-FLP) has been dealt with in a variety of ways including mathematical modeling, heuristic and metaheuristic approaches. For the first time, Palomo-Romero et al. used an Islands Model Genetic Algorithm (IMGA) to solve these issues in UA-FLP for minimizing the total material handling cost [21].

As can be concluded from the literature, various types of solution methodologies are used for warehouse layout problems. In case the problem size gets bigger, the mathematical models become less effective and heuristic based approaches are proposed. In this study, the proposed approach is based on a mathematical programming model that was developed to determine the allocation of the products to the suitable addresses in order to increase the productivity by minimizing the used area in the warehouse. Given the characteristics of the problem at hand, the model developed is a Mixed-Integer Programming (MIP) Model. Since the optimum solutions are obtained, no heuristics are needed.

3. THE CASE AND THE PROPOSED MATHEMATICAL MODEL

The related warehouse consists of two parts as domestic and export products. The products produced in the plants reach the warehouse with the tunnel system as shown in Figure 1 and the products are separated by types with sorter lines.

Figure 1: Sorter Lines for Fridge and Washing Machine

For export products, besides road transportation, the train line which is connected to the warehouse is also used. Train line separates warehouse into the export area and domestic area.

Products are moving in the warehouse according to the clamp system. Products are separated to clamps according to sizes and types. So, products that can be transported together should be stored nearby as shown in Figure 2.

Products those are not sufficient to store stock in an address, such as old products or old models, are stockpiled at certain addresses in a mixed way without separated by types. This storage area is called the mixed sector.

When the mathematical model is created, some situations are considered in the warehouse. Firstly, export and domestic parts of warehouse must stay separately. Products must be separated according to the clamp groups, products that can be transported together should be placed in close proximity. And lastly, how many times the products can be stacked is assumed as fixed and specific.

Figure 2: Stacked up products

The mathematical model

According to the literature review, there are various solution approaches for warehouse layout problems. But depending on the complexity of the problem type, heuristics such as genetic algorithm, simulated annealing, tabu search and etc. are frequently used in the studies.

However, it is observed that the problem handled in the study can be solved by mixed integer linear programming model in a reasonable time. Hence, no heuristic approaches were used.

A brief information about assumptions, objective, constraints of the proposed model is provided below.

Assumptions;

The depth measure of the products was considered to be standard and equal during calculations throughout the project since the depth information was not completely available.

Objective;

The objective of the proposed model is minimizing total width loss of addresses. The volume of products, numbers of addresses for that product, the number of floors which products stacked up and average stock amount affect objective function.

Variables:

- X_{ij} = Assignment of group j to address i (0,1)
- Y_i= Address i is selected or not (0,1)

Parameters:

- W_{ai} = Width of address i
- W_{gj} = Width of group j
- f_j=Frequency of group j
- k=Number of maximum address
- num_j= Number of stocks side-by-side in each group j

Objective: Minimization of total width loss of addresses

$$\textbf{\textit{Min z}}= \sum_i \sum_j \left(\left(X_{ij} * (w_{a_i} - num_j * w_{g_j}) \right) * f_j \right) \quad (1)$$

Constraints:

$$\sum_i X_{ij} = 1 \qquad \forall_j \quad (2)$$

$$Y_i \geq X_{ij} \qquad \forall_i, \forall_j \quad (3)$$

$$\sum_i Y_i \leq k \quad (4)$$

$$X_{ij} * \left(num_j * w_{g_j} - w_{a_i} \right) \leq 0 \qquad \forall_i \forall_j \quad (5)$$

$$\sum_j \left(X_{ij} * w_{a_i} * f_j \right) = Per_i \qquad \forall_i \quad (6)$$

$$Per_i \geq 0, \; X_{ij}, \; Y_i \in \{0,1\} \quad (7)$$

Eq. 1 denotes the objective function which aims to minimize the total unused area with respect to all groups and determined addresses. Eq. 2 ensures that each group is assigned to one address. Eq. 3 provides the selection of an address in case any group is assigned to that address. Eq. 4 limits the number of addresses with a maximum value. Eq. 5 ensures that the width of the assigned group is less than the related address' width. Eq. 6 provides the percentage of an address regarding the width and frequency of the groups assigned to that address and finally the last Eq. 7 ensures that some variables are bigger than zero and some are binary integers.

4.4. THE RESULTS OF THE MATHEMATICAL MODEL

The mathematical model is applied in the warehouse of the white goods manufacturer and the results are synthesized with respect to three indicators consisting of space saving percentage, percentages of addresses and space utilization rate. The model is run for 6 values of address numbers between 5 and 10.

The first and the most important indicator is the Space Saving Percentage. It is formulated as in Eq. 8.

$$\text{SSP} = \frac{(Previous\ Space - Proposed\ Space)}{Previous\ Space} * 100 \quad (8)$$

It is calculated for two different areas that are export and import areas for each number of address. For both areas, space saving percentage is always increasing however after 8 different address sizes, the slope of the lines is decreasingly growing as seen in Figure 3. Therefore 8 different address sizes can be regarded as suitable for both areas.

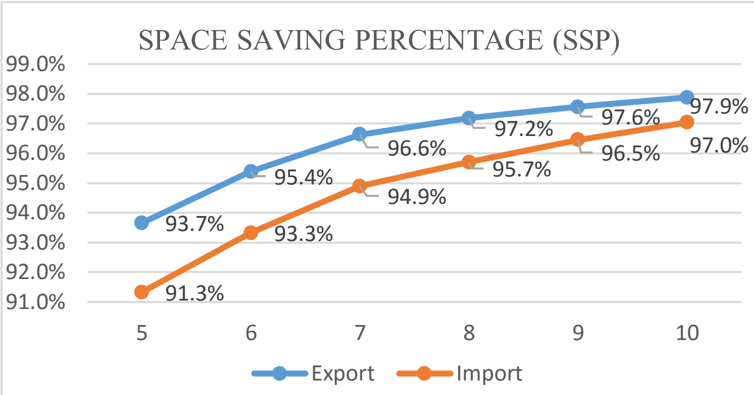

Figure 3: Space Saving Percentage (SSP)

After determining the address sizes, another important indicator is the percentages of the addresses. The formula that is used for address percentage is shown in Eq. 9.

$$\text{Address Percentage}= \frac{\sum_j (X_{ij} * W_{a_i} * f_j)}{\sum_i \sum_j (X_{ij} * W_{a_i} * f_j)} * 100 \quad (9)$$

For each number of address, proper address sizes were calculated by Lingo Optimization Program and the percentages of each address are obtained from the results. The percentage of addresses by size for import and export areas are shown between Figures 4 and 9.

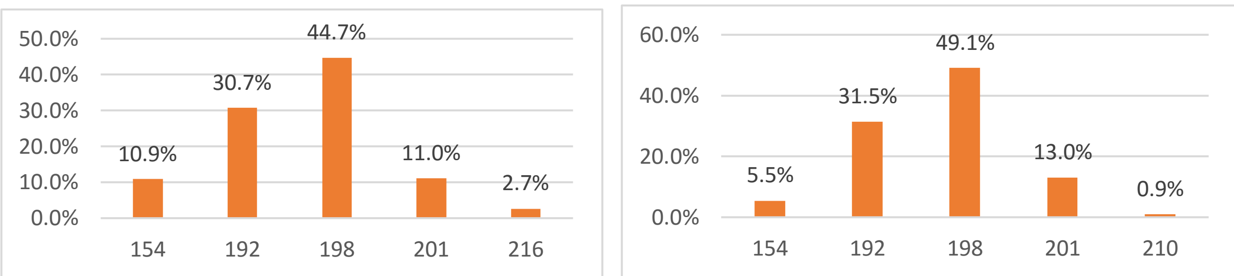

Figure 4. The Percentages of Addresses by Sizes for k=5 in Import and Export Areas, respectively

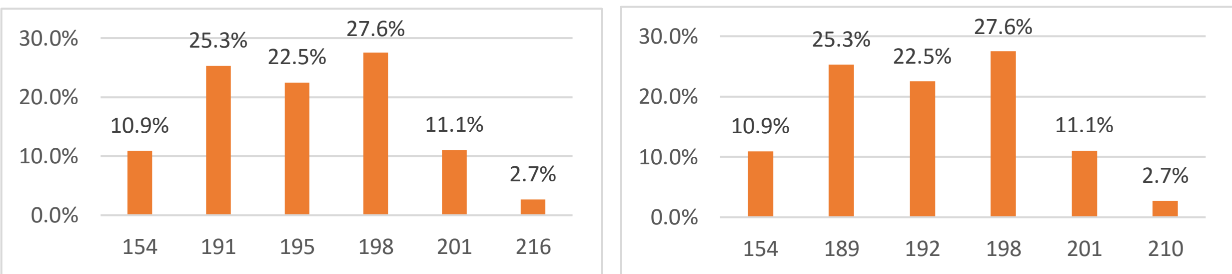

Figure 5. The Percentages of Addresses by Sizes for k=6 in Import and Export Areas, respectively

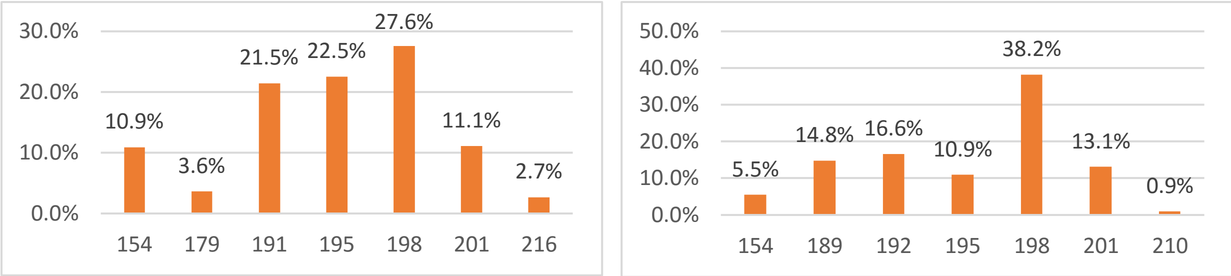

Figure 6. The Percentages of Addresses by Sizes for k=7 in Import and Export Areas, respectively

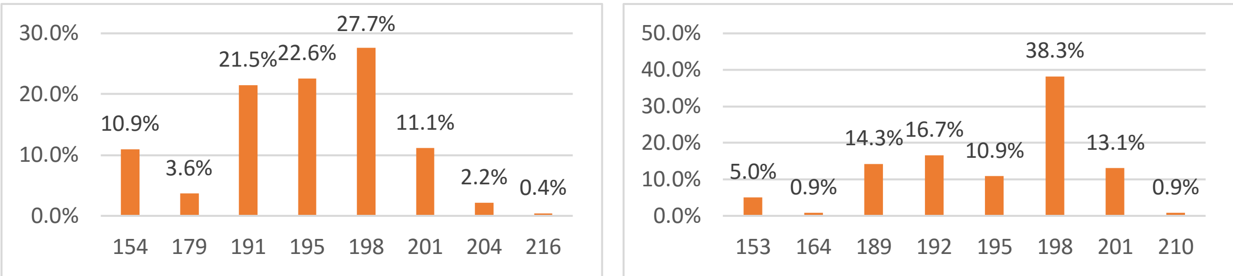

Figure 7. The Percentages of Addresses by Sizes for k=8 in Import and Export Areas, respectively

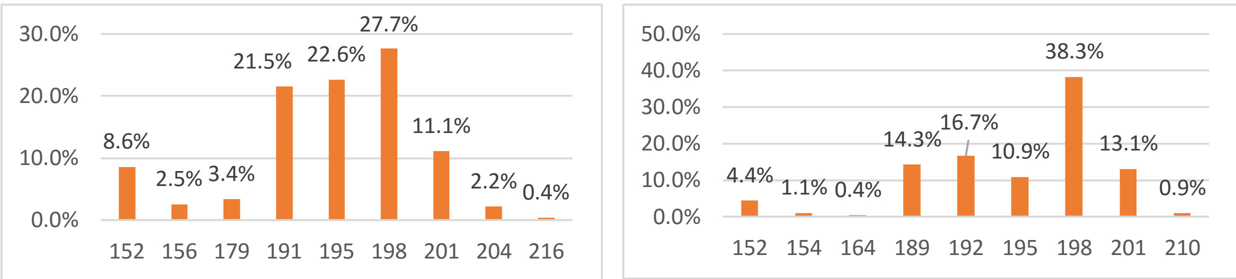

Figure 8. The Percentages of Addresses by Sizes for k=9 in Import and Export Areas, respectively

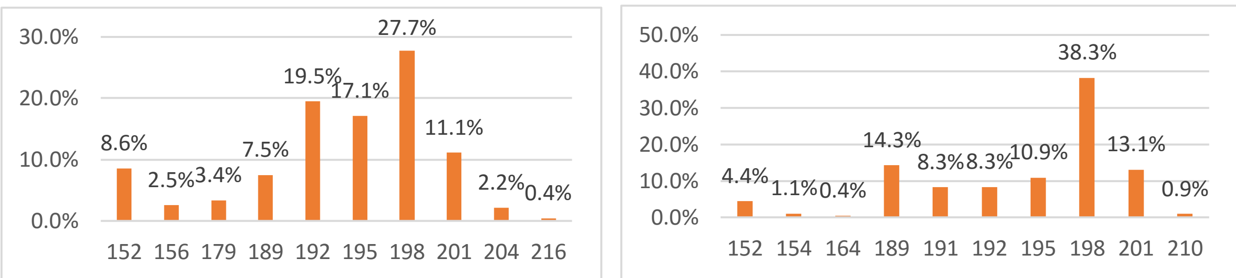

Figure 9. The Percentages of Addresses by Sizes for k=10 in Import and Export Areas, respectively

Finally, the last indicator is Space Utilization Rate (SUR) as formulated in Eqs. 10 and 11.

$$\frac{Used\ Space}{Total\ Space} = \sum_i (address\ percentage * address\ utilization) \quad (10)$$

$$\text{Address utilization=} \frac{\sum_j (\text{Group percentage in address ij} * \text{Group width j} * \text{Storage numbers})}{\text{Address width i}} \quad (11)$$

The utilization rate of the new address sizes generated for each number of address was calculated taking into account the overall weight of the product groups within the new addresses and accordingly the percentage of space used is obtained as shown in Figure 10. As suggested, if eight different address sizes are applied, a space utilization rate of 99% will occur.

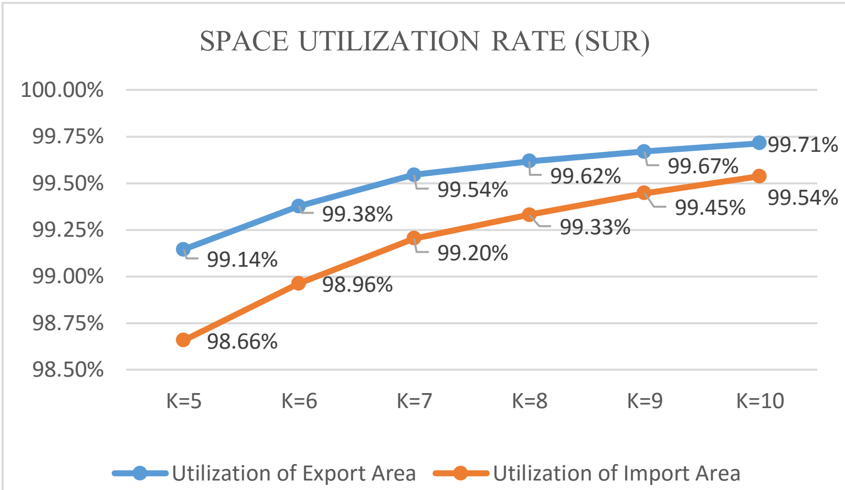

Figure 10. Space Utilization Rate (SUR)

5. CONCLUSION

Warehouse management which is one of the important components of logistics has increasingly been studied in the recent years. In this study, it is focused on the space utilization in warehouse management. A real case in the warehouse of a white goods manufacturer is handled delicately. After reviewing the literature considering the solution approaches and the cases, a similar case has not been found out. Hence, a novel mathematical model is developed regarding the real case.

Within the handled case, the main problem is to determine the addresses for the product groups in the warehouse. In case the size and number of addresses are not determined properly, efficient space utilization becomes low. With the proposed mathematical model which is based on integer programming, the optimum size of the addresses and the allocation of each group to each address are obtained. The model is iteratively run for different number of addresses. Three indicators including Space Saving Percentage (SSP), the percentage of addresses and Space Utilization Rate (SUR) are calculated and commented.

The proposed model is run easily for the case and the optimum solution is obtained. However, in the further studies, depending on the combinatorial optimization structure of the mathematical model, heuristics can be required for real cases including big data. Moreover, some parameters can be handled regarding the stochastic and fuzzy environments.

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COOPERATIVE GAME THEORY IN SUPPLY CHAIN MANAGEMENT

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Abstract− *Supply Chain Management is becoming increasingly important to gain advantage in the market today. In Supply Chains, there is more than one player, i.e. producers, wholesalers, retailers, etc. and these players try to make the best decision from their point of view. In recent years, game theoretical models are widely used in Supply Chain Management to model competition and cooperations to gain a competitive advantage against the rivals. It is necessary to make multiple decisions to reduce the cost of players in the Supply Chain and game theory provides a structure that allows making multiple decisions. In this study, main studies on cooperative game theory techniques used in Supply Chain Management will be examined and an example will be presented.*

Keywords− *Game Theory, Supply Chain Management, Cooperative Games, Cooperation*

1. INTRODUCTION

Game theory is a structure that provides making multiple interactive decisions. It tries to determine the behavior of each individual when the success of the individual depends on the preferences of the others. In game theory, individuals are called players. If each player tries to take best decisions and knows the other players are also trying to make best decisions for themselves, and if they are not sharing any information this situation is called as non-cooperative game. On the other hand, if the players want to cooperate to increase their benefits, this is called cooperative game theory. For the first time, cooperative game theory was mentioned by von Neumann and Morgenstern (1944). According to Cachon and Netessine(2006) Wang and Parlar(1994)'s work is among the first studies on cooperative game theory in supply chains.

Collaboration and exchange of information are becoming increasingly important in today's supply chain. Companies are resorting to this way to survive in competitive conditions. For this reason, cooperative game theory in the supply chain is becoming increasingly popular.

This paper is organized as follows. Section 2 presents the methods used for the literature review. Section 3 reviews Cooperative Bargaining models. Section 4 includes the models about Coalition and Section 5 discusses Profit/Cost Allocation models. Finally, Section 6 includes an example problem.

2. METHODS

2.1. Data Sources

Published studies were examined through databases of ELSEVIER, SPRINGER etc. for the period from 1944 to 2017. Keyword, title and abstract information were used. The main search terms were 'game theory', 'cooperative' , 'supply chain', 'bargain', 'allocation', 'negotiation', 'profit', 'cost'. Also, the lists of references from inspected articles were used.

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2.2. Study Selection

This paper focuses on three topics from the best practices in the supply chain on cooperative game theory.

These topics are Cooperative Bargaining, Coalition Formation and Profit/Cost Allocation.

Nagarajan and Sosˇic (2008) presented a review on Game-theoretic analysis of cooperation among supply chain agents. They included Cooperative Bargaining and Profit Sharing and Alliance Formation. In this paper, we also review the studies that includes Profit/Cost Allocation models.

3. COOPERATIVE BARGAINING

In this section, cooperative bargaining models and its applications in supply chains were reviewed to see the impact of negotiations in a supply chain.

In a bargaining game, if the feasible outcomes are such that each participant can do better than the disagreement outcome, then there is an incentive to reach an agreement; however, so long as at least two of the participants differ over which outcome is most preferable, there is a need for bargaining and negotiation over which outcome should be agreed upon. (Nagarajan and Sosˇic´, 2008) Negotiation topic can be price, quantity or delivery times of goods.

If players get the same allocation, risk neutrality arises and it is said that these players have the same negotiation power. In the other case the players have different preferences and their negotian power differs.

Thus, if a player is more risk averse, its rivals bargaining power increases.

Bargaining game concept is first introduced by Nash (1951). Nash made an axiomatic derivation of the bargaining solution. The solution is that each participant agrees unanimously. The axiomatic approach requires a list of the properties of the resulting solution. Axioms try to put restrictions on the resulting solution. Axioms do not show which agreement is made. Also, axioms do not affect the properties of the feasible set.

Nash (1953) analyzed two person cooperative games. He gave two independent derivations of solution of the two-person cooperative game. First approach was negotiation model. Firstly, he reduced the cooperative game to a non- cooperative game. In this way steps of negotiation in the cooperative game became moves in the non-cooperative model. The second approach was the axiomatic method. He applied these two methods and compared the results.

3.1. Cooperative Bargaining in Supply Chains

While searching the literature on bargaining in the supply chains, we encountered the work that is one of the earliest examples of Kohli and Park (1989). They analyzed a transactions-efficiency rationale for quantity discounts in the context of a bargaining problem in which a buyer and a seller negotiate over lot size orders and average unit prices. They illustrated the outcome of the negotiation to maximize-the joint efficiency gain between the buyer and the seller. They examined the effect of risk sensitivity and bargaining power on the negotiated discount.

Reyniers and Tapiero (1995) modelled the effect of contract parameters such as price rebates and after-sales warranty costs on the choice of quality by a supplier, the inspection policy of a producer, and the resulting end product quality using formal cooperative model. They explored non-cooperative and cooperative settings. Their aim was to highlight the importance of strategic and contractual issues in quality management.

Chen et al (2006) investigated the efficiency game between two supply chain members. They illuminated that there exist numerous Nash equilibriums efficiency plans for the supplier and the manufacturer with respect to their efficiency functions. Then, they proposed a bargaining model to analyze the supplier and manufacturer’s decision process and to determine the best efficiency plan strategy. They used Data envelopment analysis (DEA) to evaluate efficiency for supply chain operations for the central control and the decentralized control cases. They explained current study with a numerical example.

Ertogral and Wu (2001) examined a bargaining theoretic approach to supply chain coordination. They first propose a one-su pplier, one-buyer infinite horizon bargaining game for supply chain contracting, where the buyer negotiates the order quantity and wholesale price with a sourcing supplier. They illuminated that in subgame perfect equilibrium, the channel coordinated optimal quantity is also optimal for the players, but the players must negotiate the surplus generated by the contract in a bargaining game. They pointed out that the one-supplier bargaining game serves as a building block and the negotiation-sequencing problem can be solved as a network flow problem.

Lovejoy (2010) developed a bargaining-based solution to negotiations between two adjacent multifirm tiers and show its consistency with familiar solution concepts the theories of bargaining and cooperative games. He then linked up multiple bargaining modules to generate chainwide predictions for efficiency and profitability in supply chains with an arbitrary number of tiers an arbitrary number of firms per tier. He investigated the implications of the results for investments in improvements or supplier development.

Li et al (2002) developed three strategic models for determining equilibrium marketing and investment effort levels for a manufacturer and a retailer in a two-member supply chain. They pointed out the impact of brand name investments, local advertising, and sharing policy on coop advertising programs in these models. They used a cooperative bargaining approach for determining the best coop advertising scheme for achieving full coordination in the supply chain.

Zhao et al. (2010) used a cooperative game approach to consider the coordination issue in a manufacturer–retailer supply chain using option contracts. They developed an option contract model using the wholesale price mechanism as a benchmark. They demonstrated that, compared with the benchmark based on the wholesale price mechanism, option contracts can coordinate the supply chain and achieved Pareto-improvement. They studied scenarios in which option contracts are selected according to individual supply chain members' risk preferences and negotiating powers.

Cooperative bargaining implementations in supply chains is considerably limited. Risk aversion and bargaining when players have incomplete information can be shown in further topics.

4. COALITION FORMATION

Firms can make coalitions on a regular basis for reasons such as capacity sharing, economies of scales, competitiveness. In this section, cooperative coalition models and its applications in supply chains are reviewed.

One of the first studies about the coalition formation belongs to Neumann and Morgenstern (1944). Hurwicz (1945) studied the theory of games and his aim was to analyze the conditions and nature of coalition formation. Shubik (1952) examined theories of competition and coalition formation. Greenberg (1994) made a detailed examination about coalition structures and its applications.

4.1. Coalition Formation in Supply Chains

Chacho (1961) may be the first one to study about coalition in supply chains. He studied for selecting a bargaining strategy for a multiplant, multi- product, manufacturing company, engaged in negotiations with two of its distributors. He calculated the company's net profit equivalent, and the distributors' net profit. He used 52-month data to obtain net profit equivalent.

Sosic and Granot (2003) showed a three-stage model of a decentralized distribution system consisting of n retailers, each of whom faces a stochastic demand for an identical product. They worked on the effect of implementing various allocations rules in the third stage on the values of the residual supply/demand the retailers are willing to share with others in the second stage, and the trade-off involved in achieving an optimal solution for the corresponding centralized system.

Kemahlıoglu Ziya (2004), considered a decentralized, two-echelon supply chain where the the supplier bears the inventory risk. They modelled the inventory transactions among the retailers and the supplier as a cooperative game. The total profit of the coalitions is allotted to the players using a profit-sharing mechanism based on Shapley value. They found that the retailers prefer pooling partners with either very high or low service level requirements and the supplier prefers retailers with low service requirements since this gives her the ability to maximize her profit allocation. They analyzed the effects of demand variance on the allocations and the profitability of strategic retailer coalitions.

Reinhardt and Dada (2005) modelled the problem as a cooperative game and used Shapley Value to distribute the savings. When the pooled savings depend on the sum of each player's demand, they developed an algorithm that computes Shapley Value and labeled the game coalition symmetric.

Rosenthal (2008) studied a problem of setting transfer prices in a vertically integrated supply chain, in which the divisions share technology and transactions costs. He developed a cooperative game that provides

transfer prices for the intermediate products in the supply chain and allowed coalitions to form among any subset of players. In the perfect information case, the Shapley value generates the transfer prices, while in the asymmetric case we obtain transfer prices from the solution to a linear program.

Leng and Parlar (2009) analyzed a problem of allocating cost savings from sharing demand information in a three-level supply chain with a manufacturer, a distributor, and a retailer. They used concepts from cooperative game theory to find a unique allocation scheme. They presented numerical analyses to investigate the impacts of the demand autocorrelation coefficient, and the unit holding and shortage costs on the allocation scheme. They constituted a coalition that all supply chain members cooperate with each other in sharing the demand information. They allocated the savings among them according to the nucleolus and the Shapley value.

Bahinipati et al. (2009) concentrated on cooperation as a solution for hybrid coordination mechanism to form the basis for semiconductor industry supply chain management. They used the Shapley value for analyzing revenue sharing in cooperation. They explored how to make right decisions about revenue sharing. They think it is important to establishing a pooling coalition in order to provide a stable and cooperative solution.

Yu et al. (2012) worked on a single-issue negotiation between Manufacture Agent (MA) and Material Supplier Agent (MSA) of the supply chain. MSA resorts to find partners to cooperate when it cannot finish the order independently. They suggested a two stage negotiation protocol. For establishing the coalitions, they combined cooperative game with MA-Stackelberg game to resolve the negotiation problem. Then, they determined final coalition negotiates with MA to reach an agreement using the Stackelberg game.

Lin and Hsieh (2012) constructed a cooperative coalitional game as a variational inequality problem and suggest an iterative diagonalization algorithm to determine the steady state for the game. They found that supply-chain competition may not necessarily preserve the same level of social welfare, internalization of resources and costs may distort the general competition economy, and managing the power in a supply chain does not necessarily translate into higher profits.

Although coalition structures are quite appropriate for the supply chain in cooperative game theory, their implementation is still very few. Since these problems are difficult to calculate, more emphasis can be placed on hybrid models in the future.

5. PROFIT/COST ALLOCATION

The cost allocation problem emerges when individuals decide to work together for which each one of them has different purposes. Cost allocation concerns how these individuals are willing to share common costs. A cost allocation problem can be transformed into a cost game. (Tijs and Driessen, 1986) Tijs and Driessen(1986) divided the cost allocation methods into two as methods based on marginal costs in entering coalitions and methods minimizing maximum unhappiness. Hamlen et al. (1977, 1980) and Callen (1978) gave the first instances of implementations on cost allocation in cooperative game theory.

5.1. Profit/ Cost Allocation in Supply Chains

Cooperative game theory can be very helpful in analyzing supply chains. Krajewska et al. (2008) suggested an approach to help freight carriers understand how to share costs and savings. They first analyzed the profit margins resulting from horizontal cooperation among freight carriers. Then, they worked on the possibilities of sharing these profit margins fairly among the partners. They used the Shapley value to establish a fair allocation. They asserted that collaboration can yield a considerable cost decrease and efficient profit allocation is possible by using cooperative game theory.

Zhang (2009) sets a one-warehouse multiple retailer inventory model with a submodular joint setup cost function. He worked for allocating the cost to the retailers, under an optimal power-of-two policy by a cooperative game. He demonstrated that this cooperative game has a nonempty core.

Zhao et al. (2010) examined the coordination in a manufacturer–retailer supply chain using option contracts by using cooperative game theory. They set an option contract model using the wholesale price mechanism as a benchmark. They claim that, compared with the benchmark based on the wholesale price mechanism, option contracts can coordinate the supply chain and achieve Pareto-improvement.

Jin (2012) improved a Raiffa Solution model with conceiving service factors to solve the profit distribution problem. This model considered the upper and lower limits of profit distribution. For validating the model, he analyzed an iron and steel logistics alliance including six partners by using hypothetical data as an example. The results demonstrated that the modified Raiffa Solution can inspire partners to improve service level better and promote the development of iron and steel logistics industry consequently.

Xu et al. (2014) used Shapley value to solve n-person cooperative game. They described the payoff function of cooperative games with fuzzy coalitions and they demonstrated that the payoff function and modified Shapley value fulfil the axioms of super additivity and symmetry to solve the no dummy cooperative game. The results illustrated that the correcting algorithm Shapley value is consistent with the classic Shapley value.

Further research can include analysis of complex functions of cost allocation for inventory models and global supply chains.

6. IMPLEMENTATION

In this section a simple example of cooperative game theory of Brandenburger (2007) will be given to make things more informative. In this example a basic negotiation model is shown.

6.1. Problem Definition

A cooperative game consists of two elements: a set of players and a characteristic function specifying the value created by different subsets of the players in the game. Formally, let N = {1, 2, . . . , n} be the (finite) set of players, and let i, where i runs from 1 through n, index the different members of N. The characteristic function is a function, denoted v that associates with every subset S of N, a number, denoted v (S). The number v(S) is interpreted as the value created when the members of S come together and interact. (Brandenburger, 2007)

6.2. Numerical Example

In this numerical example of a cooperative game, there are three players, N = {1, 2, and 3}. Player 1 is a seller and players 2 and 3 are buyers. Player 1 has a unit to sell which its cost is $6. Each seller wants to sell at most one unit of good. Player 2's a payment request $10 for player 1's good and player 3 has a payment request$12 for player 1's good. The characteristic function v is described for this game as follows:

$v(\{1,\ 2\}) = \$10 - \$6 = \$4$ (1)

$v(\{1,\ 3\}) = \$12 - \$6 = \$6$ (2)

$v(\{2,\ 3\}) = \$0$ (3)

$v(\{1\}) = v(\{2\}) = v(\{3\}) = \$0$ (4)

$v(\{1,\ 2, 3\}) = \$6$ (5)

(Brandenburger, 2007)

If players 1 and 2 make an agreement, their total gain will be the difference between the buyer's payment request and the seller's cost which is $4 at (1). If players 1 and 3 make an agreement, their total gain will be $6 as it can be seen at (2). Equation (3) demonstrates that players 2 and 3 cannot create any value by coming together because they are both buyer, they need a seller to create value. A player cannot create a value alone, because transaction must take place to create value at (4). Selecting a higher payment request is a modeling assumption here. Player 1 would be chosen player 3. That is the reason for setting v ({1, 2, 3}) equal to $6 at (5).

Player 1 receives a price of at least $10 because takes at least $10 − $6 = $4 of value. Player 3 pays a price of at least $10 because takes at most $12−$10 = $2 of value; and player 2does not take any value. Herein, the game is based on negotiations between players 1 and 3. Because player 1 will not pay less than $10 and player 3 will not pay more than $12.

The method used here is The Marginal-Contribution principle. This principle does not deal with how this residual $2 of value will be shared. It ensures that player 3 pays at least $10, at most $12. A feasible answer is to share the residual equally. Player 1takes a total of $4 + $1 = $5 of value and player 3 takes $1 of value. However, in the specified range any value is admissible. (Brandenburger, 2007)

7. CONCLUSION

In this study, a literature review is given on cooperative game theory techniques used in Supply Chain Management and an example is presented where each player can determine the most appropriate method for himself/herself. This study reviews cooperative games in supply chains for the purpose of explaining the cooperative game theory and showing the researches done up to now in this area. Main studies in the literature are examined and an example is presented.

We have analyzed the practices of cooperative game theory in supply chains as dividing it into cooperative bargaining, profit sharing and alliance formation and cost allocation categories. This will be a guide for future works in terms of being a clear and detailed review. Further studies may be classified according to the area of implementation of cooperation in supply chains (For instance in inventory management.) Thus, a wider screening may be done.

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DESIGN OF REVERSE LOGISTICS NETWORK FOR WASTE TIRES WITH AN APPLICATION IN TURKEY

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Abstract **–** *In our current world, due to the growing human population, all sources should be used effectively for the sustainability of the life. That's why, recovery of the used products has been vital. End-of-Life Tires (ELTs) are considered an alternative fuel for especially cement plants. It is available to 32 cement factories which have Environmental Permit and License Certificate in Turkey. In this study, logistic network design of waste tires sent from the gathering ground to these factories by minimizing the costs involved is modelled. In such a network, in every period one must decide transportation plan between echelons of supply chain. Model that deal with this system is expressed as multi-period mixed integer linear programming (MILP) problem. The aim will be to get the best result by using sensitivity analysis.*

Keywords **–** *K-means, MILP, reverse logistics, sustainability, waste tires*

INTRODUCTION

Proportional to increase in population on earth and consumption trend that is caused by increasing living standards, production levels are also increased to meet demands of the humans. This increase in production makes management of resources like raw material, energy and labor important and increased consumption levels makes waste management critical. To prevent society from the damages of wastes to society and to environment or to get rid of them, methods to recycle them or to reuse them should be applied.

When one check for the reports for energy usage by World Energy Council Turkey Committee [1]-[2], it can be seen that there is an increase in total energy consumption in world and also in Turkey. Thus, it is important to use natural sources efficiently and recycling of possible energy resources is gaining importance. Annually 19.3 million tons of tires are being expired or becoming dysfunctional and this value is expected to increase with the growth in motor vehicles [3]. Report that is arranged by the European Tire and Rubber Manufacturer Association (ERTMA) in 2015 is stating that nearly 3.9 million waste tires occurred and 92 percent of them are processed. In same year, when we study data about Turkey there were 314000 tons waste tire and 63 percent of them are processed [4]. From here, Turkey is behind of the Europa when we compare the rates.

Nations are applying some legislative regulations on manufacturer of tires and trader of tires to take a part in recycling or reusing waste tires. In Turkey, "2872 sayılı Çevre Kanunu" and "Ömrünü Tamamlamış Lastiklerin Kontrolü Yönetmeliği" is referenced to process of waste tires. With the related regulation, administrative and technical fundamentals, restrictions and obligations about waste tires are stated such as prohibition of directly or indirectly and unsafe disposing to environment, setting up of for gathering and transportation system for recycling or disposing, creating of management plan and necessary arrangements and standards that are should be supplied about waste tires [5].

In this work, utilization of waste tires in cement factories will be worked. Mokrzycki and Bochenczyk are emphasized advantages of usage of waste tires in cement factories [6]. Firstly, it is possible to direct usage of them as energy source, namely additional treatment on tires are not necessary for process and using it directly cement factories is cheaper than building a new facility to burn them to generate energy. Secondly, using waste tires does not cause additional wastes to atmosphere and it complies with European standards. There are some ways to use waste tires in cement factories which are explained in article by Nakajima and Matsuyuki [7]. First way is using them as whole, second way is to turn them into rubber dust and third way is a chemical treatment namely pyrolysis which is kind a dry distillation that resolves steel, oil and carbon.

To compare the effectiveness of using waste tires as energy source, energy values of them should be considered. Deololkar studied all of the possible alternative fuels that can be used in cement factories in his work [8]. According to energy values of waste tires and tables for requirements for alternative fuels, it is feasible to use waste tires in cement production up to a degree. That degree is specified by governments by laws and this limit stands for preservation from possible harms to environment.

In cement factories, raw materials that are used to form cement are going under a chemical process at 1500°C temperature. To sustain this level of temperature, factories are consuming substantial amount of fuel. These factories also can use waste tires, which have high energy values [9]. By re-using waste tires as a source of energy, it is possible to reduce the effects of them on human health and on environment, to reduce cost of fuel that are used cement factories and to reduce consumption of natural resources.

To conclude, to use natural resources efficiently and for a sustainable world, recycling and reusing of natural resources is critical. Waste tires are one of the aspects of wastes that should be handled because of valuable materials in them. As it is possible to use them as energy resource in cement factories, their network design should be done. Need for a network design arises from the low cost of waste tires and increased cost of transportation due to generally long distances between facilities in a network of waste tires that are being used in cement factories.

LITERATUR REVIEW

Firstly, to see ways of dealing with waste tires, some of past works about waste tires or alike articles are examined. Most of them are focused on entire supply chain of waste tires and they have different methods. However, general problem is a cost minimization problem and some of them have profit maximization as a second objective. First of all, Han et al. [10], in their studies, they developed a linear model that is minimizing the cost of building recycling facilities, cost of transportation and cost of processing the waste tires. They have aimed to obtain optimized flow assessments between the levels of reverse logistic supply chain. Dehghanian and Mansour [11], in their article, proposed a multiple objective model for multiple optimization of recycling network of waste tires. Objectives of their model are maximizing the revenue generated from recycled waste tires and activities, minimizing the total cost incurred by activities while recycling the waste tires and maximizing the social benefit from it. Kannan et al. [12], in their studies, they have developed multi echelon supply chain model and a closed loop multi echelon supply chain model for tire manufacturing industry and plastic products industry. Objective of closed loop multi echelon supply chain model is minimizing costs that are incurred by gathering the product that are being circulated, transportation cost between gathering centers and recycling facilities and necessary process for recycling. Sasikumar et al. [13], constructed a mixed integer non-linear programming model that is maximizing the profit of multi echelon reverse logistic network which is for re-producing and resurfacing of waste tires. Subulan et al [14], formulized a mixed integer linear programming model and designed a closed loop supply chain network for gathering, stocking, recycling and disposing of waste tires in an efficient with the objective that is maximizing the profit and natural indicators. Amin et al. [15], designed a closed loop supply chain network and constructed a mixed integer linear programming model for that network. Model is consisting of multiple products, multiple suppliers, multiple facilities, multiple retailers, multiple demand markets and multiple disposing depots and model has an objective that is maximizing the profit generated by this network. Finally, Pedram et al. [16], developed mixed integer programming model with multiple products and with multiple objectives which are minimizing the pollution and waste caused by waste tires and maximizing the profit from the designated closed loop supply chain. By this model, information about number of facilities, location of them and material flow between facilities are obtained.

Secondly, to have insight about general transportation models and supply chain models, necessary researches conducted. Williams [17], explained related models with the supply chain in his book. Related models are profit maximizing model with multiple plant, transportation models with single product and a derivative of travelling salesman problem model. First one is dealing with the capacity allocation when operating more than one facility, second model is dealing with the assignments of transportation vehicles and the last model is for routing of transportations vehicles for multiple periods. Goetschalckx [18], illustrated related models with a supply chain network. They are single vehicle round trip routing models, vehicle routing models with time windows, some of the vehicle routing heuristics and multi echelon supply chain models. First two models are used for dealing with routing problems in a supply chain and last one is a generic model which finds optimal flow paths from sources to destinations with two different versions which are can be named as arc based and path based models.

Finally, to have information about one of the current trends in industrial engineering which is using clustering algorithms, required study have been done. As models for vehicle routing can be hard to constitute and apply to problem, it may be useful to use clustering algorithms to get routes. Naalusamy et al. [19], talked about using clustering algorithms in difficult and computationally voluminous environments. They applied clustering algorithms to multiple vehicle routing problem and multiple travelling salesman problem and showed that the efficiency of it. It is based grouping closest points of nodes together except for source and destination. Jain [20], mentioned about k-means clustering algorithm in his article. He gives general information about clustering algorithms and the purpose of them while stating the advantages of k-means algorithm. He continues with the explanation of k-means algorithm and extensions of it. Jain and Dubes [21] explained in their books about clustering algorithms. They gave details about implementation ways of these clustering algorithms and basic information about how to prepare a proper data set for clustering algorithm such as normalizing the data.

Problem Definition

In a reverse logistic supply chain, generally cost of transported good is relatively low comparing with other sectors. That makes network flow of that good between echelons of supply chain more important than the other cost aspects such as price of related good. First of all, there are some regulations about this process which is applied by Turkish government. Firstly, tire brands are responsible from the gathering and recycling of tires they sell. However, they are not fully responsible. They are responsible up to a degree which is %60-80 percent of they sell. Secondly, waste of tires is not gathered at the same place with other daily wastes which are coming from the directly consumers or brands. They are held at a different place as stockpiles. Under these conditions, nearly all of the waste tires are held at responsible brands hand or at stockpile of tires. Finally, there is an indirect quato on using waste tires in factories. This quato which is limiting outputs of a factory such as NO_2 and SO_2, is coming from the regulations by ministry of environment and urbanization [19]. This regulation is standing for preventing excess amounts of harmful outputs. Under these regulations, main concern of reverse logistic is utilizing the wastes which are valuable for our society.

Waste tire processing firms is a connection between the sources of waste tire and cement factories. They are gathering the waste tires in their hand selling it to the factories. As cost of waste tires low, their distribution plan is critical. To do it in an efficient way, they should be careful about their capacities, their gathering routes and their distribution schedule.

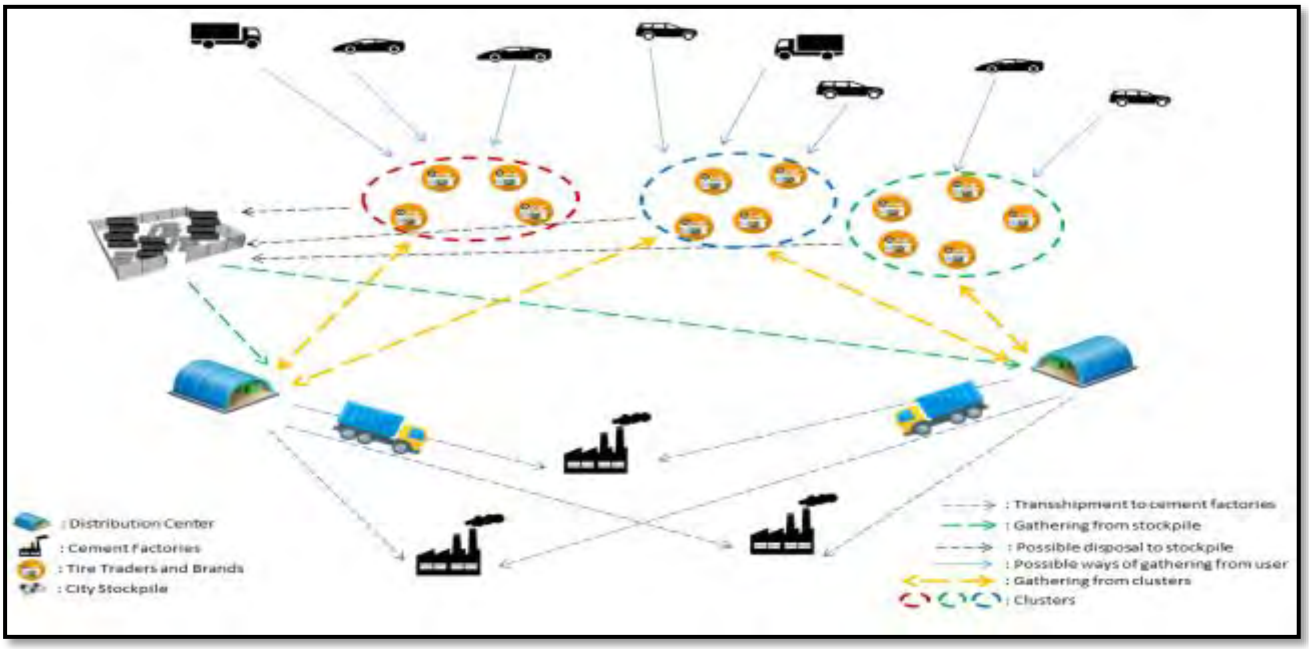

Figure 1. Representation of System of Recycling of Tires.

To sum up, problem here can be stated as, amount of waste tires in Turkey is increasing day by day and to prevent society from huge stockpiles of waste tires and to use our natural sources efficiently they should be reused in a way. One of the ways of reusing them is substituting them for energy sources of cement factories. However, bringing waste tires to cement factories from the consumers of tires can lead to high costs if it is not done correctly. To manage flow between consumers and factories a systematic approach should be taken.

Solution Approach

At this point a general representation of problem should be conducted to decide necessary parameters which are capacity of facility, type of transportation vehicle and number of it, schedule of shipping to factories and routes for gathering waste tires. In order to decide all of them, one clustering algorithm and a model will be used. Firstly, algorithm will be dealing with the gathering routes. Secondly, model will be dealing with the rest of the aspects. This model is based on optimal order quantity and resource planning by a linear model. After models are constructed connection between them should be handled. As waste tires are only product type in supply chain and they are not processed in a such process that takes days to get final product, connection point between cement factories and supply points of waste tires is doing kind a cross-docking. That is to say that separating solutions for different echelon levels of supply chain does not cause a chaos. After getting the optimal scheduling for deliveries to cement factories from connection points, their gathering schedules from suppliers of waste tires can be handled according to it. For illustration, if there is a scheduled shipment to cement factory which is known two or three days before, a gathering schedule can be arranged for next day to get necessary amount. Although, at lower levels of demand, connection between cement factories and supply points of waste tires can be managed easily but greater extents of production can obligate jointed only one model.

Algorithm for Gathering Routes

Assumptions:

- Waste tire amounts at gathering points are known.
- Gathering activity is done before the distribution so that it does not affect capacity of plant and it does not result in a shortage.
- Trucks that are used for this job are separated than distribution plan.
- Real distance between the gathering points is directly proportional with their coordinate on 2-D plane.
- Stockpile of waste tires are not considered as a gathering point when obtaining routes because it can cause infeasibilities in truck capacity and its gathering plan is not included in a route and planned differently.
- Any resulted infeasibilities due to routes are corrected by changing its cluster to nearest and feasible cluster by hand.

To deal with mentioned problem, one sorting algorithm will be used. This is for planning routes when gathering the waste tires. As mentioned in the literature review one of the most used clustering is k-means because of its advantages. Chart given below is showing the procedure of k-means algorithm.

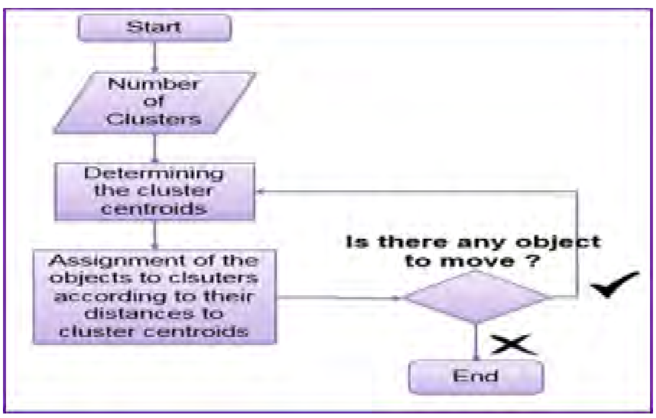

Figure 2. Procedure of K-Means Algorithm.

To start clustering with k-means algorithm number of clusters should be definite and in our problem number of cluster is stating the number of routes that are going to be used by vehicles. Number of clusters at here can be chosen as number of vehicles to initialize. After, k-means algorithm choses random cluster centroids on given data set for initializing and calculations of distances of points to these cluster centroids are made. Points are assigned to clusters according to these distances and it assigns points to closest centroid's cluster. After clusters are formed new centroids of clusters calculated and process continues with new assignments. Whole process lasts until there is no object to move in any clusters. Application it to gathering routes will be based on the coordination of them on a 2-D plane. Below figure is a simple representation of clustering of these points.

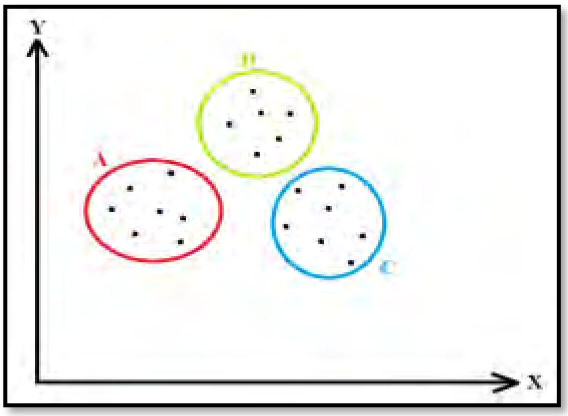

Figure 3. Example Result of Clustering.

As finding optimal routes in a big data set needs huge amount of time, a sorting algorithm can be used to simplify the problem. After these clusters got, as we reduced the problem in small sizes getting the exact routes can be done by routing algorithms such as closest neighbor. However, at this point to work in an optimal way starting and ending of routes in a cluster should be chosen according to their distance related depot. Otherwise, as one choses starting and ending points of routes in a cluster in far points from depot in can increase the total travelled distance.

To sum up, in reverse logistic of waste tires, needed routes can be obtained by using a clustering algorithm. Need for a clustering algorithm is rises from the fact that waste tires cannot be found in an area where all of the tire brands are gathered because they can be gathered in very distinct areas of a city which is most likely to occur. Rather than gathering from a stockpile of waste tires, gathering from these brands needs routing because a brand may not be able to fulfill a truck with waste tires by only itself.

Model for Distribution and Assessments

Assumptions

- Energy usage of factories is known as annually and their demand at a time is depended on distribution plan of the distribution center. Backorder is not allowed.
- There is no effect of changing prices over time.
- Effect of depreciation of equipment and of trucks is not considered and effect of unexpected situations like earthquake or a traffic accident is not considered.
- Capacity of a distribution center is calculated over by maximum daily transaction volume of it.
- Transportation cost is directly proportional to the distance between nodes and they are known.
- A truck can do a trip in a day.
- Bought trucks are used in that day and sold trucks are sold at the beginning of day. They are sold and bought immediately.
- Cost incurred from gathering routes is not considered.

In consideration with assumptions, model has eight different sets. They are explained below. Used parameters in model are explained in related part.

Sets:
i: waste tire distribution centers, namely connection points between factories and supply points of waste tires, up to number n
j: representing the factories up to number m
k: representing the type of truck is used
r: stating the individual trucks in type k up to number o
t: representing the days
s: type of product transferred, {whole, shredded, pyrolysis oil}
l: type of tire used {automobile, truck, motorcycle}
c: set of routes
Decision Variables:
x_{ijtks}: Amount of s transferred to cement factory j from distribution center i by using k type truck at t day in units of m^3
Y_{is}: Binary variable if facility i have requirements for producing s type product
Avt_{itkr}: Binary variable for every individual truck in type k available at facility i
Buy_{itk}: Amount of k type truck bought at day t by facility i
$Sell_{itk}$: Amount of k type truck sold at day t by facility i
$Assign_{ijtkr}$: Binary variable for every individual truck assigned to perform transportation between i and j at day t from truck type k
$Nosche_{ijtk}$: Number of scheduled transshipment between i and j at day t from truck type k
$Prox_{ilt}$: Amount of l type tire processed at facility i at day t
$Demand_{jt}$: Demand of cement factory j at day t in kcal that will be generated from waste tires or its derivatives
Cap_{is}: Capacity of facility i

Objective Function:

$$Min\ z = \sum_i \sum_j \sum_t \sum_k \sum_s Process_s * x_{ijtks} + \sum_i \sum_j \sum_t \sum_k \sum_s trans_{ijs} * x_{ijtks} + \sum_i \sum_j \sum_t \sum_k Fixtrans_{ijk} * Nosche_{ijtk} + \sum_i \sum_s FixPro_s * Y_{is} + \sum_i \sum_t \sum_k (Buy_{itk} * Costtr_k - Sell_{itk} * Revtr_k) + \sum_i \sum_s Costcap_s * Cap_{is} \ . (1)$$

In objective function, all of the aspects that incur cost are considered. $Process_s$ is cost of processing one unit of s type of product. $Trans_{ijs}$ is cost of transporting one unit of s between i and j. $Fixtrans_{ijk}$ is fixed cost of transportation between i and j by using k type of truck. $FixPro_s$ is fixed cost of that should be paid to enable producing s type of product. $Costtr_k$ is cost of buying one unit truck in type k and $Revtr_k$ is related revenue generated by selling one unit of truck in type k. Finally, $Costcap_s$ is cost related with the capacity of production of s type of product. All of these cost aspects are multiplied with the related decision variables to constitute total cost.

Constraints:

$$\sum_j x_{ijtks} \leq Cap_k * \sum_r Avt_{itkr} \quad \forall i, \forall t, \forall k \in \{Normal\ Trucks\}, \forall s \in \{whole, shredded\} \ . (2)$$

$$\sum_j x_{ijtks} \leq Cap_k * \sum_r Avt_{itkr} \quad \forall i, \forall t, \forall k \in \{Tank\ \ Trucks\}, \forall s \in \{prolysis\ oil\} \ . (3)$$

Cap_k is capacity of truck type k in m3. In this constraint, transported amount between i and j is limited by total capacity available.

$$\sum_r Avt_{itkr} \leq Buy_{itk} - Sell_{itk} \quad \forall i, \forall t, \forall k \ . (4)$$

To balance available number trucks, their buying and selling activities should be tracked and it cannot be larger than bought amount minus sold amount.

$$\frac{x_{ijtks}}{Cap_k} \leq \sum_r Assign_{ijtkr} \quad \forall i, \forall j, \forall t, \forall k, \forall s, \forall r \ . (5)$$

By this constraint, binary variable for checking if a truck is used for transshipment between i and j at a given day forced to be 1 for every r.

$\sum_r Assign_{ijtkr} \leq Nosche_{ijtk} \quad \forall i, \forall j, \forall t, \forall k$. (6)

To get number of scheduled trucks between i and j in type k at a certain day, variable for tracking that value should be forced to take a value from the total of individual trucks.

$\sum_i \sum_k \sum_s x_{ijtks} * dens_s * cal_s \geq Demand_{jt} \quad \forall j, \forall t$. (7)

$Dens_s$ is density of s type product and Cal_s is calorific value of s type of product. To turn m3 value to desired unit which is kcal it should be multiplied by density of s type product and calorific value of it. In this constraint, relation between demanded amount of energy that will be generated from waste tires or its derivatives and supplied amount related cement factory is established.

$\sum_i \sum_j \sum_k x_{ijtks} \leq Y_{is} * M \quad \forall i, \forall s$. (8)

M is representing a big enough number. By this constraint, a facility unenabled to provide s type of product unless it does not meet requirements for processing it. Remind that whole waste tires is also considered as a product type but that will not cause a problem as related fixed cost for it can be regarded as zero because of these does not require any procedure.

$\sum_l Prox_{ilt} * conv_{ls} = \sum_j \sum_k x_{ijtks} \quad \forall i, \forall t, \forall s$. (9)

$Conv_{ls}$ is conversion rate between tire type l and desired type of s. By multiplying it processed amount, it is possible to standardize different types tires into a standardized products type. To sustain relationship between distinct types of tires and transferred amounts of products, they should be equalized to each other.

$Prox_{ilt} \leq \sum_c Sup_{ltc} \quad \forall i, \forall l, \forall t, \forall c \in \{\text{routes that are devoted for facility i}\}$. (10)

Sup_{ltc} is available amount l tire type at route c in day t. As available amount at routes has a limit, processed amount at facility i should be limited by available amount at route c in given types. Remind that, these routes are generated by clustering algorithm and devoted according to it.

$\sum_t Demand_{jt} = Annual_j \quad \forall j$. (11)

$Annual_j$ is amount of energy that can be generated from waste tire and its derivatives that is regulated by government and calculated in accordance with regulations. As there is a capacity on usage of waste tire and its derivatives and its cheaper than main energy source of cement factories which is coal, total demand by a facility over time should be equal to annually allowed amount.

$\sum_j \sum_k x_{ijtks} \leq Cap_{is} \quad \forall i, \forall s, \forall t$. (12)

As capacity of facility i have cost other than fixed of producing s type of product that should be included in model. In this constraint capacity of facility i in type of s is forced to take the greatest value of it over time.

Summary

In summary, the recovery / recycling of used tires is very important for economy and environment. End-of-Life Tyres (ELTes) are considered in two basic areas as an energy recovery and material recovery. Our system aims to recycle waste tires and to use them as an energy source in cement factories which is one of the usage areas. In this study, logistic network design of waste tires sent from the storage areas to these factories is planned. It is available to 32 cement factories which have Environmental Permit and License Certificate in Turkey as the final processing plant [5]. The main purpose of the model is to optimize the flow of waste tires from the collection points to the final treatment plants by minimizing the costs involved.

The components in this system are; factories, tire collection areas and places where tires are to be collected and handled. The processes that convert the input tires into energy sources are done in the areas where the tires are collected. The planning required in this network can be done in two steps: First step is the creation of the necessary routes for the gathering waste tires by the clustering method. The second step is the planning of the shipments to distribute the products from the tires to the factory and achieved this through a suitable model. This model is based on optimal order quantity and resource planning by a linear model. After models are constructed connection between them should be handled. As waste tires are only product type in supply chain and they are not processed in a such process that takes days to get final product, connection point between cement factories and supply points of waste tires is doing kind a cross-docking.

For good supply chain management, the variables in this stream need to be well managed since in this system the amount of waste tire collected at the connection points or the demands from the factories will show variability. Against this variability, the safety stock can be kept in order to meet the amount of tire needed by the factories. In this way, a better reverse logistics network design can be made by using the optimal order quantity method and resource planning.

CONCLUSION

As energy is being a scarce resource day by day and also as natural resources of earth are not infinite, reverse logistic of natural resources that can be used in producing energy is becoming critical. Producing energy from waste materials is one of the ways reducing cost in factories like cement factories. As waste materials like waste tires have relatively lower cost than other energy sources that are used in cement factories, waste tires are attractive for cement factories. Due to low cost of waste tires, their transshipment plan is gaining importance because it is known that transportation cost constitutes a remarkable portion of total cost. Additionally, wrongdoings and neglects about conversations of waste tires may result in negative effects on environment and human health. These effects can be listed as [22].

- They are the potential breeding ground for mosquitoes which are the cause for spreading the viruses such as zika virus, dengue fever and chilungunya virus.
- Because of the toxic gases in waste tires, they can lead to soil and air pollution in a case of fire.

So, supply chain of waste tires should be well planned to reduce cost and reduce their effects to environment as much as possible. Proposed solution approach may be used to construct sustainable and well-planned supply chain for waste tires. As this work is still progressing, implementation of proposed solution approach will be done in future. In this implementation, a real system in Turkey that has certificated cement factories and distribution centers with real data will be studied.

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A NEW ERA IN SUPPLY CHAIN MANAGEMENT : BIG DATA CAPABILITIES

Neslihan Turguttopbaş[1], Nurcan Ozyazıcı Sunay[2]

***Abstract -** It is a fact that the ability to collect, capture, store, and process the data has enabled human beings to pass on knowledge and research from one generation to the next. In this study, the properties of big data and its applications in logistic systems have been elaborated in the first two sections. The contributions of the utilization of the big data to the supply chain management have been addressed by literature findings in the third section. The details of the survey applied to three Turkish giant logistics companies about their utilization and capabilities about big data have been and their responses have been submitted in the fourth section. It is mainly observed that the selected Turkish logistics companies have not yet started to analyze big data, but they have large-scale enterprise data which can be defined by terabytes.*

***Keywords** – big data, internet of things, logistics information systems*

1. INTRODUCTION

Tremendous increase in competition in nearly every aspect of life, as parallel to the innovation in information technologies and enriched capabilities of hardware and software, pave the way for redefinition of many operations as well as benchmarks for success in the last 2 or 3 decades. Nowadays, the key for survival and success in global scale in nearly all sectors lies on the best use of data generated by people, operations and movements.

It is a fact that the ability to collect, capture, store, and process the data has enabled human beings to pass on knowledge and research from one generation to the next. Now, after some decades of exponential increase in the ability of collection, storage and process data, with the availability of the cloud infrastructure, potentially unlimited amounts of data, Terabytes and Petabytes of data, can being generated, captured, processed, stored, and managed. However, in order to make the exact definition of big data several aspects stipulated by many researchers has to be combined. From a narrow perspective, Chen et al. (2014) defined Big Data as enormous datasets which typically include masses of unstructured data requiring more real-time analysis. Besides the volume, there are distinguished characteristics differentiating Big Data with massive amount of data or very big data. These characteristics help to better define what big data is for and what it brings to new way of doing things. Some of the definitions focus on the ability to process it such as “datasets which could not be acquired, stored, and managed by classic database software”. The most popular approach to understand Big Data refers to 3Vs (Volume, Velocity, Variety) as proposed by the model of Laney (2001) as given in Figure 1. Another V was added to the model Value which has been the core for almost all efforts in many different field IDC (2012). Another V, which makes the total 5Vs, is Veracity and was contributed by Hassanien et al (2015). 5Vs are given in Figure 1, although by time, the 6th, even 7th Vs are added, namely Variability and Visualization.

Amongst 5 Vs, the conditio sine qua non which means the primary characteristics is Volume as Big Data refers the aggregation of large-scale, voluminous, and multi-format data streams originated from heterogeneous and autonomous data sources Wu X et al (2014). The amount of data was measured in Gigabytes in the past, is now measured in Zettabytes or even Yottabytes as the IoT (Internet of Things) is creating exponential growth in data. However the massive amount of data is heterogen with diverse dimensionalities and is also useless unless the volume is reduced to effectively analyze big data (Che et.al, 2013). The velocity refers to the frequency of data streams or the speed in which data is accessible. The velocity is handled by big data systems in two ways. First, the whole data streams are collected in centralized systems, and then, further data processing is performed. In the second approach, the data streams are processed immediately after data collection before storing in big data systems. Variety indicates the various data types, including unstructured, semi-structured etc. Big Data is generated from multiple

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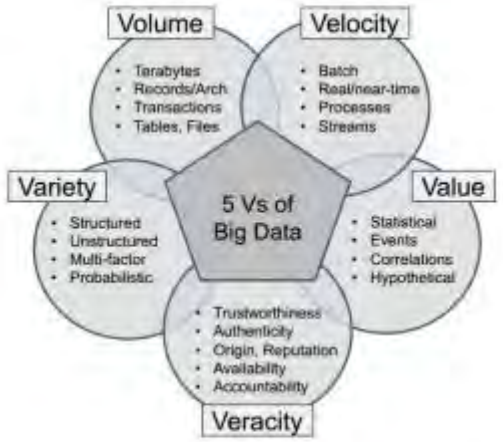
data sources which produce data streams in multiple formats contributes to its variety property-related characteristics. Variability is different from variety and it stems from the fact that all data sources in big data systems do not generate the data streams with same speed and same quality. Veracity is all about making sure the data is accurate, which requires processes to keep the bad data from accumulating in the systems.



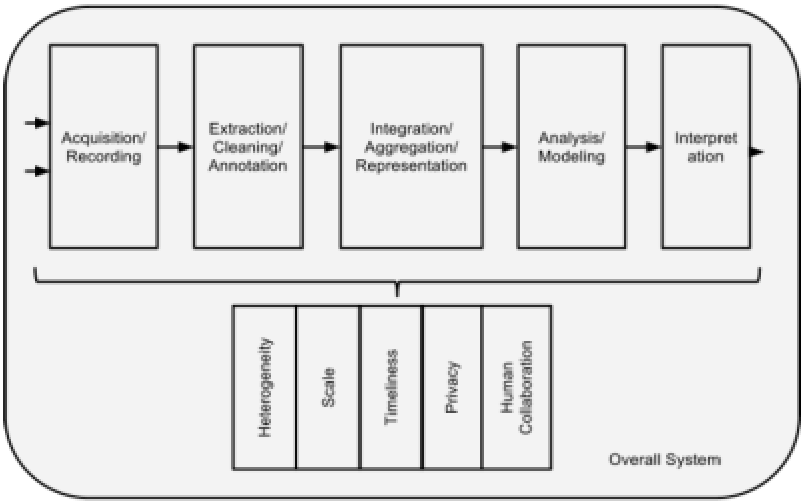
Source: http://www.telxperts.com/category/big-data/

Figure 1: 5Vs of Big Data

From another perspective big data should be generated from reliable with compromising the quality of data streams. The veracity property of big data relates to reliability and trustworthiness of big data systems. Visualization is related with the use of charts and graphs to visualize large amounts of complex data which makes it more effective in conveying meaning than spreadsheets and reports that are full of numbers and formulas. Value is the end game and after addressing volume, velocity, variety, variability, veracity, and visualization which takes a lot of time, effort and resources value will be created. In order to create value big data systems must able to deal with all 6Vs effectively by creating a balance between data processing objectives and the cost of data processing.

Big data consists of many of different types of data and the applications such as Internet of Things (IoT) generated by GPS devices, intelligent/smart cars, mobile computing devices, PDAs, mobile phones, intelligent clothing, alarms, window blinds, window sensors, lighting and heating fixtures, refrigerators, microwave units, washing machines, as well as self-quantified multimedia and social media data (Hashem et al., 2016).

There are several techniques and technologies compromising many disciplines such as computer science, economics, mathematics, statistics to end up with valuable solutions to business and academic needs. Additionally, data mining, machine learning, neural networks, social network analysis, signal processing, pattern recognition, optimization methods, visualization approaches are used within the overall system a summary of which is given in Figure - 2.



Source: Yaqoob et al. (2016)

Figure 2: Big Data Analysis Pipeline

Although, statistical methods are frequently used in order to causal relationships between different factors, completely new approaches are required to generate highlights from a bulk of noisy and heterogeneous data. Amongst the new approaches, data mining and machine learning are the most frequently used ones. Data mining includes methodogies including but not limited to clustering analysis, classification and regression. Machine learning is aimed to design algorithms that allow computers to determine patterns by using big data. Important characteristics of machine learning are discovery knowledge and making intelligent decisions automatically.[3]

In the use of big data many people focus on analysis stage as the desired outcomes are by-product of this stage, however, as can be seen from Figure 2, before the analysis stage data should be acquired and recorded. Thereafter, the extraction, cleaning phases are required in order to ensure big data to be processed. Before the analysis stage the last phase compromise integration, aggregation and representation referring to the Figure – 2.

In order to process large amounts of data in real time, there exist many information technology tools such as Storm, S4, Splunk, Apache Kafka, SAP Hana and SQL Stream, (Philip Chen & Zhang, 2014). The Storm is a distributed real-time computation system for real-time processing. The Storm cluster is comprised of master and worker nodes and nodes are implemented through two types of daemons named nimbus and supervisor. S4 is a general-purpose and pluggable platform utilized to process unbounded data streams efficiently. Splunk uses indexes and correlates real-time data to generate reports, alerts, and visualizations by using cloud computing technologies. Apache Kafka is helpful tool to manage large amounts of streaming data through in-memory analytics for decision-making. SAP Hana provides real-time analysis of business processes, while

2. BIG DATA APPLICATIONS IN LOGISTICS SYSTEMS

Logistics is one of the sectors that big data can provide invaluable support to the complex, dynamic and multi-factor requirements of the logistics business and its reliance on many moving parts that can create deficiencies in the whole system. Especially almost all logistics service providers make use big data to improve their data-driven decision making capacity. The use of big data also ensure to build up business competency in supply chain management. The effective use of big data in logistics and supply chain management requires high quality data sources including but not limited to[4]:

- Traditional enterprise data from operational systems

[3] http://cra.org/ccc/wp-content/uploads/sites/2/2015/05/bigdatawhitepaper.pdf
[4] http://www.oracle.com/us/technologies/big-data/big-data-logistics-2398953.pdf

- Traffic & weather data from sensors, monitors and forecast systems
- Vehicle diagnostics, driving patterns, and location information
- Financial business forecasts
- Advertising response data
- Website browsing pattern data
- Social media data

Chen et.al.(2012) named the use of digital technologies as a critical business capability as Big Data Business Analytics (BDBA) by combining Big Data and Business Analytics. BDBA has been used not only by the business in decision making, but also by the researchers to verify models and theories particularly in the field of supply chain management. The importance attached to BDBA in supply chain management (SCM) comes mainly from the possible achievements it proposed on business performance. The increasing amount of studied on the use of BDBA within SCM produced a new topic of research named as Supply Chain Analytics (SCA) (Wang et.al., 2016) The one of the most important contributions of the use of SCA is considered to be the shortened last mile of shipping which is known as inefficient costing up to 28%of the delivery cost of a package. Because of the low cost and high access to the fast mobile internet and GPS enabled smartphones, as well as the spread of the Internet of Things through sensors and scanners, shippers are able to see how the delivery process goes from start to finish – even during the last mile. At the same time, SCA makes the reliability to be more transparent as sensors become more prevalent in transportation vehicles, shipping, and throughout the supply chain. Optimization of routes is the key of supply chain performance and big data has many opportunities to provide on optimization by means of fuel costs, weather forecasts, highway and road information etc. One of the most challenging activities in a supply chain is delivery of sensitive goods such as perishables and big data also improves the quality of such delivery. Big data together with information technology such as Internet of Things has made many of the activities in warehouses automated through intelligently routing many different data sets and data streams[2].

The prominent research of Wang et.al (2016) grouped the possible contribution of SCA to logistics and supply chain management, as well relevant literature, under two headings and these are logistics and supply chain strategy and operations. Under the heading of logistics and supply chain strategy, the first item is related with *strategic sourcing* which was defined as "collaborative, focusing on supplier relationship management by analyzing organizational spend costs and acquiring commodities and services on a cost-effective basis". By analyzing organizational expenditure profiles, procurement processes and by evaluating supply market trends and suppliers' inputs and economics, SCA has full potential to contribute to an efficient cost structure. To formulate sourcing strategies, SCA uses analytics and assessment tools including, but not limited to cost modeling and risk assessment, to define appropriate contracting terms, create optimal bid processes and parameters, and select suppliers on the basis of their optimal value offerings (Apte et al., 2011; Shen and Willems, 2012; Jain et al., 2013).

In order to realize an effective *supply chain network design*, massive amount of data is required such as aggregate demands for products at each retailer, plant, capacities, shipping costs per unit between each pair of locations. SCA can deal with supply chain network design problems under both situations, where network design with known demand is formulated as a mixed-integer linear program (Nagurney, 2010; Lee et al., 2010; Tiwari et al., 2012; Jindal and Sangwan, 2014), while uncertain network design can be transformed into robust network design by using robust optimi- zation techniques (Klibi et al., 2010; Mir Saman et al., 2011; Hasani et al., 2012, 2014; Baghaliana et al., 2013).

In relation with product design and development, SCA enhance the capacity of the companies to produce products of high quality and reliability. It also used to make correct decisions in less time by enabling to make automate the comparison of actual performance criteria to target goals (Salicr and Civit, 2014).

Under the heading of logistics and supply chain operations, five basic issue have been addressed and it is a fact that a bulk amount of research have been realized to capture the use of SCA. These are demand planning, procurement, production, inventory and logistics. Although a critical aspect of a supply chain is managing operations to meet demand, process variation and demand variability may change the success into failure given the capacity level. Demand forecasting requires predictive analytics using time-series approaches which requires SCA and big data (Cheikhrouhou et al., 2011; Li et al., 2012).

A large amount of data in procurement has been generated from various sources through spending and supplier performance assessments which enable to use advance analytics. Additionally, an powerful SCA is strategic tool to measure, analyze and manage the suppliers' performance for better sourcing (Oruezabala and Rico, 2012). SCA also provides useful information in relation with the production capacity levels and bottlenecks and possible improvement areas in terms of productivity. SCA can also help to ensure that the right mix of resources is allocated to the right production lines (Jodlbauer, 2008; Heo et al., 2012; Noyes et al., 2014). In the field of inventory management, SCA in Vendor Managed Inventory (VMI) systems enables collection, processing, and reporting on inventory data and provide information for inventory performance improvement decisions (Borade et al., 2013). Finally, the contribution of SCA to logistics mainly concentrated on the formulation of network flows taking into consideration each shipping mode's capacity and timing. The logistics data is generated from many different sources and consists of, including but not limited to, cost realizations, timing accomplishments, supplier capacities and demand forecasts (Najafi et al.,2013).

Having reviewed the use of SCA in nearly every component of supply chain management, Wang et.al. (2016) developed a SCA framework taking into consideration both the operational and strategic goals of a supply chain. They created the framework with five levels; functional SCA, process-based SCA, collaborative SCA, agile SCA, and sustainable SCA.

3. BIG DATA IN SUPPLY CHAIN MANAGEMENT

It is a fact that the success of a supply chain lies on its ability to realize the movement of goods in the most cost effective manner. In this regard, big data has been providing supplier networks with greater data accuracy, clarity, and insights, leading to more contextual intelligence shared across supply chains.

Innovative manufacturers are orchestrating 80% or more of their supplier network activity by using cloud-based technologies to get beyond the constraints of legacy Enterprise Resource Planning (ERP) and Supply Chain Management (SCM) systems. The existence capabilities by the use of ERP are limited especially for the businesses with rapid product lifecycles so requiring speed and legacy. Business should understand the value of big data adopt it into their supply chain, ten directives are given below[5]:

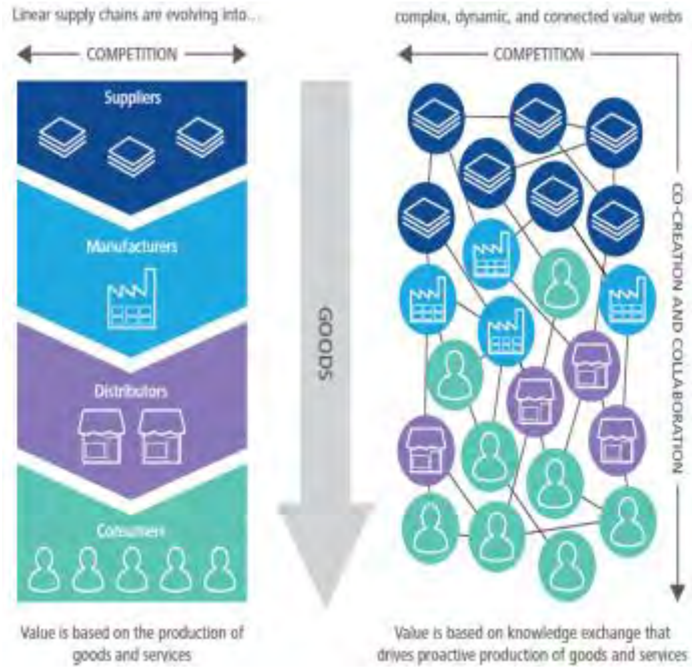
- The scale, scope and depth of data generated by the supply chains has been accelerating, providing ample data sets to drive contextual intelligence. Figure 3 gives the presentation of 52 different sources of big data generated in supply chains.

Source: Big Data Analytics in Supply Chain Management: Trends and Related Research. Presented at 6th International Conference on Operations and Supply

Figure 3 – Big Data Analysis Pipeline

[5] https://www.forbes.com/sites/louiscolumbus/2015/07/13/ten-ways-big-data-is-revolutionizing-supply-chain-management/#232815bf69f5

- Today's more complex supplier networks have to focus on knowledge sharing and collaboration and big data contributes how supplier networks form, grow, proliferate into new markets and mature over time as given in Figure 4.



- Source:Business-ecosystems-come-of-age_MASTER_FINAL.pdf

Figure 4 – Business Ecosystems (Deloitte University Press)

4. BIG DATA IN LOGISTICS: CASE STUDY OF TURKISH LOGISTICS COMPANIES

The following questions are asked to three of the Turkish logistics companies, leading companies in the field of international logistics activities including warehousing in Turkey, in order to capture their existing potential to utilize big data. Out of three, two companies responded to the questions. The first part of the survey questions is for determining the company size and operational capabilities. Thereafter, the IT capabilities and uses are evaluated. As we mentioned above section, the most popular approach to understand Big Data refers to 5Vs (Volume, Velocity, Variety, Value,Veracity) are given in Figure 1. When we choosing the questions, we considered 5Vs . Questions identify the elements of the 5Vs in Figure 1 which gives us better understand of big data.For example; Question 4 was asked to determine “variety”, Question 5 was asked to determine “volume” and “velocity” and Questions were 6 and 7 asked to determine “value”. The names of the respondent countries are confidential, however they can be provided verbally upon request. The companies did not respond some of the questions as they are not applicable to their existing organizational and\or IT capabilities.

1. Description of the company with regards to:
   - Area(s) of service
   - Number of employees
   - Number of vehicles
   - Use of container transportation
   - Destinations
   - Number of domestic and international bounded warehouses
2. Are IT Applications developed in-house or outsourced?
3. Is there a Data Center? If Yes, what is the number of staff?
4. Which are the source(s) of data amongst the followings:
   - Internet of things
   - Third party software
   - Mobile applications
   - Sales and invoices
   - Social media
   - Web-site
   - CMR and ERP systems
   - Others
5. What is the volume of data? What How has been increased over the years
6. What are the methods used for data analysis?
7. Is business intelligence applications used?
8. Is cloud system is used?
9. What are the big data applications used? What is its contributions in terms of cost, productivity, customer satisfaction etc.?

Company Information – (Company 1)

Area(s) of service	Software solutions upon the requests of customers, International transportation, Warehousing, Logistics distribution, Cargo and express distribution, Other value added services
Number of employees	41.000 (worldwide)
Number of vehicles	In domestic transportation services 2000 vehicles and the monthly departure rate 21.698
Use of container transportation	-
Destinations	More than 160 destinations
Number of domestic and international bounded warehouse	Bounded warehouses under customs control 30.000m^2 and 41 logistics warehous in 400.000m^2 area

IT In-house or out-source	Inhouse IT development by the R&D unit
Data Processing Center	Domestic and global centers. Data center in Turkey is managed by 4 employees

Sources of Data

Internet of things	Ongoing project involving the electronic devices attached to mechanic vehicles within the warehouses
Third party software	Developed in-house and outsources applications
Mobile applications	Applications are available from the distribution network Ongoing plans to collect data with a new software

Volume of data	Terabytes of data available
Methods used for data analysis	-
Business Intelligence	Ongoing project for the application of business intelligence in 2018
Cloud system	There exists in-house cloud system
Contributions of Big Data	No measurement for contributions. Ongoing project especially in terms of cost

Company Information – Company 2

Area(s) of service	Road transportation to Europe, CIS countries, Iran Road transportation to all airpo and ports, Railway transportation to France, Germany, Czechia Ro-ro transportation to Italy-Trieste and France-Sete
Number of employees	6.500
Number of vehicles	5,500 road, sea and air vehicles
Use of container transportation	Yes
Destinations	To all Europe and CIS countries
Number of domestic and international antrepos	60 bounded warehouses

IT In-house or out-source	In-house: TMS,WMS, Automation systems Out-source: ERP, CRM
Data Center	There exist a data center with 6 employees

Sources of Data

Internet of things	GPS devices, Sensors of temperature and humidity in warehouses
Third party software	IT demand management, project management and business process documentation
Mobile applications	Mobile applications sourced by drivers, port personel and suppliers. Use of hand-terminals in warehouses SAP, Salesforce
Sales and invoices	Application of TMS by using sales data and invoicing process

Volume of data	800 terabytes with an annual growth rate of 12%
Methods used for data analysis	Enterprise Data Warehouse, data visualization and Dashboard reporting infrastructure
Business Intelligence	For data visualization
Cloud system	-
Contributions of Big Data	No specific application available but plans are preparing for projects to use big dat

Company Information – Company 3

Area(s) of service	Forwarder Company (for sea, air and road transportation) International Transport with own and rental vehicles
Number of employees	1200 (all over Group)
Number of vehicles	20 own vehicles and 30 rental vehicles
Use of container transportation	They serve door-to-door service from all world ports through its widespread agency network. It has a structure that will offer different options to its customers in FCL and LCL transportation with its expert staff and technological infrastructure.
Destinations	To appr.150 countries (all of the continental shipping.)
Number of domestic and international bounded warehouse	8 bounded warehouse and 5 temporary warehouse

IT In-house or out-source	In-house: all application developed by 15 IT Developer
Data Center	There exist a data center with 25 employees

Sources of Data

Internet of things	no
Third party software	partially
Mobile applications	yes
Sales and invoices	yes
Social media	yes
Web-site	yes
CMR and ERP systems	yes
Others	-

Volume of data	60 terabytes (grow over the years)
Methods used for data analysis	using of reporting tools, to obtain the result sets according to the criteria given by using structured query language (SQL) from the actual data stored in the system ar to display these results to the user with lists, tables, various graphic types, dynamic pivots. Processes, performance indicators (KPI), periodical comparisons and changes, statistics and analysis reports are produced in accordance with request. The user has the possibility to export the data so that the data can be used in differe environments (Excel, PowerPoint, etc.).
Business Intelligence	None of the products of the marketplace business intelligence are used.
Cloud system	Their own private cloud.
Contributions of Big Data	No specific application available

Company 1 which has been well-recognized brand in international logistics indicated the use of inhouse IT development, rather than outsourcing. The main uses of IT capabilities have been the applications data collection from the distribution network and the use of internal cloud system despite their indication that they process terabytes of data. The company have data centers globally and in Turkey as well. They expressed that they realize the value of data processing and big data, consequently they have projects with regards to internet of things and data collection from mobile applications as well as business intelligence to be completed in 1 year time

Company2 has a more advanced stance in terms of IT infrastructure. It selectively uses in-house IT development for TMS,WMS, automation systems and outsourcing for ERP, CRM. There exist a data center operated by 6 employees as they utilize GPS devices, sensors of temperature and humidity in warehouses as well as mobile applications sourced by drivers, port personnel and suppliers, hand-terminals in warehouses, SAP, Salesforce. The volume of data processes was stated as 800 terabytes and it is indicated that an annual growth rate of 12% will be realized in the future. For data analysis, they utilize enterprise data warehouse, data visualization and dashboard reporting infrastructure. The use also business intelligence for data visualization purposes. Despite the fact that they have no big data achievements they have projects.

Company3 has also a more advanced stance in terms of IT infrastructure. all IT applications are developed by its own extensive IT staff. There exist a data center operated by 25 employees. The volume of data is 60 terabytes over the years (It was 10 TB in 2011, 30 TB in 2014) For data analysis, Despite the fact that they have no big data achievements they have projects. The method they use in data analysis is the reporting tools. By using these tools, result sets are obtained according to the criteria given by using the structured query language (SQL) from the actual data stored in the system and these result sets are displayed to the user with lists, tables, various graphic types, dynamic pivots. Additionally, data exported from system to the different environment such as excel, powerpoint etc. so that users can be analyze data for different purposes. We can only say that it is a stance that develops IT applications within an organization.

4. CONCLUSION

Logistics is entire set of activities and processes that are required to strategically manage products from the point of manufacture to the point they will be consumed in the right location and point of time. Competition at global level; from one side pushing companies to provide better products ,faster preparatory and delivery services and to provide input at low cost in maintaining and increasing their market share at international markets on the other side. It also provides timely supply of produced goods at competitive prices at international markets.

In such a competitive environment, the most important pillar to increase and protect the market share and profit is logistical activities that provide input at low cost and ensure that goods are offered at competitive prices without delay. In other words, the quality of the logistics services provided relies on its competiveness in international markets. For this reason, the competence to follow improvements and innovations in information technologies are the most important criteria in front of us.

The most important factor in such an improvement is based on the integration of global trade and the acceleration of goods traffic. Product variety and growing trade volumes are barriers in front of the traceability of the goods. The only possibility to track the date, time and location of the goods is using logistics information systems The companies which are using logistics information systems benefits from effective and efficient operation of business processes, elimination of bureaucracy and hierarchical structure, the ability to provide efficient services to customers, increase the efficiency of the employees and reduce the routine operations and usage of time effectively. The final and more important result of these benefits are the cost efficiency.

Big data creates the informational framework for financial demand &supply chain analytics and a macroeconomic outlook is created on universal supply chain data that helps financial institutions not just to simplify their process, but improve their rating as well as investment decisions. It also serves to the requirements of risk evaluation & resilience planning by tracking as well as forecasting about events that lead to supply chain disturbances, the flexibility level of transportation is improved.In this study the impacts of Big Data on Logistics industry has been evaluated and the observations of two international logistics company based in Turkey are collected by a survey. The outcomes of the survey show that:

- Companies have invested in IT Systems and large amount of data expressed in Terabyte are stored.
- The utilization rate of information technologies is increasing day by day.
- Companies generate data by using Logistics Information system mainly in applications such as mobile applications, sales and invoices and CMR and ERP systems.
- Companies focused on IT applications to manage their business process.
- The variety and complexity of the data also increased.
- Since the collected data are not evaluated completely as meaningful and processable data , they are not called as "Big Data.
- Companies are trying to manage data, which has not been easily managed and analyzed, by using legacy technics such as reporting tools rather than using business intelligence tools.
- Companies have ongoing project for application of business intelligence together with big data in 2018.

It is a fact that all of the three Turkish giant companies amongst should affectively utilize the big data they have collected and transform the information output into operational and strategic action in order to ensure their digital transformation. The information which has been provided by the cross analysis of the data produced within the company will address the past and current position of the company and will ensure most effective decision making and improvement in the competitive power. The information technology provides not only capabilities for the collection and storage of big data, but also that for the analysis of it. The past behavior of utilizing data sourced by defined reports for specific purposes has not provided the required information today. The today's information should be easily accessed, easily processed, capable of analysis of huge amount of data and interactively. However, it is not easy to analyze such amount of data, as well as clarify the interconnections amongst the different data categories. The solutions provided by Business Intelligence tools contain the technology required for the analysis of big data so the companies should consider to invest in those technologies.

In today's environment, it has been observed that logistic companies among their strategies mainly prefer to analyze and evaluate the data, rather than store it to gain competitive advantages. It is necessary to have a qualified work force and information systems infrastructure to analyze and manage the huge amount of available data. So that, a number of projects are planned for using big data tools by each of the companies. It is also observed that currently the selected Turkish logistics companies have not yet started to analyze big data, but they have large-scale enterprise data which can be defined by terabytes. This enterprise data has been generated from various sources and then restored interoperated and queried at Relational Databases. However, as the variety of data sources increases and data collection from non-structural sources is needed, business intelligence applications are needed to manage this potential data. Consequently, in order to finalize their digital restructuring, the survey respondent companies should achieve the capabilities to effectively use the big data, analyze it and take action by the provided information.

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LOGISTICS HUB: A MAGIC WAND IN REGIONAL PLAN DOCUMENTS IN TURKEY

Senay Oğuztimur1

Abstract *– 26 development agencies have been established in Turkey. This is occurred due to the need of new flexible and dynamic regional structures, which can take decisions and implement them fast, to improve the capacity of competition of the regional economies. Agencies prepare strategic plan documents to direct and develop strategies in means of sectors and location. In this context, logistics is accepted as one of the most significant sector. Logistics vision, strategic decisions and their spatial orientation are decided in these plans. Yet; due to the lack of national master plan and inter-communication; regions are like the ships that can not find the direction. -Almost- all of the regional plans propose to establish logistics hubs in their regions as if logistics hubs were magic wands. This unrealistic plan decision is useless and disturb the concentration of regions from real potential economic sectors. This paper focuses on basic national documents and 26 development plans and evaluate strategies developed regarding with logistics hubs.*

Keywords *– Logistics hub, National Strategy Document, Regional plan, Spatial Orientation*

INTRODUCTION

Regions have to become more competitive to accelerate their economic growth by becoming integrated with global markets. Globalization both increases competition and creates various opportunities for regions in all economic sectors. It is seen that, the regions, which can accord with global economy easily, grow faster and provide increase in prosperity for nations. In the new world order, new flexible and dynamic organizational structures are needed, which can take decisions and implement them fast, to improve the skill of keeping up with conditions of competition of the regional economies and to prepare all kinds of required substructures. From this point of view, development agencies have been established based on level 2 regions in coordination of Ministry of Development. Totally 26 level 2 regions remain with establishing of Development Agencies, that have become planning and development units in Turkey.

Plans are strategic documents which are legal basis to determine socio-economic development rates of regions, growth potential of settlements, sectoral goals, distribution of activities and substructures, are called regional plans. In this context, logistics sector is one of the most significant issue to ensure development direction. Logistics vision, strategic decisions and their spatial orientation are decided in these plans. Yet; due to the lack of national master plan, coordination and communication inter-regions; development agencies are like the ships that can not find the direction. All of the level 2 regions plan to establish logistics hubs in their regions as if logistics hubs were magic wands. This unrealistic plan decision is useless and disturb the concentration of regions from real potential economic sectors. Due to this reasons, national documents and regional plans are evaluated from the view of logistics hubs.

LOGISTICS SECTOR IN NATIONAL PAPERS

Strategic Plan of The Ministry of Transportation, Maritime Affairs and Communications

The strategic plan prepared by the Ministry of Transportation, Maritime Affairs and Communications (MTMAC) covering the years of 2014-2018 focuses on 5 strategic areas. The strategic areas in the plan are:

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determining policies and planning, regulation and supervision, infrastructure investments, supporting sectoral R&D and achieving institutional development by providing incentives.

STRATEGICAL GOAL 1. To rebuild the transportation, maritime and communicational infrastructure in order to serve at technical and economical efficiency and meet the commercial, economical, social needs as well as to create balanced and innovational policies.

STRATEGICAL GOAL 2. Realization of more efficient regulations, implementations and controls to reach a sustainable transport system, providing the security of life and prosperity at the highest level. STRATEGICAL GOAL 3. To develop and extend the transportation, maritime and communicational infrastructure by using the national resources in the most rational manner in order to provide better, cheaper and safer services.

STRATEGICAL GOAL 4. To promote and extend the local production of advanced transportation, maritime and communicational technologies by creating an innovational and ever developing productional identity. STRATEGICAL GOAL 5. To develop institutional capacity in order to present a better quality service.

A total 33 of targets have been determined in order to realize the aforementioned strategical goals [46].

National Smart Transportation Systems (STS) Strategical Paper and Action Plan

Another strategical plan prepared by the Ministry of Transportation, Maritime Affairs and Communications is "National Smart Transportation Systems" strategical paper and action plan. This strategic paper covers the years of 2014-2023 while the action plan covers the years of 2014-2016. 5 Strategical Goals have been determined within this scope. The first one is: *"Development of administrational and technical legislations parallel to the local and international requirements in order to integrate STS with nationwide planning procedures"*. There are 3 determined targets leading to the realization of this goal. The second strategic goal is: *"Creation of a globally competent STS sector"*. There are 5 determined targets leading to the realization of this goal. The third goal is: *"Increasing the traffic security and mobility by promoting STS applications in all of the country"* . There are 10 determined targets leading to the realization of this goal. The fourth goal is: *"Utilization of STS in order to make public transportation vehicles and services more accessible for people with restricted mobility"*

. There are 2 determined targets leading to the realization of this goal. And the fifth strategic goal is: *"Reduction of fuel consumption and emissions coming from on-road transportation"*. There are also 2 determined targets leading to the realization of this goal [47].

Special Expertise Commission Report prepared by the Ministry of Development

The Special Expertise Commission Report prepared by the Ministry of Development and the tenth Development Plan called "Development of Logistics Services" cover the years of 2014-2018. This report focuses on short, middle and long term goals, policies and actions related to the institutions and legislations, as well as infrastructure, big projects, education, retail and disaster logistics which are fundamental parts of Turkey's logistics services. **The long term goals** (2023) include, *"increasing the share of railway cargo transportation to over 10% and over 15% in passenger transportation, increasing the share of on-road cargo transportation to 60% and passenger transportation to 72%, increasing the number of Turkish Airlines planes to 300 while achieving 1.6 millions tons in cargo transportation by Turkish Airlines, transforming Istanbul into an airline transportation hub, utilizing the third Bosphorus bridge as a cargo connection line and making railway cargo a big part of it, integrating the third bridge with the Northern Marmara highway and the third airport and designing it as a green corridor, building the third airport in Istanbul"* . **The mid-term goals include** *"forming an effective cooperation mechanism between the relevant ministries, preparing a master plan focusing on the products produced in Turkey and on the logistics matters regarding their distribution, extending the works towards logistics education, R&D and innovative activities"* **. The short term goals are:** *"Completing the electronical infrastructure which enables the coordination of individuals, corporations and the Ministry of Customs and Commerce in order to finish the one window and paperless declaration processes within customs procedures, launching train-ferry trips between Tekirdağ - Bandırma and Tekirdağ - Derince, redesigning logistics education based on the experimental learning concept and increasing the number of implementational activities, issuing penalties to the companies with unlicenced transport vehicles, employing qualified staff in all of the public bodies, especially the General Directorate of Disaster Affairs and the Red Crescent.* [37].

Turkey’s Industrial Strategy Paper

Turkey’s Industrial Strategy Paper (draft) prepared by the Ministry of Science, Industry and Technology in 2014 covers the years of 2015-2018. The general goal of the report is *“To increase the competitiveness and efficiency of Turkish industrial sector which will lead to the increase of its share in global exports, encourage the production of valuable and state-of-the-art products, provide qualified labour force and thus transform the sector into an environmentally and socially aware industrial structure”.* And there are 3 fundamental strategic targets on the way to realize this goal:

a. Creating local industrial production with high added value based on information and technology;

b. Ensuring the efficient use of resources by industrial sector while giving it a greener and more resilient structure;

c. Building an industrial structure that contributes to the social and regional development and incorporates qualified labor force” [36].

LOGISTICS SECTOR ON REGIONAL SCALE PLANS

Regional Plans

Turkey also adopted the NUTS system in 2003 as part of the EU adjustment policies (Nomenclature of Territorial Units for Statistics). The system consists of 3 levels: Level 3 covers single provinces while Level 2 covers a province together with its neighboring provinces and the Level 1 covers the combination of the neighboring Level 2 units. There are 26 of Level 2 regions and each of them has a development agency preparing its regional plans and organizing the investments made on the region. The regional plan prepared by the agencies are especially important in terms of organizing the investments in order to assess the current situation and the strategic decisions regarding Turkey’s logistics sector. Currently the agencies have prepared plans covering the years of 2014-2023. The Table 1 summarizes the important statements and the main goals regarding the current situation in logistics. This table has been compiled using the 2014-2023 Regional Plans and the relevant papers.

TABLE 1. CURRENT PLANS OF DEVELOPMENT AGENCIES

Development Agency *(Containing Provinces)*	**The Main Goals Regarding Logistics**
AHİLER *(Aksaray, Kırıkkale, Kırşehir, Niğde, Nevşehir)*	The region is planned to be a logistics hub within scope of Konya Plain Project (KOP) however the plan is not mentioned among the goals.
ANKARA *(Ankara)*	Supporting the competitiveness of logistics sector while integrating it with industrial and agricultural sectors. The goal is to increase the effectiveness of Ankara Logistics hub with industrial accumulation in the region.
WESTERN BLACK SEA REGION *(Antalya, Burdur, Isparta)*	It is aimed to better the transportation and logistics infrastructure, strengthen the infrastructure of information technologies and connect the region to the other regions via logistics sector. It is also stated that construction of a logistics village will be useful
WESTERN MEDITERRANEANREGION *(Bartın, Karabük, Zonguldak)*	Strengthening transportation infrastructure, creating industrial and logistics hubs and centers in the region.
BURSA, ESKIŞEHIR, BILECIK *(Bilecik, Bursa, Eskişehir)*	Setting up and coordination of logistics centers, integration of urban transportation and logistics centers, supporting industries with logistics.
ÇUKUROVA *(Adana, Mersin)*	Making it the logistics center of Turkey and Eastern Mediterranean Region, benefitting from strategic location to advance in logistics, building a logistics village.
EASTERN MEDITERRANEAN *(Hatay, Kahramanmaraş, Osmaniye)*	Building logistics and logistics support centers, connecting the energy sector with logistics sector, improving the human resources potential in logistics
EASTERN ANATOLIA Bitlis, *(Hakkâri, Muş, Van)*	Transforming the region into a logistics center and improving transportation infrastructure
EASTERN BLACK SEA	Building a logistics center to make the region a logistics hub, increasing the logistics alternatives.
(Artvin, Giresun, Gümüşhane, Ordu, Rize, Trabzon)	
EASTERN MARMARA *(Bolu, Düzce, Kocaeli, Sakarya, Yalova)*	Improving the logistic center features, increasing the share of logistics activities and setting up logisticsvillages.
DICLE *(Batman, Mardin, Şırnak, Siirt)*	Setting up logistics centers and villages, defining logistics focus points in order to support raw material and industrial system
FIRAT *(Bingöl, Elazığ, Malatya, Tunceli)*	Studying logistics centers and improving their infrastructure.
SOUTHERN AEGEAN REGION *(Aydın, Denizli, Muğla)*	Increasing accessibility, building a logistics center, integrating different modes of transportation.
SOUTHERN MARMARA *(Balıkesir, Çanakkale)*	Setting up a logistics village, realizing an effective integration with the help of Greater Anatolia Logistics Organizations project.
SILKWAY *(Adıyaman, Gaziantep, Kilis)*	Developing the regional logistics hub, setting up a logistics village, increasing the number of logistics companies, creating a upper scale logistics corridor.
İSTANBUL *(Istanbul)*	Integration of the widely scattered logistics units, increasing the carrying capacity of transportation modes, building a port in Istanbul or in the region, developing combined transportation and the capacity of suitable ports.
İZMIR *(Izmir)*	Setting up a logistics village, focusing on railway and sea transportation, achieving industrial clustering by using logistics.
KARACADAĞ *(Diyarbakır, Şanlıurfa)*	Developing logistics sector, creating logistics infrastructure, building a logistics center.

NORTHERN ANATOLIA *(Çankırı, Kastamonu, Sinop)*	Improving logistics capacity, strengthening transport connections and warehousing infrastructure.
NORTH-EASTERN *(Bayburt, Erzincan, Erzurum)*	Realizing the logistics center project.
ZAFER *(Afyonkarahisar, Kütahya, Manisa, Uşak)*	Setting up a logistics village, increasing the effectiveness of the region with help of Istanbul- Izmir highway project.
MEVLANA *(Konya, Karaman)*	Focusing on activities to develop logistics sector, strengthening the infrastructure, supporting aggregation in logistics sector.
CENTRAL ANATOLIA *(Kayseri, Sivas, Yozgat)*	Increasing logistics capacity, Building logistics villages and putting them into operation.
CENTRAL BLACK SEA REGION *(Amasya, Çorum, Samsun, Tokat)*	Strengthening in-region connections, providing multimodal transportation, building logistics infrastructure.
SERHAT *(Ağrı, Ardahan,Iğdır, Kars)*	Realization of the Kars logistics center project, finishing construction of Baku-Tbilisi-Kars and Kars-Iğdır-Nakhichevan international railways.
THRACIAN *(Edirne, Kırklareli, Tekirdağ)*	Building logistics and disaster logistics centers, transforming it into a logistics hub serving South-East Europe, creating multimodal connections.

When regional plans are examined in terms of logistics, it is seen that all the plans have a special emphasis on this topic. This originates from the fact that the Tenth Development Plan defined a goal to make Turkey a global logistics hub. The goal is to especially focus on the locationally privileged regions to build logistics centers or villages. Many regions stand out with their aim of being a logistics hub. Development agencies of Istanbul and the nearby areas (Thrachian Development Agency, Southern Marmara Development Agency, Eastern Marmara Development Agency, Bursa- Eskişehir- Bilecik Development Agency) prominently focus on industrial and logistics sector as a whole. The plans prepared for these regions also bring forward the goal to provide multimodal transportation by integrating different types of transportation.

CONCLUSION and EVALUATION

The logistics subject is being focused on in the global platform and it has been considered to be of high importance for many years. The researches focusing on the subject aim to evaluate the global tendencies as well as determine the position of countries in the global market. These researches indicate that the market is still growing and is nowhere near its saturation point. So it is obvious that the logistics sector will keep growing as long as there is distribution of production and developing global market.

Similar to the global tendencies, the logistics sector in Turkey keeps gaining significance and being researched. The national NGOs as well as the public sector conduct researches that guide us on the subject and determine the problems. The main institutions in charge of determining a vision for the whole country and the region are the Ministries and Development Agencies (regional representatives of the Ministry of Development). While the ministries mostly focus on visions for the whole country, the development agencies act rather independent from each other on the way to promote the local potential and attract investments. So it can be said that Development Agencies act more like individual institutions rather than acting like a group.

The literature research on global scale shows us Turkey has a higher position among the list of middle-high class countries, although it is not among the list of developed countries with high competitiveness. And Turkey's famously known location "as a bridge between three continents" does not make its logistics sector an important economical input. The relevant nationwide problems need to be addressed before the country utilizes its potential in this sector to be more economically powerful.

Investigation of the national logistics market reveals that the issue mostly originates from uneven distribution of transport modes in the sector which favors the on-road transport more. The country sometimes uses bottlenecks for the cargo movements of industrial sector which is aggregated in the Western part and especially in the Marmara region.

The regional studies by the development agencies occasionally mention the logistics subject although it turns out that they imply the transportation sector instead of logistics itself. While it is true that transportation sector is an essential part of logistics, it still cannot be limited with transport modes and investments. The studies theoretically emphasize this fact although they neglect the service oriented branches of logistics like warehousing and packaging which also have high added value.

Another important topic is that the regional and national studies attach particular importance to the "logistics village" concept. Logistics villages are mentioned as if they are a magic tool solving all logistics related problems of all the regions (regardless of their economical differences, geographical location, cargo production pattern and productional relations). There are also not enough propositions in regards to strengthening the transport connections of logistics villages and integrating it with other means of transport than on-road transportation.

Reports covering Istanbul in this framework also appear to be more or less on the same axis and their goal is to increase the number of terminal points, cargo volumes and capacities. However, the infrastructure investments which will lead to this increase have not been mentioned in the studies, as they are costly in short term though also environmentally friendly and cost reducing in the long term.

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SUPPLY CHAIN 4.0 IMPLEMENTATIONS IN INDUSTRY 4.0

Handan Hacıalioğlu, Erkut Akkartal

Abstract *– In the last decade, companies have begun to rethink of designing their supply chain processes because of the digitalization of the process in all levels of supply chain. The concepts; Internet of Things (IoT), big data and advanced robotics forced the partners of the supply chain to upgraded a new version of supply chain. The aim of this paper is to define the status of supply chain 4.0, expectations and to review schemes of new ERA. Moreover, three key enablers of digital supply chain will benefit users to get ready for supply chain 4.0 since it looks so different from the past, the term value chain 4.0 should be used in order to re-combine and re-think how companies should be organized. Expectations for Supply Chain 4.0 include up to %30 fewer operational cost %75 fewer lost sales and a decrease inventories %75. These numbers are based on experiences, with numerous studies, of the companies. As a result this study will evaluate the principles and advantages of supply chain 4.0 in the scope of industry 4.0.*

Keywords – Supply Chain 4.0, industry 4.0, IoT

INTRODUCTION

As the expectations and the demand of customer profile changes, the views of the companies regarding supply chain has changed as well. In order to keep pace with these trends firms had to accelerate their supply chain with new technologies. Digitalization of the supply chain facilitate evaluation of new requirements of the firms, helps to find difficulties on the supply side and creates expectations for the feasibility improvements. In this connection, internet provides benefits for the companies at all levels of their transactions. And nowadays internet of things (IoT) is the last particular position where we reached.

THE REVOLUTION OF THE INTERNET OF THINGS (IoT)

The revolution of IoT in which every living thing and inanimate object with a certain economic value will become intelligent by connecting to the internet and becoming a communication and interaction with other objects, is developing rapidly. [1]

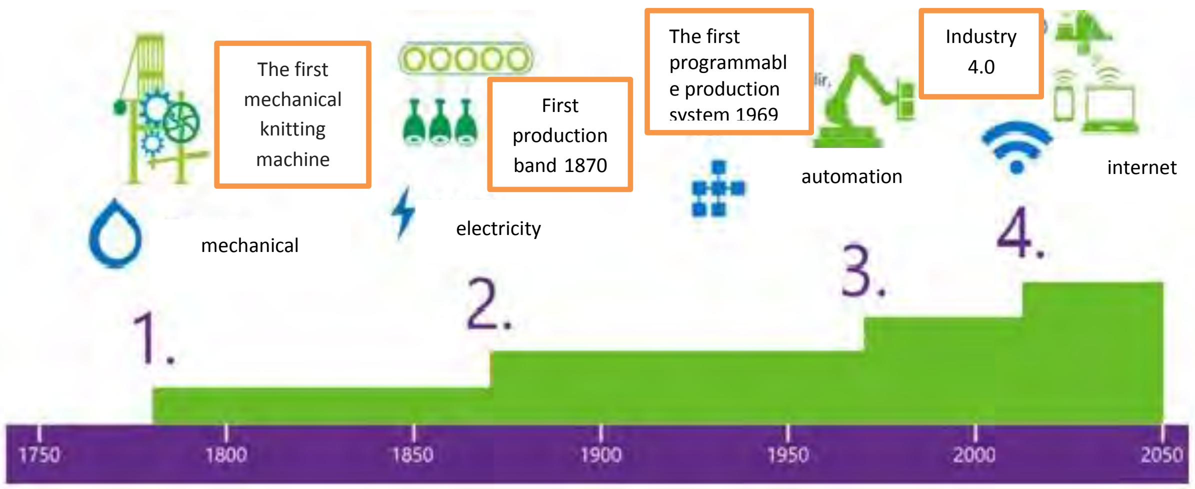

Figure 1. Reproduced by Hacialioglu; source: http://icc-turkiye.com/endustri-4-0-nesnelerin-interneti/ ; 04.07.2017 [1]

The story is the end of the industrial revolution. Perhaps the beginning of a look (Industry 5.0, Industry 6.0) Who knows? The industrial revolution process is separated to 4 parts from the past to today. In the first process, also referred to as Industry 1.0, there were mechanical systems that used water and steam power. (The first mechanical weaving loom-1784).

In the second process called Industry 2.0, the use of electric energy started with serial production (the first moving band system used in the slaughterhouse-1870). The third industry 3.0 process began with the integrated use of electronics and information technology (SPS-1969, the first programmable management system.)
In the forthcoming fourth phase, virtual and physical systems will be integrated, connected to the main station and production will continue. A new era "Industry Distribution - Industry 4.0" will begin. In the internet production, business development-engineering will bring a lot of innovation.
Tools of this age; All the tools, devices, objects, systems and more such as smart phones, smart cars, intelligent houses, smart cities, smart factories, smart warehouses, smart markets, intelligent hospitals, intelligent schools, smart bureaus and intelligent... all of these happen at the last stage Industry 4.0. Let's explain this with an example. Two robots working in the production-related paint department in one factory communicate with each other and ask one another; I'm going to paint, do you finish the lining process? According to the response of the other robot, the second robot starts to paint or wait. This situation may be a simple communication or ordinary process between two robots.
The supply chain is not only about efficiency, but also it reduces operating capital and cost for managing inventory.
3PL Logistic; The overall logistics activities are carried out by outsourcing. It can cover all activities and also specific activities too. Since the 3PL was insufficient, the concept of 4PL began to appear after the 1990s.4PL provides expertise on complex logistics chain solutions.

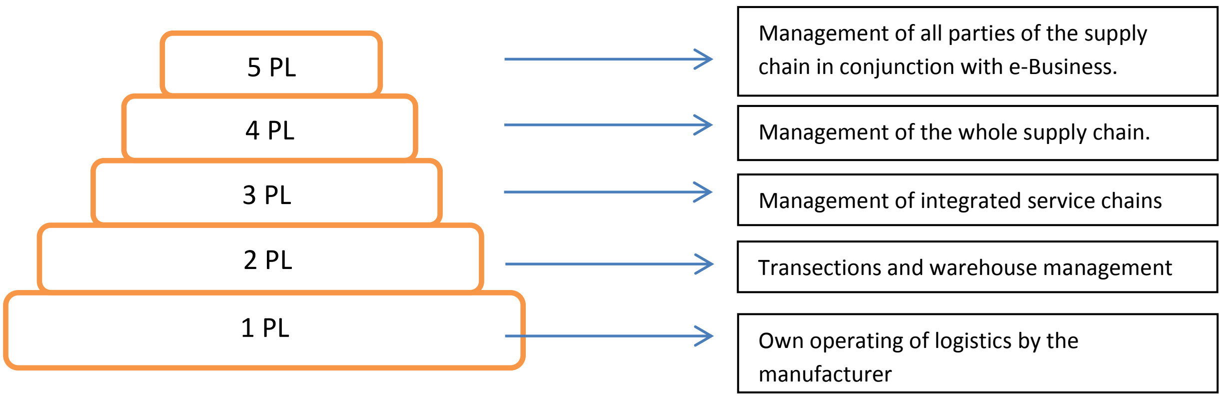

Figure 2. Reproduced by Hacialioglu; source: http://www.chetak.co.in/industry-faq [2]

IMPACT OF SUPPLY CHAIN 4.0

The biggest impact on the structure of supply chains is expected from the concepts of smart logistics and smart factory. All supply chain will be impacted from a structural and technological perspective by applications. Chain activities fall into a digitization process. ''The distribution activities will be rethought and new technologies will be implemented as well [3] since with transporting systems performing autonomous decisions based on pre-implemented algorithms, the logistics processes are already within the autonomization process [4]. Algorithms may also enable products to make autonomous decisions during outbound-logistics activities in the digitalized supply chain of the future. This could be a real-time analysis of the currently existent quality on their way to the customer. Automation in logistics means the autonomous decision-making, controlling, planning and initiation of logistics activities [5].''Thanks to the miniaturization of electronics, transport, storage and production costs can be reduced [6]. Based on this miniature process, AIDC and RFID technologies provide digitalization supply chain process and real-time information for logistics activities. [7]
In the past industrial revolutions, it was not only those who invented and operated some of the new machines that were affected but also the effects went much wider. The entire supply chain of goods has been rewritten. Industries physically transported. The lives of ordinary people have been changed.

Industry 4.0 is basically a process that will deeply impact production. We can foresee that in the logistics sector Industry 4.0 has started to affect the whole world because production and logistics are can't be thought separately, it will define the way of doing business. Industry 4.0 will affect all the phases of the right product, the amount, the time, the source, the way, and the supply of the product. From this perspective, when we approach change from this point, the value chain of the Industry 4.0 framework naturally triggers the transformation in the logistics, software and finance sectors, from production-oriented raw material supply to production, from production to consumption. [8]

There is a saying, "The need is the very essence of inventions." It has always been an obligation for mankind to produce needs since we existed and we have always been searching for new ways to continue production. For example, in the Industry 4.0 process, when machines communicate with each other over the Internet, they can ensure that "on time" logistics services can work much more efficiently or prevent machine failures, reduce idle time in production, and ultimately enable more efficient use of resources. New vehicles, new fuel and energy sources, infrastructure and new employment areas will affect all types of logistics, especially transport logistics. In the light of historical developments of industrial revolutions, it would not be wrong to foresee that Industry 4.0 will affect the logistics processes as well as the revolution that will be created in production industry. [9]

SUPPLY CHAIN 4.0'S IMPROVEMENT LEVERS

Supply chain 4.0's improvements can separate as six value drivers. Outer of circle shows main supply chain 4.0 improvement levers. At the end, service, agility cost, capital can be changed by improvements.

Figure 3. Source: http://www.mckinsey.com/industries/consumer-packaged-goods/our-insights/supply-chain-4-0-in-consumer-goods [10]

Planning: Supply chain planning will benefit enormously from large data and advanced analysis and from automation to further processing. Several main consumers use predictive analysis in demand planning to analyze variables influencing hundreds to thousands of internal and external demand, using machine-learning approaches to model complex relationships and establish a correct demand plan. Prediction errors are reduced by 30 to 50%.

Physical flow: Logistics will proceed to, thanks to better connectivity, advanced analytics, value-added production and advanced automation, develop traditional warehousing and inventory-management strategies.

Usable, easy-to-use interfaces, basic on-site instructions give direction to workers. Advanced robot and stone skeletons can have dramatic effects at the same level in the warehouses.
Performance management: Maximizing the performance of a department or function does not mean that the whole business reach the best performance. The days of producing the dashboard were an important accomplishment and the performance indicators were only available at aggregate levels. Performance management becomes a real operational process for real-time exception handling and continuous improvement.
Order management: Order management is developed with precautions: integrating non-touch order processing, ordering system to existing-delivery (ATP) process and real-time re-planning, snapshot, in-memory reconfiguration order history confirmations. The net result is reduced through automation, improved reliability (through granular feedback), and better customer experience (with urgent and reliable responses).
Collaboration: The supply chain cloud forms the next level of cooperation in the supply chain. Procurement companies, customers and suppliers offer joint supply chain platforms or common planning solutions. Particularly uncompetitive people, partners and managers can decide to deal with supply tasks together to save management costs and learn each other.
Supply-chain strategy: Following the more individualization and privatization of the supply chain, supply chain installations adopt more departments. To ensure excellence in this environment, supply chains must dominate the micro-division. A dynamic, large data approach enables massive privatization of supply chain quotes by separating the supply chain into customer needs and face-to-face individual supply chain segments based on the company's own capabilities. Special products give the best value to the customer and help to minimize the costs and inventories in the supply chain. [10]

KEY CHARACTERISTICS FOR IOT STACKS

Three different stacks can be defined as the software requirements for IoT. A typical IoT solution is one in which many devices (in other words) can use some gateway to communicate over a network connecting to an enterprise back-end server running an IoT platform that helps integrate IoT knowledge into existing corporate. The roles of devices, gateways, and cloud platform well-defined and each provides specific features and functionality required by a robust IoT solution.

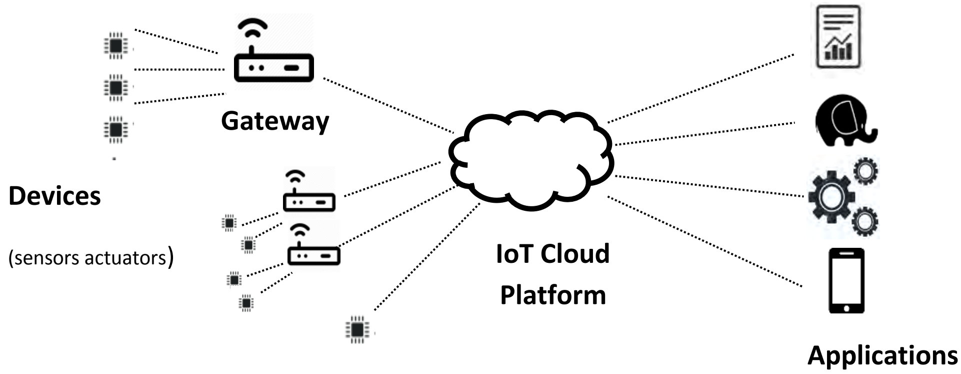

Figure 4. Reproduced by Hacialioglu; source: A collaboration of the Eclipse IoT Working Group September 2016 [11]

Loosely connected: Three IoT stacks are defined, but each stack can be used independently from other heaps. It is possible to use an IoT cloud platform from a third supplier to another vendor and device stack from an IoT gateway.
Modular: Each batch should allow features to be sourced from different suppliers.
Platform-independent: Each stack must be independent from main hardware and cloud infrastructure. For example, the device stack must be located on more than one MCUs, and the IoT cloud platform should work on different Cloud PaaS.
Defined APIs: Each heap must have defined APIs; for easy integration ~~and integration~~ with existing applications and with other IOT solutions.
Dependent on open standards: Communication between stacks must be based on open standards to ensure interoperability. [11]

HOW BIG IS IOT?

IoT implementations can be used in such a classification that Bosch IoT platform. Connected manufacturing (industrial internet solutions), Connected energy (smart metering, virtual power plant, and more), Mobility (connected cars, intermodal transportation, e-mobility), Smart Home& building (homes and commercial buildings are connected by software). [12]

This new wave of connectivity goes beyond computers and smart phones; connected cars, intelligent houses, connected clothes, smart cities and connected health services. Think a connected life! According to a small survey which prepared by HP report, from 2013 to 2025, estimated the rise of connected devices over a hundred times in 12 years and the results are unbelievable. This brings to mind that question: Are we going towards a fully robotic world?

Year	Number of Connected Devices
1990	0.3 million
1999	90.0 million
2010	5.0 billion
2013	9.0 billion
2025	1.0 trillion

Figure 5. Source: HP [13]

A research conducted by KRC Research in the UK, USA, Japan and Germany revealed that the first adopters of the IOT, had the possibility of using the devices in the coming years, smart appliances like thermostat, intelligent refrigerator.

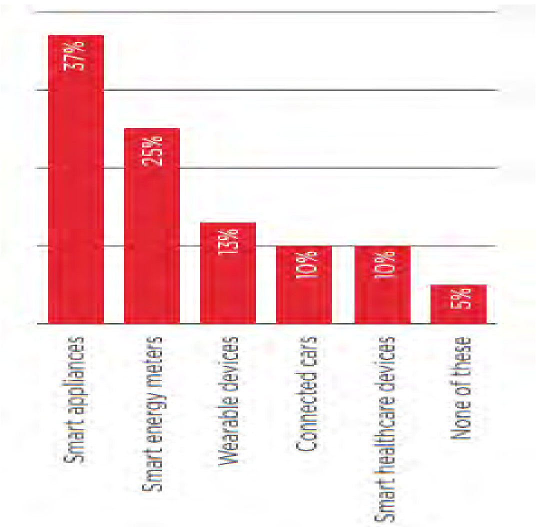

Figure 6. Reproduced by Hacialioglu; Source: GSMA Report [14]

IoT capture Smart homes are the most anticipated feature and already entering the competition with smart applications. Wearable is another feature on the internet. Together with the flow of Apple Watch and other devices, these connected devices will continue to capture us in our interconnected world. [15]

10 REAL WORLD APPLICATIONS FOR IOT

1. Smart home: Who do not like to turn on the lights or air conditioner before getting home? Smart home products promise to save energy, time and money. With smart house companies, several names will become home brands and plan to offer an experience never seen before.
2. Wearable: Google and Samsung have invested heavily in building such devices. Wearable device is installed with sensors and software to collect data and information about users. This data is necessary to inspect the user. These devices generally meet sports, health and entertainment requirements. The pre-requisite for applications that can be worn by internet technologies is extremely energy-efficient and small size.
3. Connected cars: A connected car is a vehicle that can optimize the comfort of its own operation, maintenance and passengers using the built-in sensors and internet connection at the same time. Most major automakers work on some of the courageous ventures as well as connected vehicle solutions. Tesla, BMW, Apple, Google are trying to bring the next revolution in automobiles.
4. Industrial internet: This data can help companies be efficient and detect problems more quickly. IoT has great potential in terms of quality control and sustainability.
5. Smart cities: Intelligent surveillance, automatic transportation, smarter energy management systems, water distribution, urban security and environmental monitoring are examples of smart cities. IoT will solve the major problems that face people living in cities such as pollution, traffic congestion and lack of energy supply. Products such as cellular communication will send warnings to municipal services when people need evacuation.
6. IoT in agriculture: Smart agriculture is one of the fastest growing areas in IoT. Farmers use meaningful views of the data to get a better return on investment. Detecting soil nutrients and, controlling the use of water for plant growth and determining specific fertilization constitute simple uses of IoT.
7. Smart retail: IoT provides retailers the opportunity to connect their customers to enhance their store experience. Retailers use smart phones to reach consumers and stores.
8. Energy engagement: The basic idea behind intelligent networks is to analyze the behaviors ~~or~~ of the electricity consumers and suppliers in order to automatically collect data and increase efficiency as well as electricity consumption.
9. IoT in healthcare: The research shows that IoT will have a great effect at the health field in the coming years. In health care, the aim is to have a healthier life with connected devices.
10. IoT in poultry and farming: Animal husbandry supervision is concerned with animal breeding and cost saving. Farm owners who know sick animals in the early hours can help prevent a multitude of cattle-by using IoT applications. [15]

THE VISION OF IOT AND SUCCESS STORIES

Digitalization pioneers to supply chain 4.0 have to possess specific skills. The first skill is, of course, rapidity concepts, relevant to distribution performed by monthly, weekly or even daily. However, in the near future a new concept such as ''predictive shipping'' might be executed in such a way that the product may be delivered before they have been ordered and could be matched according to the needs of the customers on the road simulation. Second skill, we face agility. Real time planning provides prompt response for the changes in supply and demand of the companies. Thus, planning cycles and stationary periods can be reduced to minimal levels. Third, we reach the concept of ''detail''. The demand of privatization of the products purchased by the customers has pushed the companies in such a more detailed demand management which includes micro segmentation and the next point of vision is exactness. New generations performance management systems provide real time transparency along with the supply chain. The integration of the information collected from each level of supply chain to the supply chain cloud provides making decision regarding same sources for the all supply chain partners. The last but not the least 'effectiveness.' Automation of planning and the physical transaction increase the efficiency of supply chain.

According to Cordon [16], there are a few success stories about a sports company. In order to fulfill customer demands the company began to start an Omni channel strategy providing customers to select among some alternatives, namely, online or fishily store. So the product turns to be available from anywhere (distribution center or warehouse) to be delivered in any way (at the pick-up point, store or at home). Of course, this was just possible by implementing radio frequency identification system. The company suddenly realized that up to 70% of online sales were through click and collect. The issue was not only about reducing cost but also about increasing sales. Industry 4.0 implementations gave inspiration to supply chain such in a good manner that it is not just all about manufacturing but also about logistic and supply chain.

Figure 7. Source: https://it-motive-bcs.com/industrie-4-0 [17]

With Industry 4.0, intelligent manufacturing facilities will be able to meet specific customer requirements and become more capable of running on single products. The design process of prototype products can be accelerated with 3D printers, thus reducing the production costs of customized products. The systems will be controlled by more intelligent machine instead of the human workforce, and therefore autonomous plants will be installed. The number of workforce will decrease and socio-economic changes will begin at this point. The unqualified working class will almost end.
Adidas had much more sales using the ship from store. When using traditional deliver systems, shipping from one part of the country to other one can take15 days in Russia, the largest country in the world. Adidas expected to decrease delivery and transit times and to increase sales but it also supposed that delivery cost will increase. Amazingly, delivery costs fell and sales increased importantly. If the customers know delivery will be made within 24 hours, 50% of them give up to shop online but if they know it will be takes three days, up to 70% of customers might return. Therefore, more speed delivery means fewer returns, which supports higher sales and logistics costs go down.

One of the main purpose of the supply chain management is reducing logistics cost. Amazon started to use drone for its deliveries to achieve this purpose. One of executive of Amazon says that “We look at savings in terms of cents, not dollars or euros”. At first, it can be seemed as crazy but delivering 15 minutes means fewer returns and higher sales and higher profit. [16]

NEW MANUFACTURING ERA

By 2020, 50 billion devices are supposed to be connected and telecommunicated with each other. By using intelligence cites, homes, logistics, and interconnection of these elements, the network constructed by intelligent manufacturing systems is supposed to increase the trade volume roughly 46% in the fourth coming 25 years. Besides in 2018 2.3 million unit robotics are being planned to be used. Especially, developments of robotics in production sector are being expected to trigger the construction of intelligence manufacturing system. On the other side, European commodity targets to increase to percentage of the contribution of industry in gross national product, from %15 to 20%. [17]
As far as the industry concerned a remarkable sympathy is being observed companies, by workshop panels and forums display partnership to the issue in order to get benefit experience yet, as a result of this mobility’s ‘sanayi 4.0 report’ was released in March 2016 by TUSIAD. All these efforts don’t appear far behind the industry. And all dividends are veiling to be the part of this transformation.
Looking ahead, the Cisco IBSG predicts that by 2015, 25 billion devices will be connected to the Internet and 50 billion devices will be connected to 2020. It is important to note that these estimates do not account for the

rapid progress in the Internet or device technology; the numbers presented are based on what is true today. [18]

CONCLUSION

In order to cope with competition, making investment to technology which had been started 20 years ago in the world, must be a core business. Approximately, 10-15 billion TL investment must be performed for adapting industry 4.0 technologies to production processes in the next 10 years, on the basis of current prices and economic growth. Otherwise it will be impossible to compete with global economy. Moreover skilled human resources will be also important as smart systems. Human 4.0 must be trained to be transferred to industry 4.0. In the beginning, where IoT looks like a futurist approach, nowadays, any device manufactured incompatible with IoT will be disregarded. The future of the IoT is more enchanting than billions of things will talk to each other and human intervention will be the least. The macro change will be improved in the way we live and work by IoT implementations.

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SUPPLIER EVALUATION WITH FUZZY MOORA METHOD IN GREEN SUPPLY CHAIN

Yıldız Şahin[1], Pınar Yıldız Kumru[2], Öznur Ergül[3]

Abstract – The natural resources that are exhausted from day to day have great importance in order to sustain the vital activities of all living things. The companies implements enviromental policies to minimize the damage that caused by productions of the companies. Some of these implemenst are made by goverment and some of them by companies. While mandatory legal regulations are the same for all companies other regulations which is not legal and made by companies set policies for companies to view green processes of the companies.
In recent years, as a new approach, the green-facing supply chain processes within the scope of environmental awareness in all the processes that face the challenge have come to a standstill and have brought a different perspective to the entire process, ranging from the supply chain, supplier selection, procurement operations, to the final destination of the product. The companies should make continually improvement plans in order to minimize the negative impacts on enviroment in their existing operations. In this study, it was aimed to evaluate the performance measures in the green supply chain according to certain criteria of the suppliers providing the service for the same product to an operator and the results were evaluated using the fuzzy MOORA method for this purpose.

Keywords – Fuzzy MOORA, Green Supply Chain, Supplier Selection, Multi Criteria Decision Making Method

1.INTRODUCTION

The green supply chain is the whole of the processes involving the steps starting from the supplier to the end consumer consuming the product or evaluating the waste to be generated after use. Companies should product the goods without risking the health of future generations by damaging the environment in minimum while continuing their production activities. Recently, the legal environmental policies that come to the fore and the businesses that the businesses have implemented within themselves have given a new perspective to the green supply chain. Green supply chain management starts from the supplier in terms of the classical supply chain and gives a perspective to environmentally sensitive, environmentally harmful and environmental protection to the entire supply chain stages from main producers, producers, logistics and after sales services. In today's competitive environment, suppliers are aiming to sell to the final consumer at the best price and with the best quality, and the first step to this goal is to start with the supply of the raw materials required for production. Choosing the most suitable supplier among the suppliers that supply these raw materials depends on many criteria. In this study, it was aimed to measure the approaches of green procurement chains to suppliers who have become certified suppliers in the business after passing certain criteria. In this context, five approved suppliers were evaluated using fuzzy MOORA method with thirteen criteria and the results were interpreted.

2. LITERATURE RESARCH

Although the green supply chain is still considered a new approach in some countries, it has emerged in many countries towards the end of the 1990s. When we look at the work done in the green supply chain; Noci [1] has examined environmental efficiencies in an automotive firm and has done one of the first studies of the green supply chain and environmental approach to businesses. Hong-jun and Bin [2] conducted a study on the selection of green suppliers. Wang, F et al. [3] In 2011 they worked on an optimization study in the green supply chain network design problem. Hashemi et al. [4] In their study in 2014, they selected suppliers in the green

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supply chain by analytical neural network method and gray relational analysis method. Mallidis et al. [5] conducted a study on logistic network design alternatives and evaluated the effect of stock level on cost and circulation of CO2 gas to the environment. Govindan et al. [6] they conducted a literature search on the selection and evaluation of green suppliers with multi-criteria decision-making methods in their study in 2015.

Ilgın et al. [7] In their work in 2015, they worked on multi-criteria decision-making methods in choosing green suppliers and focused on environmentally sensitive production and recycling. Fahimnia et al. [8] They worked on a lean model for green supply chain planning in their work in 2015, and according to Fahimnia [8] environmental management has become more of a concern in the past decade, although it started earlier. Akman [9] chose the suppliers that served an operation in two phases. In the first stage, the suppliers evaluated the suppliers in terms of service, quality and service, evaluated these suppliers in the second stage in terms of the green supply chain and ranked suppliers according to the results. Ene et al. [10] conducted a study on network optimization in meta-analytic methods in the green supply chain, first examining the effect of total cost minimization and objective functions on network optimization decisions on a small problem and then applying the algorithms to different sets of problem sizes. Fat [11] worked on the selection of green suppliers using the fuzzy moora method. Coşkun et al. [12] aimed at measuring the relationship between the green supply chain and consumer behavior in their work. For this, he categorized consumers as green, inconsistent and red, and proposed a target programming model. Awasthi et al. [13] NGT worked on the selection of a green supplier development program using the Vikor method. Kuo et al. [14] worked on the selection of green suppliers and preferred ANP and MADA methods. When we look at recent studies on MOORA and Fuzzy MOORA; MOORA method; was first introduced by Willem Karel M. Brauers and Edmundas Kazimieras Zavadskas [15] as a whole in 2006 with the work "Control and Cybernetics". Kalibatas and Zenonas [16] used the MOORA method in their study of a ventilation system in a study they conducted in 2008. In 2010 Brauers et al. [17] benefited from the MOORA method in evaluating plant sites. Dey et al. [18] studied the optimal storage location selection using the Fuzzy MOORA method for solving the problem of multi-criteria decision making in the supply chain. Şişman [19] evaluated the financial performances of Turkish banks using Fuzzy AHP and Fuzzy MOORA methods. Archana et al. [20] used the Fuzzy MOORA method to solve a multi-criteria decision-making problem. Mandal et al. [21] MOORA multiple criteria using fuzzy operation on the choice they have made have made a decision-making problem. Dey et al. [22] used the Fuzzy MOORA method in selecting the supply chain strategy. Patriot et al. [23] using the method of AHP and Fuzzy MOORA, they have done a practical study on enterprise resource planning. Akkaya et al. [24] on the choice of sectors for industrial engineers have used is made a study MOORA Fuzzy and Fuzzy AHP method in this study. Yıldırım et al. [25] MOORA using fuzzy AHP and fuzzy methods to have made a sort of cloud technology firms.

3. FUZZY MOORA METHOD

The MOORA method is a very new method in the literature. Among multi-criteria decision making methods, it is relatively easy and faster to calculate than other methods. According to Brauers et al. [26], the comparison of the MOORA method with several other commonly used methods in the literature in terms of mathematical calculation, data type, reliability, simplicity, and computation in table 3.1.

Table 3.1. Comparison of Some of the Multiple Criteria Decision Making Methods

Method	Calculation Time	Simplicity	Mathematical Operations	Reliability	Date Type
MOORA	Very little	Easy	Minimum	Good	Quantitive
AHP	Too much	Very critical	Maximum	Not Good	Mixed
TOPSIS	Normal	Normal	Normal	Middle	Quantitive
VIKOR	Little	Easy	Normal	Middle	Quantitive
ELECTRE	Too much	Normal	Normal	Middle	Mixed
PROMETHEE	Too much	Normal	Normal	Middle	Mixed

Fuzzy MOORA method is a much more effective method than MOORA for handling unclear and fuzzy problems. The steps of the Fuzzy MOORA Ratio method, which is achieved by using the fuzzy set theory together with the MOORA method, are as follows [27].

Step 1: Preparation of the fuzzy decision matrix in accordance with the opinions of the decision makers, using triangular membership functions. Xlij, Xmij, Xnij values j.; in terms of criteria i.; the alternatives for the alternative are fuzzy numbers with small, medium and large values, respectively, in the triangular membership function.

$$\begin{bmatrix} [X_{11}^l \quad X_{11}^m \; X_{11}^n] \; [X_{12}^l \quad X_{12}^m \; X_{12}^n] \dots [X_{1n}^l \quad X_{1n}^m \; X_{1n}^n] \\ [X_{21}^l \quad X_{21}^m \; X_{21}^n] \; [X_{22}^l \quad X_{22}^m \; X_{22}^n] \dots [X_{2n}^l \quad X_{2n}^m \; X_{2n}^n] \\ \dots \\ \dots \\ [X_{m1}^l \quad X_{m1}^m \; X_{m1}^n] \; [X_{m2}^l \quad X_{m2}^m \; X_{m2}^n] \; [X_{mn}^l \quad X_{mn}^m \; X_{mn}^n] \end{bmatrix} \tag{3.1}$$

Step 2: Generate a blurred decision matrix by normalizing the vector.

$$r_{ij}^l = \frac{x_{ij}^l}{\sqrt{\sum_{i=1}^m \left[\left(X_{ij}^l\right)^2 + \left(X_{ij}^m\right)^2 + \left(X_{ij}^n\right)^2 \right]}} \tag{3.2}$$

$$r_{ij}^m = \frac{x_{ij}^m}{\sqrt{\sum_{i=1}^m \left[\left(X_{ij}^l\right)^2 + \left(X_{ij}^m\right)^2 + \left(X_{ij}^n\right)^2 \right]}} \tag{3.3}$$

$$r_{ij}^n = \frac{x_{ij}^n}{\sqrt{\sum_{i=1}^m \left[\left(X_{ij}^l\right)^2 + \left(X_{ij}^m\right)^2 + \left(X_{ij}^n\right)^2 \right]}} \tag{3.4}$$

Step 3: Generate a fuzzy decision matrix with weighted normal.

$$v^l_{ij=w_j r_{ij}^l} \tag{3.5}$$

$$v^m_{ij=w_j r_{ij}^m} \tag{3.6}$$

$$v^n_{ij=w_j r_{ij}^n} \tag{3.7}$$

Step 4: The order of each alternative is calculated in terms of benefit and cost criteria. For the benefit criteria, the following equations are used.

$$s_i^{+l} = \sum_{j=1}^n v_{ij}^l | j \in J^{max} \tag{3.8}$$

$$s_i^{+m} = \sum_{j=1}^n v_{ij}^m | j \in J^{max} \tag{3.9}$$

$$s_i^{+n} = \sum_{j=1}^n v_{ij}^n | j \in J^{max} \tag{3.10}$$

For the cost criterion, the following equation is used.

$$s_i^{-l} = \sum_{j=1}^n v_{ij}^l | j \in J^{min} \tag{3.11}$$

$$s_i^{-m} = \sum_{j=1}^{n} v_{ij}^{m} \Big| j \in J^{min} \tag{3.12}$$

$$s_i^{-n} = \sum_{j=1}^{n} v_{ij}^{n} \Big| j \in J^{min} \tag{3.13}$$

Step 5: The Si index is determined for each alternative. This indexing phase uses the vertex method for refinement [28].

Step 6: The results are sorted from small to large according to the performance index and the highest value is considered as the best option.
When fuzzy MOORA method is applied, triangular fuzzy numbers for each variable are expressed according to the linguistic values in Table 3.1 [14].

Table 3.1. Linguistic Values

Linguistic Values	Triangular Fuzzy Numbers
Very Low	(1,1,3)
Low	(1,3,5)
Middle	(3,5,7)
High	(5,7,9)
Very High	(7,9,9)

4. SUPPLIER EVALUATION APPLICATION

The manufacturer of the supplier evaluation is in the food sector. By taking the opinions of experts who have at least 5 years experience in the procurement department of the business in question, management-specific green supplier evaluation criteria have been established and environmentalist approaches of 5 suppliers have been evaluated. Green supplier evaluation criteria and evaluation approach has been showed in Table 4.1.According to this the highest criterion is the highest criterion (EBEI), the lowest value is the lowest criterion, and the lowest criterion is the best (EKEI).

Table 4.1. Green Supplier Evaluation Criteria

Criteria	**Evaluation Approach**
Ownership Of Environmental Procedures Documents	EBEİ
Risk Of Landslide Accidents	EKEİ
Compliance With The Posted Environmental Rules	EBEİ
Regular Recycling Management For Generated Wastes	EBEİ
Budget Allocated For Annual Environmental Activities	EBEİ
Co2 Emissions Released To The Environment For Materiel Deliveries	EKEİ
Green Purchasing Performance	EBEİ
Green Logistics Performance	EBEİ
The Energy Rate Used For Unit Production	EKEİ
Ratio Of Raw Materials Used For Unit Production	EKEİ
Percentage Of Water Spent For Unit Production	EKEİ
Percent CO2 Emitted To The Environment For Unit Production	EKEİ
Percentage Of Achieving Annual Environmental Targets	EBEİ

During the solution of the problem, suppliers are called T1, T2, T3, T4 and T5, while the supplier evaluation criteria are called K1, K2, K3 .. K13 respectively. While the enterprises are legally subject to some environmental procedures by the government, some procedures form themselves. In this context, the environmental policy documents which are owned and communicated by the environmental policy documents express the environmental policies and the environmental protection procedures established by them legally. Factors that may cause business accidents in production or other areas of some businesses may be the subject. These are revealed by the risk analysis. The risk of environmental accidents in the field is the risk analysis that suppliers make and score within themselves. The CO_2 rate attacked by the suppliers while delivering the material to the next main producer is one of the other criteria to be minimized. For this minimization, the proximity of the supplier to the main producer as a location is one of the most fundamental factors. According to Min et al. [29], green purchasing decisions are the whole of purchasing activities of recyclable, reusable or newly recycled materials. In the case of green procurement, the product specifications must be environmentally friendly, as well as the supplier's environmental policy practices. According to Jain and Kaur [30], green logistics is designed to inflict minimal damage to the environment. The ratio of CO_2 emitted to raw materials, water, energy and environment used for unit production is among the biggest factors affecting both suppliers environmental approaches and production costs, and the minimization of these criteria is targeted. Compared with the production of new products from raw materials by regeneration according to fires [31], it is observed that the regeneration is more advantageous, the energy use and the waste rates are reduced, and the current production in production causes relatively less costly production. The steps of the application part are as follows;

Step 1: Criteria and supplier's expressed in linguistic variables Table 4.2.

Table 4.2. Initial Matrix

	T1			T2			T3			T4			T5		
	l	m	n	l	m	n	l	m	n	l	m	n	l	m	n
K1	1	3	5	1	3	5	5	7	9	5	7	9	1	1	3
K2	1	3	5	1	3	5	1	1	3	1	3	5	1	3	5
K3	3	5	7	1	3	5	5	7	9	1	3	5	1	3	5
K4	3	5	7	3	5	7	7	9	9	1	3	5	1	1	3
K5	1	1	3	1	1	3	1	3	5	1	3	5	1	1	3
K6	3	5	7	5	7	9	1	1	3	5	7	9	3	5	7
K7	1	3	5	3	5	7	5	7	9	1	3	5	1	1	3
K8	1	3	5	3	5	7	7	9	9	1	3	5	1	3	5
K9	3	5	7	5	7	9	1	1	3	3	5	7	5	7	9
K10	1	3	5	3	5	7	1	1	3	1	1	3	1	3	5
K11	1	3	5	3	5	7	1	3	5	1	1	3	7	9	9
K12	3	5	7	3	5	7	1	3	5	3	5	7	5	7	9
K13	1	3	5	1	3	5	5	7	9	3	5	7	1	3	5

Step 2: Using the equations (3.2), (3.3) and (3.4), the vector normalization and the normalized fuzzy decision matrix are constructed. The normalized values are as shown in Table 4.3.

Table: 4.3. Normalize Values

		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13
	l	0,13736	0,4472	0,4932	0,3612	0,4472	0,3612	0,1644	0,128	0,3612	0,2774	0,128	0,0119	0,1644
	m	0,27735	0,4932	0,4975	0,4211	0,0842	0,4096	0,3111	0,2601	0,4096	0,4472	0,2683	0,4336	0,2985
T1	n	0,33634	0,4789	0,4889	0,4796	0,3419	0,4268	0,3637	0,3492	0,4268	0,4623	0,3637	0,4401	0,3492
	l	0,13736	0,4472	0,1644	0,3612	0,4472	0,6019	0,4932	0,3841	0,6019	0,8321	0,3841	0,0119	0,1644
	m	0,27735	0,4932	0,2985	0,4211	0,0842	0,5735	0,5185	0,4336	0,5735	0,7454	0,4472	0,4336	0,2985
T2	n	0,33634	0,4789	0,3492	0,4796	0,3419	0,5487	0,5092	0,4889	0,5487	0,6472	0,5092	0,4401	0,3492
	l	0,6868	0,4472	0,822	0,8427	0,4472	0,1204	0,822	0,8963	0,1204	0,2774	0,128	0,004	0,822
	m	0,64715	0,1644	0,6965	0,7579	0,2526	0,0819	0,7259	0,7804	0,0819	0,1491	0,2683	0,2601	0,6965
T3	n	0,60541	0,2873	0,6286	0,6167	0,5698	0,1829	0,6547	0,6286	0,1829	0,2774	0,3637	0,3143	0,6286
	l	0,6868	0,4472	0,1644	0,1204	0,4472	0,6019	0,1644	0,128	0,3612	0,2774	0,128	0,0119	0,4932
	m	0,64715	0,4932	0,2985	0,2526	0,2526	0,5735	0,3111	0,2601	0,4096	0,1491	0,0894	0,4336	0,4975
T4	n	0,60541	0,4789	0,3492	0,3426	0,5698	0,5487	0,3637	0,3492	0,4268	0,2774	0,2182	0,4401	0,4889
	l	0,13736	0,4472	0,1644	0,1204	0,4472	0,3612	0,1644	0,128	0,6019	0,2774	0,8963	0,0198	0,1644
	m	0,09245	0,4932	0,2985	0,0842	0,0842	0,4096	0,1037	0,2601	0,5735	0,4472	0,805	0,607	0,2985
T5	n	0,2018	0,4789	0,3492	0,2056	0,3419	0,4268	0,2182	0,3492	0,5487	0,4623	0,6547	0,5658	0,3492

Step 3: Using the equations (3.5), (3.6) and (3.7), we find the weighted normalized matrix. In this study, each criterion value is taken as 1 because each criterion value is considered equal. The calculation is as shown in Table 4.4.

Table: 4.4. Weights and Normalize Values

		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13
	W	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00	1,00
	l	0,13736	0,4472	0,4932	0,3612	0,4472	0,3612	0,1644	0,128	0,3612	0,2774	0,128	0,0119	0,1644
	m	0,27735	0,4932	0,4975	0,4211	0,0842	0,4096	0,3111	0,2601	0,4096	0,4472	0,2683	0,4336	0,2985
T1	n	0,33634	0,4789	0,4889	0,4796	0,3419	0,4268	0,3637	0,3492	0,4268	0,4623	0,3637	0,4401	0,3492
	l	0,13736	0,4472	0,1644	0,3612	0,4472	0,6019	0,4932	0,3841	0,6019	0,8321	0,3841	0,0119	0,1644
	m	0,27735	0,4932	0,2985	0,4211	0,0842	0,5735	0,5185	0,4336	0,5735	0,7454	0,4472	0,4336	0,2985
T2	n	0,33634	0,4789	0,3492	0,4796	0,3419	0,5487	0,5092	0,4889	0,5487	0,6472	0,5092	0,4401	0,3492
	l	0,6868	0,4472	0,822	0,8427	0,4472	0,1204	0,822	0,8963	0,1204	0,2774	0,128	0,004	0,822
	m	0,64715	0,1644	0,6965	0,7579	0,2526	0,0819	0,7259	0,7804	0,0819	0,1491	0,2683	0,2601	0,6965
T3	n	0,60541	0,2873	0,6286	0,6167	0,5698	0,1829	0,6547	0,6286	0,1829	0,2774	0,3637	0,3143	0,6286
	l	0,6868	0,4472	0,1644	0,1204	0,4472	0,6019	0,1644	0,128	0,3612	0,2774	0,128	0,0119	0,4932
	m	0,64715	0,4932	0,2985	0,2526	0,2526	0,5735	0,3111	0,2601	0,4096	0,1491	0,0894	0,4336	0,4975
T4	n	0,60541	0,4789	0,3492	0,3426	0,5698	0,5487	0,3637	0,3492	0,4268	0,2774	0,2182	0,4401	0,4889
	l	0,13736	0,4472	0,1644	0,1204	0,4472	0,3612	0,1644	0,128	0,6019	0,2774	0,8963	0,0198	0,1644
	m	0,09245	0,4932	0,2985	0,0842	0,0842	0,4096	0,1037	0,2601	0,5735	0,4472	0,805	0,607	0,2985
T5	n	0,2018	0,4789	0,3492	0,2056	0,3419	0,4268	0,2182	0,3492	0,5487	0,4623	0,6547	0,5658	0,3492

Step 4-5: The criteria are grouped in terms of benefit cost values and are processed according to Step 4 in the narrative section. The data are then refined according to the formula given in Step 5 (3.14). Subsequent values are sorted by size to size and the position of suppliers in the green supply chain is found. Accordingly, Table 4.5. Te T3 supplier comes first, followed by T5, T2, T4, T1 suppliers respectively.

Table 4.5. Supplier Ranking

	S+			S-			S	Sıralama
	l	m	n	l	m	n		
T1	1,896	2,150	2,709	1,587	2,462	2,599	0,261	5
T2	2,152	2,332	2,854	2,879	3,266	3,173	0,708	3
T3	5,339	4,557	4,332	1,097	1,006	1,609	3,560	1
T4	2,204	2,520	3,069	1,828	2,148	2,390	0,497	4
T5	1,326	1,222	2,015	2,604	3,335	3,137	1,566	2

5.RESULTS

The green supply chain approach, which has yet to be taken as a new approach for businesses, is an ongoing process starting with the raw material procurement process and continuing from incoming logistics, production, shipment, marketing and after sales. The green supply chain not only minimizes damage to the environment, but also reduces the use of inputs, labor, energy, etc., and reduces waste. Businesses that support the green supply chain can go one step ahead of their competitors with various marketing campaigns, increasing sales potential and customer satisfaction. With the integration into the green supply chain, businesses can also minimize the risk of accidents in terms of occupational health and safety. Suppliers compliant with the green supply chain are leading a step in green purchasing. In this study, approaches to green supply chain of suppliers that have been approved suppliers by exceeding certain criteria such as service to an enterprise, quality price etc. have been evaluated. According to this assessment, while the business is expanding its business volume with its highest rated supplier under its environmental policy, it encourages all suppliers to the green supply chain approach. In this study, the criterion was shaped by the expectation of the supplier. It is hoped that the other work to be done in this area is to shed light. The study can be evaluated by other methods among multi-criteria decision making methods in future studies other than the fuzzy MOORA method and the results can be interpreted by comparing.

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THE TRAVELING SALESMAN PROBLEM UNDER DYNAMIC UNCERTAINTY

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Abstract *− Travel times in transportation networks are typically uncertain and the level of uncertainty change with time. In this study, we account for such dynamic uncertain travel times when dealing with the travelling salesman problem (TSP). In classical robust optimization, the uncertain cost of each arc is represented by an interval. Here we consider that each arc has multiple uncertainty profiles, where an uncertainty profile consists of an interval to be activated at a certain period of time of the day. We formulate the TSP under dynamic uncertainty using a robust minimax model. We use a branch-and-bound algorithm seeking the minimum cost tour, integrated with a mixed integer linear programming (MILP) formulation which finds the worst possible cost of the evaluated tour, following the robust optimization approach. To test out solution methodology, we conduct numerical studies to investigate the effects of (i) the number of traffic-affecting events, and (ii) conservativeness degree.*

Keywords *− travelling salesman problem, robust optimization, dynamic uncertainty modelling, branch-and-bound, MILP*

INTRODUCTION

Traveling salesman problem (TSP) is a well-known combinatorial optimization problem in which we aim to construct a route for a salesperson, such that she/he visits all given cities, ending up back in the first city, and the total cost is minimized. The traditional version of TSP does not consider uncertainty, and it assumes that all the problem data are known exactly. However, in reality, values of the problem data might differ from the assumed (nominal) values in the model, because of unforeseen realistic events (e.g. traffic jams, bad weather conditions, and other similar events), which affect the travel costs. Arguments against ignoring the uncertainty can be seen in detail in [1], [2] and [3].

To deal with problems under uncertainty, a classical robust optimization technique is proposed in [4], where the uncertain data are expressed as intervals (each interval specifying the range of values that can be encountered by a piece of uncertain data), instead of as exactly known fixed numbers. Considering a cost-minimization problem, the Soyster approach in [4] assumes a fully pessimistic scenario, where all the cost coefficients are maximized, and seeks the solution with minimum cost in this fully pessimistic scenario. The more recent robust optimization studies presented in [1], [5], [2] and [3] introduce the concept of conservativeness degree, which allows the decision maker to configure the level of pessimism while evaluating the solutions, instead of using the fully pessimistic (and possibly over-conservative) scenario. Robust models are developed for transportation problems in, for example, [6], [7], [8] and [9].

In this study, we propose a new robust modelling technique, where in addition to expressing the uncertain data via intervals, we also consider that the boundaries of the intervals change depending on the time. For example, the cost interval of the path between location A and location B can be wide and take on high values in the morning rush hours, because people are going to their workplaces during those hours and cause a heavy traffic; however, the cost interval of this path during the noon is narrower and take on lower values because and there are less people in the traffic. This common pattern observed in any transportation settings can be characterized as dynamic uncertainty. Note that transportation problems with travel costs dependent on the arrival times of the vehicle(s) have been studied before (see, for example [10]). The distinctive feature of our study is that we consider time-dependent uncertainty intervals, instead of time-dependent deterministic travel costs.

In our methodology for robust optimization under dynamic uncertainty, we consider that an arc does not have a single cost interval, but has multiple profiles of uncertainty, each profile storing a cost interval and an arrival time interval. If the arrival time on an arc is within the arrival time interval of an uncertainty profile of that arc, that profile is activated and the travel cost of that arc is assumed to be within the cost interval stored by that activated profile. We model our minimax solution approach as follows: the inner maximizing model is a mixed integer linear programming (MILP) model which makes assumptions on the travel times and on the activated uncertainty profiles, such that the total travel time/cost of a solution is maximized (i.e. such that the solution's worst-case cost is found). The outer minimization model is solved using a branch-and-bound approach which searches the solution space by constructing routes, always looking for the solution with the minimum worst-case cost.

The sections of this paper are as follows: we define the travelling salesman problem under dynamic uncertainty and formulate the model of this problem in Section 2. In Section 3, we present our hybrid solution methodology combining the branch-and-bound and MILP approaches and the computational results Finally, Section 4 concludes with the insights obtained based on the findings and suggestions for future work.

PROBLEM DEFINITION AND MODELLING

The TSP under dynamic uncertainty is modelled on a graph $G = \langle V, A \rangle$, where V is the set of vertices and A is the set of arcs, an arc being a pair of vertices: $A = \{(i,j) | \ i \in V,\ j \in V,\ i \neq j\}$. Here, a vertex represents a location, and an arc represents the path between two locations.

Each arc $(i,j) \in A$ has a set of associated uncertainty profiles. Each uncertainty profile stores an activation time period, and a travel cost interval. Considering an arrival time t to the beginning of an arc (i,j), the uncertainty profile whose activation time period contains the time t is activated. The cost of traveling the arc (i,j) is assumed to be within the boundaries specified by the cost interval of the active uncertainty profile.

The uncertainty profile set PROF_{ij} for each arc $(i,j) \in A$ is formally defined as follows:

$$\text{PROF}_{ij} = \left\{ \begin{array}{c} \langle \text{TFROM}_{ij}^{1}, \text{TTO}_{ij}^{1}, \left[\underline{K}_{ij}^{1}; \overline{K}_{ij}^{1}\right] \rangle, \\ \langle \text{TFROM}_{ij}^{2}, \text{TTO}_{ij}^{2}, \left[\underline{K}_{ij}^{2}; \overline{K}_{ij}^{2}\right] \rangle, \\ \dots \\ \dots \\ \langle \text{TFROM}_{ij}^{|\text{PROF}_{ij}|}, \text{TTO}_{ij}^{|\text{PROF}_{ij}|}, \left[\underline{K}_{ij}^{2}; \overline{K}_{ij}^{|\text{PROF}_{ij}|}\right] \rangle \end{array} \right\} \quad \forall (i,j) \in A$$

where, TFROM_{ij}^{p} is the beginning of the activation time period of p-th profile, TTO_{ij}^{p} is the ending of the activation time period of p-th profile, $\left[\underline{K}_{ij}^{p}; \overline{K}_{ij}^{p}\right]$ is the cost interval to be imposed on the arc (i,j) if the p-th profile becomes active. Also, to ensure continuity within the uncertainty profile sets, we make sure that:

$$\text{TFROM}_{ij}^{p} = \begin{cases} 0, & \text{if } p = 1 \\ \text{TTO}_{ij}^{p-1}, & \text{otherwise} \end{cases} \quad \forall p \in \{1,2,\dots,|\text{PROF}_{ij}|\}$$

Because we are dealing with uncertainty, evaluating a solution x cannot be as straightforward as adding the fixed costs of all the arcs of the solution route. Instead, we need a function, WORSTCOST(x, Γ), which finds the worst possible cost that the solution x could encounter, by making the most pessimistic assumptions on the uncertainty realizations and the uncertainty profile activations as much as the conservativeness degree Γ allows. With the help of such a function, the definition of the TSP variation we are dealing with becomes:

Minimize $\textsc{WorstCost}(x, \Gamma)$ (1)

subject to $\sum_{j \in (V \setminus i)} x_{ij} = 1 \quad \forall i \in V$ (2)

$$\sum_{i' \in (V \setminus 1)} x_{i',i} = 1 \quad \forall i \in V \quad (3)$$

$$x \in \textsc{NoSubTour} \quad (4)$$

The objective (1) states that our goal is to find a solution with the minimum most pessimistic cost. The constraint (2) imposes that each vertex has an arc coming to itself, and the constraint (3) imposes that each vertex has an arc going from itself. Considering that NoSubTour is the set of all solutions which do not contain subtours, the constraint (4) imposes that the solution x belongs to NoSubTour.

Let us now explain the function $\textsc{WorstCost}(x, \Gamma)$, which represents the inner maximization problem of our minimax structured problem. Focusing on a solution x, let us now provide the following definitions:

- Q^x: collection of arcs contained by the solution x.
- Q_k^x: k-th arc of the solution x, Q_1^x being the arc starting from the depot.
- P_k^x: set of uncertainty profiles of the k-th arc of the solution x. Therefore: $P_k^x = \textsc{Prof}_{Q_k^x}$.
- $\left[\underline{T}_{kp}^x; \overline{T}_{kp}^x\right]$: activation time period of the p-th uncertainty profile of the k-th arc of the solution x. Therefore: $\underline{T}_{kp}^x = \textsc{TFrom}_{Q_k^x}^p$ and $\overline{T}_{kp}^x = \textsc{TTo}_{Q_k^x}^p$.
- $\left[\underline{c}_{kp}^x; \overline{c}_{kp}^x\right]$: cost interval of the p-th uncertainty profile of the k-th arc of the solution x. Therefore: $\left[\underline{c}_{kp}^x; \overline{c}_{kp}^x\right] = \left[\underline{K}_{Q_k^x}^p; \overline{K}_{Q_k^x}^p\right]$.
- $\hat{c}_{kp}^x$: size of the interval $\left[\underline{c}_{kp}^x; \overline{c}_{kp}^x\right]$, calculated as $\overline{c}_{kp}^x - \underline{c}_{kp}^x$.

We also define the following decision variables for the inner optimization problem within $\textsc{WorstCost}(x, \Gamma)$ as follows:

- $z_{kp} \in \{0, 1\} \ \forall k \in \{1,2, \dots, |Q^x|\}, p \in \{1,2, \dots, |P_k^x|\}$:

  decides whether p-th profile of the k-th arc is assumed to be active(=1) or not(=0).
- $\gamma_{kp} \in [0; 1] \ \forall k \in \{1,2, \dots, |Q^x|\}, p \in \{1,2, \dots, |P_k^x|\}$:

  decides the uncertainty realization on the p-th profile of the k-th arc. The p-th profile being active, if $\gamma_{kp} = 0$, the cost of the k-th arc is assumed to be the cost lower bound of the p-th profile (i.e. $\underline{c}_{kp}^x$). On the other hand, if $\gamma_{kp} = 1$, the cost of the k-th arc is assumed to be the cost upper bound of the p-th profile (i.e. $\overline{c}_{kp}^x$). The value of γ_{kp} can also be a non-integer, expressing the assumption that the cost of the k-th arc is somewhere between the cost boundaries expressed by the p-th profile.
- $t_k \geq 0 \ \forall k \in \{1,2, \dots, |Q^x|\}$: arrival time to the beginning of the k-th arc.

By using the definitions above, we can now define $\text{WORSTCOST}(x, \Gamma)$ as follows:

$$\text{WORSTCOST}(x,\Gamma) = \quad \text{maximize} \quad \sum_{k\in\{1,2,\dots,|Q^x|\}} \sum_{p\in\{1,2,\dots,|P_k^x|\}} \underline{c}_{kp}^x z_{kp} + \hat{c}_{kp}^x \gamma_{kp} \tag{5}$$

$$\text{subject to} \quad t_1 = 0 \tag{6}$$

$$z_{1,1} = 1 \tag{7}$$

$$\gamma_{kp} \le z_{kp} \quad \forall k \in \{1,2,\dots,|Q^x|\}, p \in \{1,2,\dots,|P_k^x|\} \tag{8}$$

$$t_k - t_{k-1} = \sum_{p\in\{1,2,\dots,|P_{k-1}^x|\}} \left(\underline{c}_{k-1,p}^x z_{k-1,p} + \hat{c}_{k-1,p}^x \gamma_{k-1,p}\right) \quad \forall k \in \{2,3,\dots,|Q^x|\} \tag{9}$$

$$\sum_{p\in\{1,2,\dots,|P_k^x|\}} z_{kp} = 1 \quad \forall k \in \{1,2,\dots,|Q^x|\} \tag{10}$$

$$\sum_{k\in\{1,2,\dots,|Q^x|\}} \sum_{p\in\{1,2,\dots,|P_k^x|\}} \gamma_{kp} \le \Gamma \tag{11}$$

$$t_k \ge \underline{T}_{kp}^x - \left(1 - z_{kp}\right)M \quad \forall k \in \{1,2,\dots,|Q^x|\} \tag{12}$$

$$t_k \le \overline{T}_{kp}^x + \left(1 - z_{kp}\right)M \quad \forall k \in \{1,2,\dots,|Q^x|\} \tag{13}$$

The objective (5) specifies that we are looking for the highest cost the solution x can encounter by finding the worst possible combination of profile activations and uncertainty realizations. The constraint (6) imposes that the arrival time on the first arc of the route is 0 (i.e. the tour starts at time 0). The constraint (7) imposes that the active profile of the first arc is the first profile (i.e. the profile which begins at time 0). The constraint (8) makes sure that there is no uncertainty realization on an inactive profile. The arrival time on the k-th arc is calculated in (9), by using the uncertainty profile and realization assumptions on the $(k-1)$-th arc. The constraint (10) makes sure that there is exactly one active profile for each arc. A constraint inspired by the work of [2] and [3], the inequality (11) imposes that the total uncertainty realization is bounded by the conservativeness degree parameter Γ. Finally, the inequalities (12) and (13) forces consistency on the arrival times on an arc and its active profile, with the help of a large-enough constant M.

SOLUTION APPROACH AND THE NUMERICAL RESULTS

As previously mentioned, our TSP variation is minimax structured, and therefore it is actually two optimization problems, the maximization problem being nested within the minimization problem. To solve this TSP variation, we use a hybridization of branch-and-bound and MILP approaches. On the outside, the branch-and-bound approach generates solutions (i.e. x vectors) (see Figure 1). For the evaluation of a solution the optimization problem expressed within the function $\text{WORSTCOST}(x, \Gamma)$ is solved with the help of MILP.

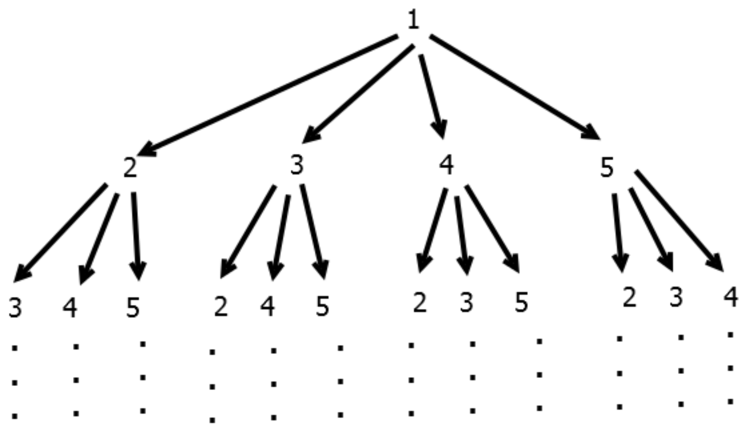
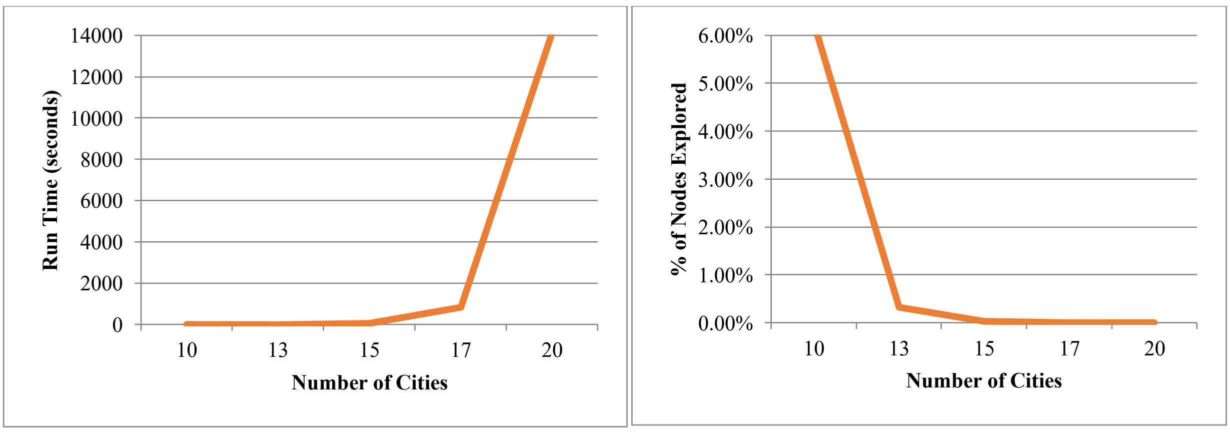


Figure 1. Visualization of a branch-and-bound tree expansion on an example TSP instance, assuming we have 5 locations and our depot location is 1.

We have tested our proposed solution methodology using a number of experiments. The instances to be used in our experiments are generated with various numbers of cities (i.e. number of elements in set) and various numbers of traffic-affecting events (a traffic-affecting event increases both lower and upper bounds of the arc costs on a certain route within a certain time period), and each instance is solved with different values of conservativeness degree parameter Γ. Solving each instance with different Γ values allows us to gain insight on how optimum solutions behave with respect to the level of protection against the dynamic uncertainty.

We set the experimental design levels of these parameters as follows: (*i*) the number of cities is decided as 10, 13, 15, 17 and 20; (*ii*) the number of events is varied as 5 and 10 and (*iii*) the conservativeness degree parameter Γ is set as 0, 1, 2, 3, 10 and 20 (20 being valid only for the instances of 20 cities). For each combination of number of cities and number of events, 10 instances are generated. The tests are conducted on an Intel® Core ™ i5-6200 CPU@ 2.40 GHz computer with 8.00 RAM and 64-bit operating system. In Figure 2 (a), we show the average run-time (in seconds) of the solution methodology with respect to different numbers of cities, each of which forms a complete graph. Then the percentage of the nodes explored with respect to number of cities is depicted in Figure 2 (b).



(a) (b)

Figure 2. Run-time and the % of nodes explored of the proposed methodology with respect to number of cities in a complete graph

The solution run-time increases exponentially with respect to the number of cities in a complete graph. All of the instances of 10, 13, 15 and 17 cities are solved, whereas we encountered high run-times for the instances of 20 cities. Thus, two out of ten instances have been killed for "20 cities and 5 events" instances, and seven out of ten have been killed for "20 cities and 10 events" instances. The remaining instances are solved and the highest run-time is 45182 seconds for the case of 20 cities, 10 events and a conservativeness level of 3. We also observe that the node exploration percentage in the branch-and-bound tree of our proposed solution methodology decreases exponentially as the tree enlarges with the number of cities.

For each case of the experimental setting, we show the average and the standard deviation of the results of solved instances in Table 1. The table displays numbers of cities on the columns, and numbers of events and conservativeness degrees (Γ) on the rows. The average and standard deviation of each case show, as expected, that as the conservativeness degree increases the travel costs increase. The number of cities also has an increasing effect on the travel costs. In most of the cases, average travel costs also increase as the number of events increase. There exist few exceptions, which may be due to random problem sets. In those exceptions, we observe that the standard deviations are high.

Table 1. The average and standard deviations of travel costs for each experimental case. (Avr. = Average travel cost, SD. = Standard deviation)

		Nr. of Cities									
		10		**13**		**15**		**17**		**20**	
Nr. of Events	**Γ**	**Avr.**	**SD.**	**Avr.**	**SD.**	**Avr.**	**SD.**	**Avr.**	**SD.**	**Avr.**	**SD.**
5	0	29.34	3.93	32.30	2.37	34.49	2.78	35.31	1.87	36.69	1.57
5	1	30.16	4.03	32.94	2.44	35.10	2.80	35.94	1.83	37.20	1.60
5	2	30.73	4.14	33.42	2.50	35.55	2.87	36.40	1.83	37.61	1.60
5	3	31.17	4.22	33.80	2.56	35.94	2.96	36.79	1.85	37.93	1.62
5	10	32.31	4.48	35.11	2.90	37.56	3.35	38.19	1.95	39.42	1.56
5	20	-	-	-	-	-	-	-	-	40.00	1.49
10	0	30.73	2.97	31.55	2.57	33.84	2.73	35.88	3.21	36.77	1.63
10	1	31.73	3.09	32.24	2.70	34.53	2.81	36.47	3.22	37.45	1.66
10	2	32.37	3.23	32.71	2.74	35.01	2.87	36.92	3.23	37.88	1.76
10	3	32.87	3.37	33.15	2.84	35.38	2.88	37.29	3.24	38.22	1.79
10	10	34.03	3.71	34.50	3.08	36.73	2.99	38.82	3.44	39.71	1.92
10	20	-	-	-	-	-	-	-	-	40.27	1.94

We also observe that the robust approach has a significant implication on the obtained solution vectors and routes. In the experimental study, results of 91 instances were obtained in total. Among them, we observe that different solution vectors are reported for 54 instances by changing the conservativeness degree, namely gamma.

CONCLUSIONS

In real-life settings, we observe that the travel-time uncertainty changes dynamically depending on the time of day. This dynamic uncertainty phenomenon can cause significant perturbations on the travel costs. Thus, we aim to incorporate the dynamic uncertainty characteristic in the well-studied TSP model. We formulate a minimax model and use a hybrid solution methodology of branch-and-bound and MILP. The computational results show that an increasing number of routes having dynamic uncertainty behavior within a graph increase the travel costs. Thus, we conclude that more robust tours can be achieved using models with explicit consideration of dynamic uncertainty. It is also shown that the solution method reports predictably higher travel costs as the conservativeness degree and the graph size increase.

The experimental study confirms that the computation time increases exponentially as the graph size (number of nodes) increases due to the NP-hard nature of TSP. Thus, we aim to improve the efficiency of the proposed solution methodology in future research. We will also plan to deal with other problems under the phenomenon of dynamic uncertainty.

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ALGORITHMIC APPROACH TO OPTIMIZATION OF QUEUED COMMODITY FLOW THROUGH CRITICAL PATH WITH TIME-COST ANALYSIS

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Abstract – *An attempt has been made to create an algorithm for optimization of queued commodity flow under finite capacity constraints.It is the simulation of optimum queued commodity flow in random network with extension of Ford Fulkerson algorithm in the notion of delivery scheduling. The execution of the overall queued commodity flow through different routes of deliveries and its scheduling with the Critical Path Method/PERT and the total delivery completion time is minimized as well as the scheduled time is met at minimum cost.*
Keywords – *Cost function, CPM/PERT, Ford Fulkerson Algorithm, M/M/1/N queueing model.*

Introduction

An algorithmic approach has been employed for estimation of the optimum flow of queued commodity with the optimum expected delivery time and its associated cost. Since, the system of flow refers as a dynamic queueing system in which some commodity flows or is transferred through one or more finite capacity channels in order to go from one point to another. For instance, the transfer of goods in railway system or flow of automobile traffic through a road network or steaming of water through a dam, or transmission of telephone or telegraph messages, or passage of customers through a supermarket checkout counter, or the flow of computer programs through a time sharing computer system. The finite capacity refers to the fact the channel can satisfy the demands (placed upon it) at finite rate only. The analysis of systems of flow naturally break into two classes: steady and unsteady flow. In the first class, the quantity of flow exactly known and constant over the interval of interest; the time when that flow appears at the channel, and how much of a demand that flow place upon the channel is known and constant. The more interesting case of steady flow is that of a network of channels. For stable flow, we obviously require that requirement is less than capacity for each channel in the network. B. Filipowicz and J. Kwiecien [8] gave a brief history of queuing systems and queuing networks. They also presented queuing systems with Poisson arrival processes and exponential service times, some non-Markovian systems, the most common queuing networks and some area of applications of queuing theory. Jay Kumar Sharma et al [14] discussed the approach of Queuing theory and evaluated the performance of Networking in parallel and Distributed System models.
Mishra P.P. et.al [21] have analyzed the node wise level of commodity in the supply chain and total minimum variance cost of the network with the economic inflow quantities under non-negative constraints and concluded that the level of commodity is very sensitive about the size parameter.
Mishra and Yadav [12] have focused on the cost and profit analysis of clocked queued networks with respect to arrival and service parameters using advanced technique of optimization for non-linear systems. Mishra and Sharma et.al [22] discuss the inventory flow in supply chain with deteriorating items for customers in queue and its profit optimization in fuzzy environment by using computational approach.
An Zhang et.al.[6] considered an analysis for an M/M/1/N queuing systems with balking, reneging and server vacations and formulated a cost model to determine the optimal service rate. Mamata Kuila[16] discussed about a steady state solution of the ordered queueing problem with balking and reneging by taking the waiting line as chi-square queue with balking probability. Liming Liu et.al [5] developed a multi-stage inventory queue system and presented an efficient procedure to minimize the overall inventory in the system. Mishra and Mishra [13] computed the optimal inventory in the phase wise supply chain for queued customers in the interval of lower and upper bounds with particular life of the items. Total optimal costs and total expected delivery have also been computed by using dynamic programming and Dirichlet theorem. Viswanadham N. and Srinivasa N.R., Raghavan [3] considered Fork-Join queueing systems for analyzing supply chain networks in a dynamic and

stochastic setting. F.R.B. Cruz and T. Van Woensel [19] discussed the merits of the Generalized Expansion method for the performance evaluation of the finite queuing networks and discussed about the different optimization models on a complex queuing network. Goran Petrovic et.al.[10] presented an application of the Markov theory to the queued transport network systems to determine the performances of the system.

The second class into which systems of flow may be divided is the class of random or stochastic flow problems. By this we mean that the times at which demands for service (use of channel) arrive are uncertain or unpredictable, the randomness, unpredictability, or unsteady nature of this flow leads considerable complexity to the solution and understanding of such problems. Furthermore, it is clear that most real word system fall into this category. Fork-Join queueing systems for analyzing supply chain networks in a dynamic and stochastic setting. Trdlicka and Zdenek Hanzalek [11] described the routing problem as a multicommodity network flow optimization problem and presented a distributed algorithm for the energy optimal data flow routing in sensor networks. Tom Leighton and Satish Rao[1] established max-flow min-cut theorems for several important classes of multicommodity flow problems and also showed substantial applications to the field of approximation algorithms.

Dimitri.P.Bertsekas[17] analysed minimum cost shortest path problems even under the worst possible instance of uncertainty using the recent abstract semi contractive dynamic programming models and proposed a finitely terminating Dijkstra-like algorithm for problems with non-negative arc lengths. Dimitri.P. Bertsekas [18] analysed deterministic and stochastic shortest path problems using abstract semi contractive dynamic programming models and have highlighted three characteristics: the non-negativity of arc lengths, the existence of an optimal policy and zero-cycle effects. Angelo Sifaleris [15] presented an overview of the classic linear Minimum Cost Network Flow Problem and some other closely related problems. In this paper, state-of-the-art techniques and sources of optimization software for the MCNEP problems were also given. Charles Sutton and Michael I Jordon [9] analysed queueing networks of M/M/1/FIFO queues from the probabilistic modeling perspective applying inference methods from graphical models.

M. Sivakumari Sundari and S. Palaniammal [20] simulated a single server infinite capacity queueing model using Artificial Neural Network (ANN) and the results are compared with those obtained from analytically. Mishra S S.[23] developed an intelligent index measures the performance of fuzzified inventory flowing in supply chain which involves various factors of storing cost, backorder cost, cost of placing an order, holding cost, transportation cost, penalty cost, total demand, order quantity, and shortage quantity as the triangular fuzzy numbers. Prabhakar et al. [2] analysed the dynamics of the synchronization node, both an isolation and in networks of service and synchronization nodes with an cyclic synchronization skeleton and showed that synchronization preserves the Poissonanian nature of flows.

L.Brenner et al [4] presented the principles and the scientific foundations of the MQNA(Markovian Queueuing Networks Analyser), software tool to model and obtain the stationary solution of a large class of Queueing Networks. Dequan Yue et al. [7] considered M/M/c/N Queueing system with balking, reneging and synchronous vacations of partial servers and obtained some performance measures of the system and formulated a cost model to determine the optimal number of servers on vacation.A common scenario of a network-flow problem arising in industrial logistics concerns the distribution of single homogeneous product from plants (origins) to consumer markets (destinations). The total number of units produced at each plant and number of units required at each market are assumed to be uncertain. The product need not be sent directly from source to destination, but there may be capacity restrictions that limit some of the shipping links. The objective is to minimize the variable cost of producing and shipping the products to meet the consumer demand.

In this paper, we have an uncertain flow of commodity from source to sink. Let N(V,E) be the network of the flow of commodity from source node to sink node. V is the set of all the centers of warehouses including the source (manufacturing unit). E is the set of all the transport connection among the intermediate warehouses. We assume that the arrival pattern of the commodity at any intermediate node follow Poisson probability distribution and warehouses (intermediate vertices) are serving the commodity with exponential probability distribution function. Each edge of the network has finite capacity of flow. We optimize the queued commodity flow by Ford Fulkerson Algorithm and obtain the maximum lead time from manufacturer to deliver the commodity to the consumer by using CPM. The critical path method (CPM) is a project management technique that is used widely in both government and industry to analyze, plan, and schedule the various tasks of complex projects. CPM is helpful in identifying which tasks are critical for the execution of the overall delivery project, and in scheduling all the tasks in accordance with their prescribed precedence relationships so that the total delivery project completion date is minimized, or a target date is met at minimum cost.

We have obtained the maximum flow of the queued commodity as well as the minimum cost on the maximum flow of the network system. Critical path for the delivery of commodity from the source till the consumer as well as expected time and variance is also obtained. The normal distribution of the average time of delivery is obtained as well as use the six sigma approach to find the maximum delivery time of commodity.

Model Development

In this paper, we assume that commodity units are supplied from single source and it follows the Poisson probability distribution. There are various channels of the intermediate nodes receive the commodity through different edges having limited capacity C_e, $e \in E$ of M/M/1 system of commodity flow.

Here, Random flow $f: E \to R$, where the sample space is set edges E such that $f(e) = f_e \in R$ for $\forall e \in E$. Further, we consider an average arrival rate λ_e of commodity follows the Poisson distribution on edge e towards the next node and at the end node of the edge the commodities are served with average service rate μ_v to the next nodes with exponential distribution. A source node $s \in V$ and a sink node $t \in V$.

Now, we intend to find out the probability of $f_e$units of commodity at time $t + \Delta t$ on the edge e if $P_{f_e}(t)$ is the probability of flow f_e on the edge e at time t.

$$P_{f_e}(t + \Delta t) = P_{f_e}(t)(1 - \lambda_e \Delta t)(1 - \mu_v \Delta t) + P_{f_{e-1}}(t).(\lambda_e \Delta t)(1 - \mu_v \Delta t) + P_{f_e+1}(t).\mu_v \Delta t(1 - \lambda_e \Delta t)$$

$$P_{f_e}(t + \Delta t) = P_{f_e}(t)(1 - \mu_v \Delta t - \lambda_e \Delta t) + P_{f_e-1}(t).(\lambda_e \Delta t) + P_{f_e+1}(t).\mu_v \Delta t$$

$$P_{f_e}(t + \Delta t) - P_{f_e}(t) = (-\mu_v \Delta t - \lambda_e \Delta t)P_{f_e}(t) + P_{f_e-1}(t).(\lambda_e \Delta t) + P_{f_e+1}(t).\mu_e \Delta t$$

$$\frac{P_{f_e}(t + \Delta t) - P_{f_e}(t)}{\Delta t} = -(\mu_v + \lambda_e)P_{f_e}(t) + P_{f_e-1}(t).(\lambda_e) + P_{f_e+1}(t).\mu_v$$

Taking $\lim_{\Delta t \to 0}$ on both sides,

$$\frac{dP_{f_e}(t)}{dt} = -(\mu_v + \lambda_e)P_{f_e}(t) + P_{f_e-1}(t).(\lambda_e) + P_{f_e+1}(t).\mu_v$$

For $f_e = 0$,

$$\frac{dP_0(t)}{dt} = \{-\lambda_e\}P_0(t) + P_1(t).\mu_v$$

For the steady state of flow $\frac{dP_0(t)}{dt} = 0$

i.e. $\{-\lambda_e\}P_0(t) + P_1(t).\mu_v = 0$

$$P_1 = \left(\frac{\lambda_e}{\mu_v}\right)P_0,\ \sum_{f_e=1}^{C_e} P_{f_e} = 1,\ P_0 = \frac{1}{\sum_{f_e=1}^{C_e}\left(\frac{\lambda_e}{\mu_v}\right)^{f_e}} = \frac{(1-\rho_e)}{1-\rho_e^{(f_e+1)}}\ ,\rho_e \neq 1$$

$$\overline{f_e} = \sum_{f_e=0}^{C_e} f_e \rho_e^{f_e} P_0 = \rho_e P_0 \sum_{f_e=0}^{C_e} f_e \rho_e^{(f_e-1)} = \rho_e P_0 \frac{d}{d\rho_e}\left(\sum_{f_e=0}^{C_e} \rho_e^{f_e}\right)$$

$$= \rho_e P_0 \frac{d}{d\rho_e}\left(\frac{1 - \rho_e^{C_e+1}}{1 - \rho_e}\right) = \frac{\rho_e[1 - (C_e + 1)\rho_e^{C_e} + C_e \rho_e^{C_e+1}]}{(1 - \rho_e)(1 - \rho_e^{(C_e+1)})}$$

Now let us find the density function of the response and waiting times. By using the theorem of total probability we have

$$f_T(x) = \sum_{f_e=0}^{C_e-1} \mu \frac{(\mu x)^{f_e}}{f_e} e^{-\mu x} \frac{P_{f_e}}{1-P_{f_e}}\ , F_T(x) = \sum_{f_e=0}^{f_e-1}\left(\int_0^x \mu \frac{(\mu t)^{f_e}}{f_e!} e^{-\mu t} dt\right)\frac{P_{f_e}}{1-P_{f_e}}$$

$$= 1 - \sum_{f_e=0}^{f_e-1}\left(\sum_{i=0}^{k} \frac{(\mu x)^i}{i!} e^{-\mu x}\right)\frac{P_{f_e}}{1-P_{f_e}}\ ;$$

The expected waiting time of commodity on each edge $e \in E$ (waiting + service) $W_e^S = \frac{\overline{f_e}}{\lambda_e(1-P_{f_e})}$;

After getting the amount of expected flow on each edge of the network, we also calculate the waiting time of the commodity during flow from one node to another node. The following definitions are playing important role to make the computer program in C++ for the computation of results.

Definitions

Maximum Flow in Networks-Maximum flow problems arise in networks where there is a source and a sink connected by system of directional links, each having a given capacity. The problem is to determine the greatest possible flow that can be routed through the various network links, from source to sink, without violating the capacity constraints. The source node has only arcs directed out of it, and the sink node has only arcs directed into it. Intermediate nodes neither contribute to nor diminish the flow passing through them. The maximal Flow Problem can be stated precisely as a linear programming formulation. Let n be the number of nodes and let 1 and n be designated as source and sink, respectively Here, we wish to send as much material as possible from a specified node one as s in a network called the source to another n^{th} node specified as t, called sink. No costs are associated with flow. If v denotes the amount of material sent from node s to node t and f_{ij} denotes the flow from node *i* to node *j* over arc *(i,j)* the formulation is

Maximize v

Subject to $\sum_j f_{ij} - \sum_k f_{ki} = \begin{cases} v & if\ i = s\ (source) \\ -v & if\ i = t\ (sink) \\ 0 & otherwise \end{cases}$; $0 \le x_{ij} \le C_{ij}$

Ford-Fulkerson Method- An initial feasible flow can always be found by letting the flow through the network be zero ($\forall\ f_{ij} = 0$). The algorithm then operates through a sequence of iterations, each iterations consisting of two phases (i) First we look for a way to increase the current flow, by finding a path of arcs from source to sink whose current flow is less than capacity (This is called flow augmenting path)

(ii) We increase the current flow, as much as possible, along that path. If in step (1) it is not possible to find a flow augmenting path, then the current flow is optimal.

Delivery Management

For the project is to deliver the commodity from source to sink. There are two methodologies were developed independently and simultaneously its management, one method, called the Critical Path Method (CPM) was developed for the management of construction and production activities; while the other called the Program Evaluation and Review Technique (PERT), was developed for scheduling research and development activities. CPM is based on deterministic specifications of task durations. On the other hand, PERT is based on probabilistic estimates of task durations hence it is most useful in a research and development environment where task completion times can not be known in advance. Because both PERT and CPM approach project scheduling using similar network models and methods, the terms PERT and CPM are sometimes used interchangeably or collectively as "PERT-CPM methods."

Probabilistic Delivery Scheduling-

When there is no previous experience from which to determine the duration of individual activities. PERT provides a means of handling such uncertainties through the use of probabilities for the completion times of the activities. There are mainly three time estimates for each activity: an optimistic duration denoted as "**a**" specifying the minimum reasonable completion time and pessimistic duration, denoted as b specifying the maximum duration if things go badly; and a most probable duration denoted as m. Here we have applied critical path methods to a project layout based on probabilistic competition time estimates. We have computed the expected time to complete each activity is used as actual time in order to find a critical path (as in the deterministic case) and the variance will give an indication of the amount by which project might deviate from its expected project duration. This is obtained in PERT based on the assumption, the expected time μ for an activity is approximated as $\mu = \frac{(a+b+4m)}{6}$.Under PERT assumptions, the Central limit theorem implies that the project duration (being the sum of independent random variables) is normally distributed with mean μ and variance σ^2.

Capacitated Transshipment Problem- The most general form of the minimum cost network flow problem arises when some commodity is to be distributed from source to destinations. Each node can create a certain supply or absorb some demand of the commodity. It is not necessary for each unit of commodity to be shipped directly from source to a destination; instead, it may be transshipped indirectly through intermediate nodes on its way to its destination. In fact, the total supply could conceivably be routed through any node in transit. Links can have upper and lower bounds on the flow that may be assigned to them. The object is to meet the demands without exceeding the available supply and to do so at minimum cost.

Minimum Cost Network Flow-

When the costs associated with shipping or transporting a flow through a network, the goal might be to establish a minimum cost flow in the network, subject to the capacity constraints on the links. Let C_1 = maintainance cost / capacity per unit time and C_2= waiting cost per unit commodity per unit time, C_3 = service cost per unit time.

Minimum

$$Total\ Cost \quad = \sum_{i=1} \sum_{j=1} (C_1 C_{ij} + C_2 f_{ij}) + \sum_{i=1} (C_3\, \mu_i)$$

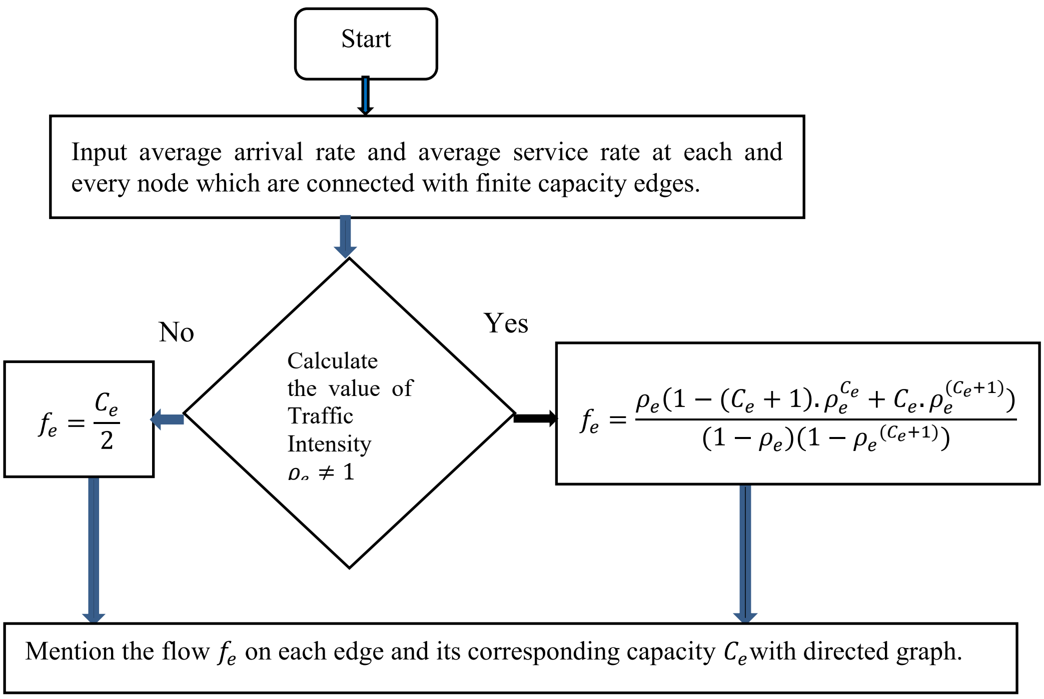
Subject to

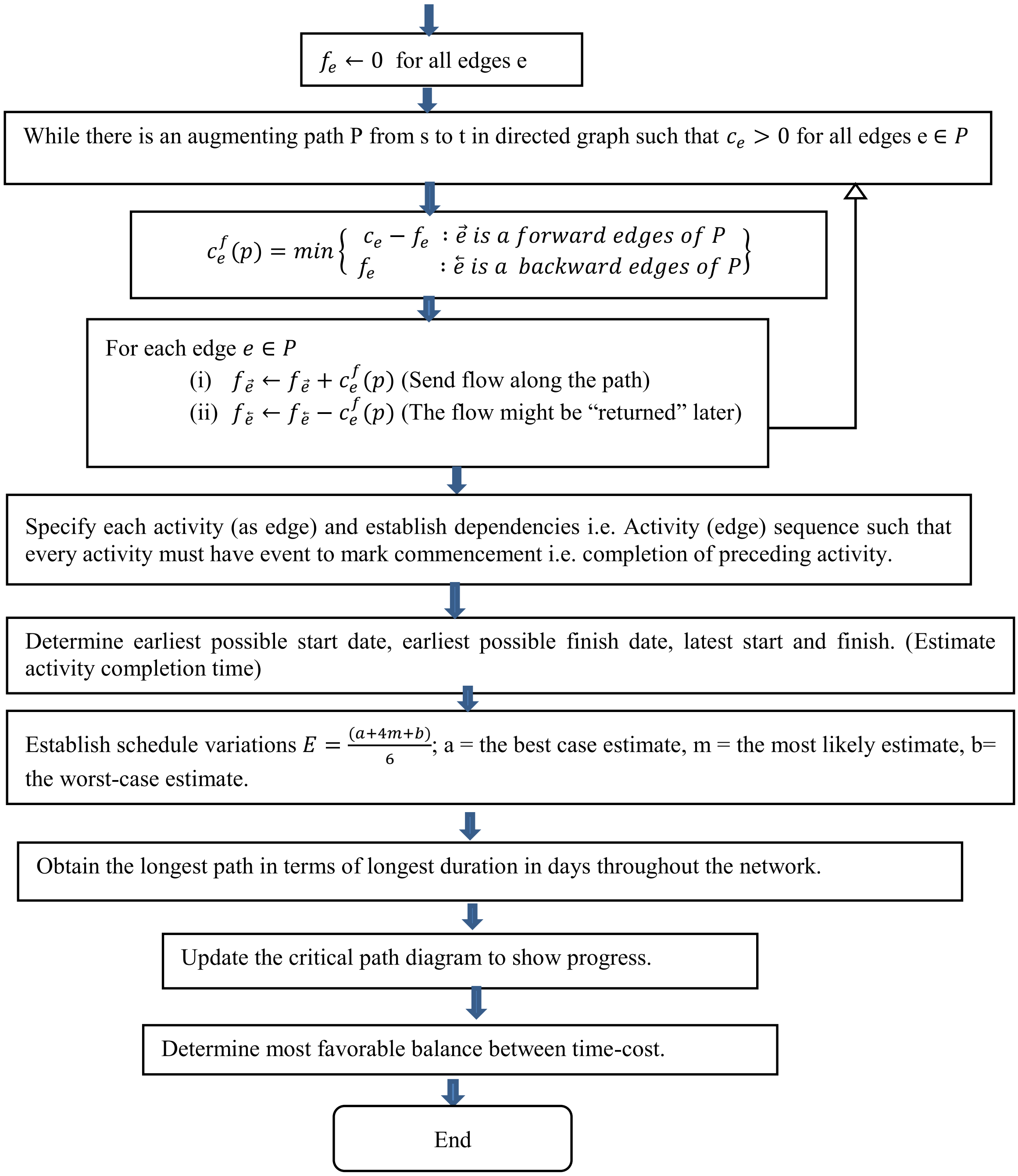
$$\sum_{j=1}^{n} f_{ij} - \sum_{k=1}^{n} f_{ki} = s_i \text{ for } i=1,2\ldots.\ n$$

$0 \le f_{ij} \le C_{ij}$ for all i and j.

Considering all the above definitions we have made an algorithm for queued commodity flow with finite capacity constraints, where inputs are (i) Average arrival rate λ_e through e edge at any vertex v and its capacity C_e in Network (ii) Average service rate μ_v at each node $v \in V$ in Network N (V,E). We get the output as the network of maximum flow, Critical path of delivery of the commodity, maximum lead time of commodity from source to sink. Optimal cost of the commodity maximum commodity flow. Interval of the delivery scheduled time.

Flow Chart of Algorithm





Application of Algorithm

For instance, suppose that, after doing the sampling of random arrival of commodity at very node of a specified network with edge capacity constraint, the sampled data is fitted on Poisson probability distribution and the average service rate is fitted on exponential distribution. These are taken as inputs at each node of the network which are given in the following table of 1.1 After the computation of the flow at every edge of the network and their capacities are mentioned on every edge of the network in form of ordered pair. See in Figure1.

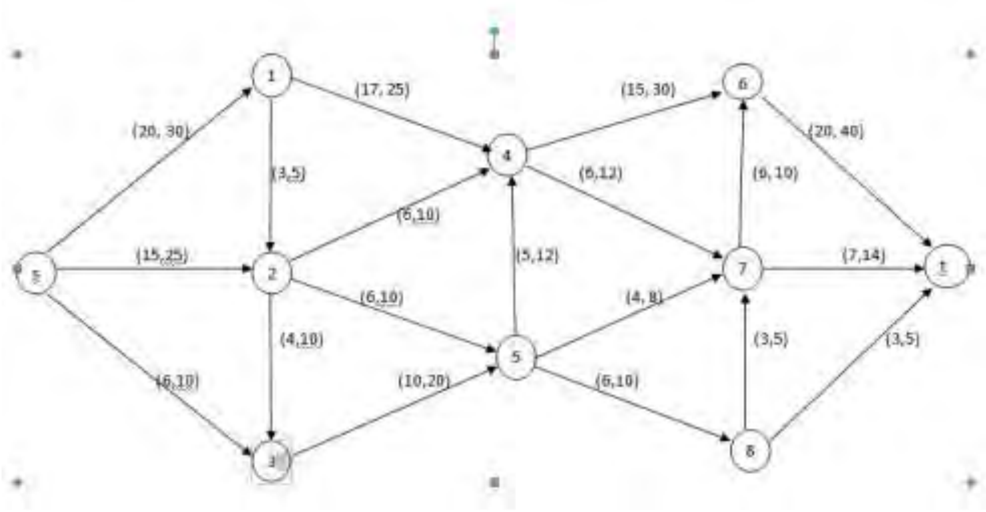


Figure 1 Network of uncertain flow

TABLE- I
(The amount of flow and capacity on each edge with first iteration)

Edge	Average arrival from initial node	Average Service at end node	Expected flow on the edge (f_e)	Capacity of edge (C_e)	Updated flow in forward edges (in Iteration 1)
(s,1)	30	28	20	30	28
(s,2)	25	24	15	25	15
(s,3)	10	9	6	10	6
(1,2)	5	5	3	5	3
(1,4)	23	21	17	25	25
(2,3)	9	10	4	10	4
(2,4)	10	9	6	10	6
(2,5)	10	9	6	10	6
(3,5)	19	19	10	20	10
(4,6)	30	30	15	30	23
(4,7)	11	11	6	12	6
(5,4)	10	11	5	12	5
(5,7)	8	8	4	8	4
(5,8)	10	09	6	10	6
(6,t)	39	39	20	40	28
(7,6)	10	9	6	10	6
(7,t)	13	13	7	14	7
(8,7)	5	4	3	5	3
(8,t)	4	4	3	5	3

In the above table-I, hypothetically data is used for the computational purpose. The average arrival rate of the commodity as well as average service rate are obtained by the sampling methods on each and every node of the random network. This is to provide the flow through finite capacity edges. The amount of flow is obtained computation on each links of the network.

TABLE-II (Updated flow in each iteration)

Edge	Iter.1	Iter.2	Iter.3	Iter. 4	Iter.5	Iter.6	Iter.7	Iter.8	Iter.9	Capacity of edge
(s,1)	28	28	30	30	30	30	30	30	30	30
(s,2)	15	17	17	21	21	21	23	25	25	25
(s,3)	6	6	6	6	7	9	9	9	10	10
(1,2)	3	3	5	5	5	5	5	5	5	5
(1,4)	25	25	25	25	25	25	25	25	25	25
(2,3)	4	4	4	4	4	4	6	8	8	10
(2,4)	6	8	10	10	10	10	10	10	10	10
(2,5)	6	6	6	10	10	10	10	10	10	10
(3,5)	10	10	10	10	11	13	15	17	18	20
(4,6)	23	23	23	23	23	23	23	25	26	30
(4,7)	6	6	6	10	10	10	12	12	12	12
(5,4)	5	3	1	5	5	5	7	9	10	12
(5,7)	4	4	6	6	6	8	8	8	8	8
(5,8)	6	6	6	6	6	6	6	6	6	10
(6,t)	28	28	28	28	28	28	28	28	28	40
(7,6)	6	6	6	6	6	6	6	6	6	10
(7,t)	7	7	7	7	7	7	7	7	7	14
(8,7)	3	3	3	3	3	3	3	3	3	5
(8,t)	3	3	3	3	3	3	3	3	3	5

In the table-II, focus on the iterated values of the amount of flow in the random network for getting the maximum flow through the network. In the last we obtain the stable network for the maximum flow. In the maximum flow network, we apply the CPM/PERT Techniques to obtain the delivery schedule time

TABLE-III (Daley in scheduling)

Activity	a	m	b	t_e	σ_e^2	$t_e - 3\sigma_e$	$t_e + 3\sigma_e$
s-1	15	17	20	17.17	0.69	14.68	19.66
s-2	10	15	18	14.67	1.78	10.67	18.67
s-3	15	17	21	17.33	1	14.33	20.33
1-2	14	17	20	17	1	14	20
2-3	8	11	14	11	1	8	14
1-4	16	20	25	20.17	2.25	15.67	24.67
2-4	13	17	19	16.67	1	13.67	19.67
2-5	15	17	20	17.17	0.69	14.68	19.66
3-5	10	13	16	13	1	10	16
5-4	9	13	18	13.17	2.25	8.67	17.67
4-6	10	12	15	12.17	0.69	9.68	14.66
4-7	11	14	18	14.17	1.36	10.67	17.67
5-7	10	13	17	13.17	1.36	9.67	16.67
5-8	14	17	21	17.17	1.36	13.67	20.67
7-6	13	17	22	17.17	2.25	12.67	21.67
8-7	16	20	25	20.17	2.25	15.67	24.67

6-t	9	13	17	13	1.78	9	17
7-t	11	14	18	14.17	1.36	10.67	17.67
8-t	19	22	27	22.33	1.75	18.36	26.30

The critical path of the delivery is $S \to 3 \to 5 \to 8 \to t$ and the expected delivery time is (17.33+13+17.17+22.33=69.83 time units) through critical path and its lower and upper bounds are 56.36 and 83.30 time .

TABLE-IV (Computation of costs)

Edge	$c_m(e_i)$ $C_e \times 10p/min$	$c_f(e_i)$ $f_e \times 15p/min$	$c_s(e_i)$ $\mu_v \times 5p/min$	$c_w(e_i)$ $f_e \times 10p/min$	Total cost on edge (in Rs/min)
(s,1)	3.00	3.00	1.40	2.00	9.40
(s,2)	2.50	2.25	1.20	1.50	7.45
(s,3)	1.00	0.90	0.45	0.60	2.95
(1,2)	0.50	0.45	0.25	0.30	1.50
(1,4)	0.25	2.55	1.05	1.70	5.55
(2,3)	1.00	0.60	0.50	0.40	2.50
(2,4)	1.00	0.90	0.45	0.60	2.95
(2,5)	1.00	0.90	0.45	0.60	2.95
(3,5)	2.00	1.50	1.35	1.00	5.85
(4,6)	3.00	2.25	1.50	1.50	8.25
(4,7)	1.20	0.90	5.50	0.60	8.20
(5,4)	1.20	0.75	5.50	0.50	7.95
(5,7)	0.80	0.60	0.40	0.40	2.20
(5,8)	1.00	0.90	0.45	0.60	2.95
(6,t)	4.00	3.00	1.95	2.00	10.95
(7,6)	1.00	0.90	0.45	0.60	2.95
(7,t)	1.40	1.05	0.65	0.70	3.80
(8,7)	0.50	0.45	0.20	0.30	1.45
(8,t)	0.50	0.45	0.20	0.30	1.45

In this table IV, we conclude maximum total costs for getting the delivery in random network of flow and also obtained the minimum total costs for completion of the commodity flow project.

Conclusion- In this paper, we mainly focus on the development of algorithm for the optimization of random flow of queued commodity in network. With the help of developed algorithm, we can obtain the network of maximum flow, Critical path of delivery of the commodity, maximum lead time of commodity from source to sink. Optimum cost of the commodity for maximum flow. Interval of the delivery scheduled time. Our further research would be the extension of the maximum flow problem, with the existence of multiple sources and multiple sinks, requires only a minor change in our original network model. The network is modified to include a super-source node which is connected to the multiple sources via links unrestricted in capacity and likewise, the multiple sinks are connected to the super sink by uncapacited links.

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THE SUPPLY CHAIN OF RELIEF MATERIALS: A GUIDELINE FOR CONTAINER PORTS IN SUB-SAHARAN AFRICA

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Abstract *− In a world of growing crisis, both natural and political, the operations of humanitarian organisations, which provide relief to critically affected communities, have become increasingly significant. The increase in the spate of disasters in Sub-Saharan Africa continues to generate interest, particularly in the supply chain of relief materials to the victims of disasters. However, little work has been done on humanitarian logistics in developing countries. The importance of this research lies in the development of a guideline that outlines the processes in the supply chain of relief materials handled at Sub-Saharan African ports and reduces cargo dwell time through the use of appropriate documentation. Prior to this research, there were no such guidelines that the stakeholders could use.*

Keywords *− Cargo dwell time; Container ports; Guideline; Humanitarian logistics; Relief materials; Sub-Saharan Africa*

INTRODUCTION

In a world of growing natural and political crises the operation of humanitarian organisations, which provide relief to critically affected communities, have become increasingly significant [1]. With the increased relevance of disaster relief and development programs on a global scale, more and more research is being conducted to improve the efficiency of humanitarian logistics around the world [2].

The increase in the spate of disasters in Sub-Saharan Africa continues to generate interest particularly in the supply chain of relief materials to the victims of disasters [3]. However, [4] aver that little work has been done on humanitarian logistics in developing countries. This identified the importance of conducting research on supply chain management, specifically for the handling of relief materials in developing countries.

Reference [5] confirmed that the field of humanitarian logistics is in need of both conceptual and empirical studies in order to improve the field. They also emphasised the fact that the majority of research conducted in the field of humanitarian logistics focuses on Asia. This identified the need for this research to focus on Sub-Saharan Africa.

This study focuses on selected container shipping lines and freight forwarding companies and selected humanitarian organisations that have a wide coverage in selected Sub-Saharan African ports. It provides solutions to the problems that affect the seamless flow of the supply chain of relief materials. This research is critical to Africa, because ten of the world's 20 most disaster-prone countries are in Africa [6].

The importance of this research lies in the development of a guideline that outlines the processes in the maritime supply chain for selected ports and reduces cargo dwell time through the use of appropriate documentation. This paper is categorized into the sections as follows; section 2 covers the literature review, section 3 outlines the methodology, section 4 presents the results and discussion, section 5 draws the conclusions and section 6 provides the recommendations.

LITERATURE REVIEW

Reference [7] defines a port as "a logistics and industrial centre of an outspokenly maritime nature that plays an active role in the global transport system (for containerized cargoes) and that is characterized by a spatial and functional clustering of activities that are directly and indirectly involved in seamless transportation and information processes in production chains." This definition of a port was chosen for this study, because relief materials are predominantly transported via container ports [8].

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Container ports serve as an important node in facilitating the efficient flow of containerized cargoes [7]. A container port is further differentiated by its functions, which consists of serving primarily as a gateway port that acts as an interface between hinterland and deep-sea routings of containerized cargoes, or of serving primarily as a transhipment port that acts as an interface for interchange between deep-sea routings of containerized cargoes [7].

Natural Disasters

According to [9], "natural disasters occur throughout the world, but their economic and social impacts have been increasing and are generally much greater in developing countries than in developed ones. Disasters can wipe out development gains and eclipse years of development investment". Historically, disasters were treated as one-time, random events by governments and the agencies that helped them responded accordingly. Currently, disasters strike with regular periodicity - and repeatedly in some parts of the world. The potential for disaster is foreseeable to the extent that it is possible to predict generally where an event is likely to occur at some time in the near future (but not precisely when or what its magnitude will be) [9].

The objective of an effective supply chain for relief materials is to provide humanitarian assistance in terms of food, water, medicines and shelter to areas affected by disasters. When a disaster or conflict occurs, the ports in Sub-Saharan Africa have a role to play in any of the three phases of humanitarian logistics. In the preparatory stage, ports can be used as a preventive medium; this means materials and resources can be shipped to areas that are prone to disasters or conflict. In the immediate response stage, the port is instrumental in ensuring that the necessary resources are made available for the nation in the midst of a disaster. In the reconstruction stage, major building equipment is shipped through the ports for the reconstruction and development of the country.

A successful humanitarian operation is one that mitigates the urgent needs of a population within the shortest time and with least amount of resources [10]. The humanitarian supply chain is agile as well as unpredictable [4]. The implication of this is that it is flexible in the midst of severe disruption. On the other hand, the supply chain may actually break, therefore, causing the failure of the whole process.

Delays at the Port

A port can contribute to the unpredictability of a maritime supply chain when there are delays in the clearance of shipments at the port of destination. Disruptions of port operations can have a detrimental effect on the supply chains of relief materials [11]. Other causes of delay at the port include a lack of infrastructure or cargo handling equipment, which may not be enough to handle the flow of cargo. In addition, the cargo handling equipment may not be in good condition, causesing further delays at the ports [12].

Ports have various policies that govern how cargoes are cleared [13]. Most humanitarian officials may have to rely on shipping agents to assist in clearing the relief materials. Delay arises when the humanitarian organisation does not provide the shipping agents with all the required documents to facilitate the clearing of the relief materials [13]. In addition, a lack of understanding on the necessary documents can lead to delays in the clearance of shipments [13].

Port Congestion is another cause of delays at a port. Reference [14] defines port congestion as the period "when port users interfere with one another in the utilization of port resources, thereby increasing the time spent in the port. Port congestion can be intentional or unintentional". Reference [14] further differentiates between the two categories of congestion. Intentional congestion occurs when there is pre-emptive priority, for example, when a port grants priority to ships or vehicles transporting a certain type of cargo over ships or vehicles transporting another type of cargo. Unintentional congestion occurs when the demand for the use of a port resource exceeds its supply. This type of congestion occurs in the normal utilization of port resources. Port queuing (waiting time) costs are part of congestion costs [14].

In order for the logistics chain to operate efficiently and at the lowest cost, the whole chain must act at the same speed, the links in the chain must act as equal partners, and the management of the chain must become closely integrated [15]. The implication of this is that interruption in the supply chain will increase the risk of waste in the form of damage or pilferage [16]. The effect of delays on the supply chain is that it will result in an increase in the costs. Procedures at the ports such as lengthy clearance time raise the inventory and financing costs by up to 30% for firms [17]. The significance of delays on the supply chain of relief materials is that it can affect its success or failure. Prolonged delays can actually spoil or damage the consignments if adequate arrangement is not made for its storage. For example, in 1984 at the Port of Assab in Ethiopia, unexpected rain spoilt 10 000mt of grain due to the inexperience of the Port Authority. Furthermore, the food management personnel did not take the necessary measures to save this commodity after the rain [18].

The Criticality of Proper Documentation for Seamless Flow of the Supply Chain

Global transportation involves the movement of goods from one country to another making use of various modes of transport [19]. One of the major challenges in global transportation is maintaining and controlling freight as it moves across borders and is handled between carriers and intermediaries [19]. Timely information sharing and the use of technology can vastly improve shipping visibility. Proper freight documentation ensures compliance with government regulations and facilitates the uninterrupted flow of goods through potential bottlenecks at border crossings and ports [19]. Paperwork may seem like a simple issue in this era of information technology, but there are still communication channel challenges. This is because more are involved in global transactions, therefore, the country of export, country of import, transportation companies, banks and importers all require varying documents [19]. Freight documentation controls the cargo on its journey from the origin in the country of export to its final destination in the country of import [19]. Missing or incorrect paperwork can cause delays and additional costs. A failure to provide complete cargo information 24 hours prior to loading at an international seaport can lead to denial of loading, fines and penalties. Paperwork errors can lead to customs clearance delays, additional inspection and improper application of duty rates. Hence, proper and accurate documentation is critical to the timely and cost efficient flow of international cargo [19].

Training

Natural disaster management requires role players to be properly trained to handle an emergency [20]. It is important that ports and humanitarian organisations focus on specialised training for their personnel. When there is a limited number of trained personnel and staff, it causes many problems when disasters occur.

The Role of a Guideline

Transportation is the second highest cost of any humanitarian operation and the highest logistics cost [21]. Prolonged delays at the port have further contributed to this cost [22]. Lack of exemption from customs and other difficulties in customs procedures translates to lack of preparedness in the country [5]. The generic guideline developed through this research is primarily aimed at reducing the cargo dwell time in ports in Sub-Saharan Africa. It is expected that when the shippers know the correct information and documentation to provide to the ports, it will reduce the cargo dwell time. This guideline is intended to provide information and best practice guidance to port users and other members of the maritime supply chain that have the responsibility for ensuring and/or facilitating maritime trade during emergency situations. For example, East African countries with sea ports such as Tanzania and Kenya have an important role to play in the delivery of relief materials to landlocked countries such as South Sudan, Ethiopia, Uganda and the Central African Republic. Any delay at the Port of Mombasa or the Tanzania International Container Terminal will lengthen the process of delivery at the destination country.

This guideline may be adopted by the Port Authority and other stakeholders at their own discretion. The guideline is not intended to form the basis for a mandatory instrument. The guideline stresses the importance of communication between the Port Authority and other port users in improving supply chain resilience and in facilitating maritime trade.

METHODOLOGY

This research is qualitative in nature and leans towards an inductive methodology. A qualitative method was used due to lack of prior research conducted on guidelines for the seamless flow of relief materials via the ports. This research focused on the ports, shipping lines and freight forwarding companies and humanitarian organisations as the units of analysis. The research instruments used for the qualitative research methods included semi-structured interviews; telephonic interviews and questionnaires (electronic and hard copy).Seven container ports of entry were selected from Southern, East and West Africa, namely the Port of Tema in Ghana, Port of Walvis Bay in Namibia, Tanzania International Container Terminal, Ports of Durban and Cape Town in South Africa and the Port of Mombasa in Kenya. These container ports were chosen, because they were points of entry for relief materials to regions experiencing natural disasters or conflict at the onset of the research.

Seven shipping lines and freight forwarding companies were used, because of their coverage, as they do business with 54 countries in Africa. The shipping lines and freight forwarding companies have experience in handling relief materials in containers and these shipping lines and freight forwarding companies have been exposed to the challenges of Africa, for example, infrastructural problems in West Africa.

Six humanitarian organisations were selected, because of their coverage, as most of the humanitarian organisations have offices in at least half of the 54 nations in Africa. These humanitarian organisations have experience sending relief materials to regions in Africa. They know and understand the needs. In terms of exposure, these humanitarian organisations have been exposed to incidences of natural disasters and conflict.

RESULTS AND DISCUSSION

Relief materials are sent via different modes of transport, but the focus of this guideline is on relief materials sent via deep-sea transport in container vessels to affected Sub-Saharan African nations. This consequently poses a significant demand on the port system to facilitate the clearing of these emergency containers without affecting normal port activity. As speed is important when supplying relief materials, ports should not cause a bottleneck in the supply chain of relief materials [23].

It was observed during the course of the research that there are currently no guidelines in place for the handling of relief shipments. Consequently, interviews were conducted with shipping lines and freight forwarding companies to determine the need for a guideline for humanitarian logistics. Eighty six percent (86%) of the shipping lines and freight forwarding companies interviewed were in favour of having a set of guidelines to govern humanitarian logistics operations and practices.

The shipping lines and freight forwarding companies were asked to indicate what they considered to be important to include in the development of a guideline for humanitarian logistics. The collective answers are listed below:

- Priority berthing
- Co-operation amongst customs and port authorities
- Listing of all documentation required to ensure quick customs release
- Vessel waiting time and cargo standing time
- Special customs procedures
- Preferential treatment
- Waiving/reduction of certain terminal costs
- Time frames for unloading/loading of relief cargo
- Communication
- Special staff incentives (for after-hours shifts)
- Equipment
- Stacking areas
- Personnel

The six humanitarian organisations covered in this research are representative of humanitarian organisations by virtue of their scope, coverage and expenditure in Africa. From the interviews conducted with the humanitarian organisations, it was clear that some of the humanitarian organisation officials do not know who to meet with at the ports in order to assist them in the expediting of relief materials and this causes unnecessary delays. When asked about the need for a humanitarian logistics guideline only one of the six humanitarian organisations consulted (17%) was unsure about the need for a guideline. However, representatives from this organisation mentioned that they would be interested to see how the set of guidelines would be implemented and might adopt it.

From the field work conducted on ports in Sub-Saharan Africa it was observed that one of the reasons why relief containers are delayed in the port is that the port users do not have all the information or documentation required and as a result they cannot fulfil the requirements of the terminal operator. The guideline developed in this research is aimed at enabling the port users and Port Authorities to expedite action on the maritime supply chain of relief materials. It is intended to prevent any form of information or communication confusion.

The ports were asked whether they gave their employees specialised training in the handling of relief materials and if so, what type of training they give their staff. Half of the ports responded that they trained their staff, but it was on-the-job training. The rest stated that they did not provide specialised training for handling relief materials. Therefore, it is evident that the skills shortages in the supply chain for relief materials are yet to be alleviated.

The guideline developed combines all the information collected through the research into a checklist that can be used by ports, shipping lines and freight forwarding companies and humanitarian organisations to improve the overall efficiency and effectiveness of their supply chains for relief materials. The guideline provides the stakeholders with prior knowledge regarding the steps for clearing or receiving incoming relief materials, for both food items and non-food items, including the documentation involved in each step and the personnel responsible for each step. The purpose of the guideline is to perform the following functions:

- Provide a step-by-step process of clearing cargo at the port
- Prevent chaos and confusion
- Reduce human error
- Allow for proper communication amongst the stakeholders
- Reduce theft and damages
- Enable port users to have the necessary information to expedite the clearing of relief containers

Figure 1 shows the generic flow of documents from the humanitarian organisation to the point where the shipment is cleared from the gate. (The specific documents required by each of the ports investigated, are listed in the guidelines.) The humanitarian organisation contacts the shipping lines. The shipping line contacts the shipping agents, who submit the important basic documents such as the commercial invoice, packing list and the bill of lading to the customs as well as to the container terminal. The customs issue a custom clearance, which is submitted to the shipping line. After all documents have been verified and authenticated by the ports and customs, the container is cleared.

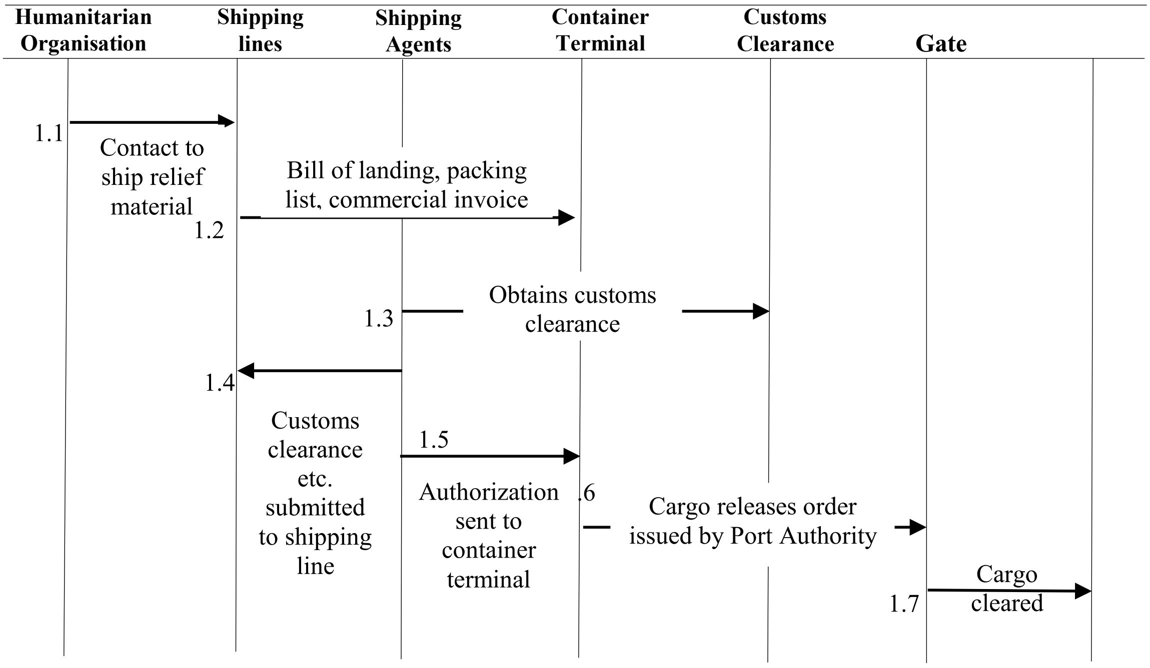

Figure 1: Generic import document flow

The generic guideline was tested for use at the Port of Durban container terminal. This guideline focused on maritime stakeholders that make use of the Port of Durban container terminal; but have no idea about the processes involved in the clearing of relief shipments at the Port of Durban. The guideline helped in reducing the dwell time of the Corn Soybeans shipment that was en-route for Zimbabwe via the Port of Durban. The containers were cleared within 36 hours of entering the Port of Durban.

CONCLUSIONS

The ports, shipping lines and freight forwarding companies and humanitarian organisations face an increasingly challenging situation, owing to the surge in natural disasters and conflict situations. The onus is on maritime stakeholders to work together to ensure that humanitarian shipments are not unduly delayed at the ports.

The purpose of developing a guideline for the handling of relief materials in Sub-Saharan African ports is to assist in reducing the cargo dwell time at the ports. This guideline, if adopted, will facilitate streamlining the supply chain of relief materials by reducing cargo dwell time in the ports, thereby saving costs for all the maritime stakeholders.

Furthermore, logistics activities (from purchasing to the last-mile delivery of items) account for a large share of the cost in any disaster relief operation. Any improvement in the way logistics provides humanitarian assistance has the potential to deliver a positive impact on the people affected. The role of ports and how they can become more efficient in providing this important function during natural disasters and consequent humanitarian emergency relief aid have not received the attention they deserve. Since seaports are vital elements in the logistics and supply chain process of humanitarian emergency relief aid [24], it is important that they are efficient.

The humanitarian supply chain cannot be viewed in isolation. Rather, it has to be viewed holistically, i.e. to incorporate all the stakeholders. It is important for the stakeholders to be aware of the challenges they face in order to pave the way for progress and productivity. The guideline developed in this research is intended to ensure that all the stakeholders perform their roles and responsibilities to reduce confusion and chaos in the supply chain of relief materials.

The generic guideline was developed to prepare maritime stakeholders for the clearing of emergency shipments. It shows steps to be followed for the clearing of humanitarian shipments at any Sub-Saharan African port. All the required documents are listed and important issues that maritime stakeholders should take into consideration are provided. A generic import document flow is included in the guideline in order to elucidate the process. In addition, the generic guideline mentions the various responsibilities for each of the maritime stakeholders and a relief container checklist was also designed to assist all the stakeholders.

Collaboration between the stakeholders is important to the overall efficiency of the guideline. Clear and constant communication and information is critical for the effectiveness of the supply chain of relief materials.

RECOMMENDATIONS

Timeline

Due to of the emergency nature of the relief materials, they need to be handled with speed. A timeline, which shows the date and time of day that the port specifies for each of the activities for handling the relief materials, should be drawn up by the port. This information should be made known to the shipping lines and freight forwarding companies as well as to the humanitarian organisation to ensure the efficiency and effectiveness of the operations. It also allows the stakeholders to know how to plan their time, people and resources. Timelines are also a function of the co-operation of all the stakeholders as they ensure that all the necessary information is given to the ports when required.

Training

The research identified the need for continuous training for port operations officials involved in the handling of the relief materials, in terms of the key line officials, in areas relating to the scope of practice. Training for port officials is essential. It helps to:

- Determine competence
- Improve and retain staff
- Task-shifting is avoided
- Proper training promotes efficiency

Effective collaboration between the stakeholders is encouraged in order to enhance productivity.

Prioritization

It would be of great benefit to humanitarian supply chains if ports in Sub-Saharan Africa give the shipments of relief materials top priority.

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CONCEPTUALIZING INITIAL FRAMEWORK OF A SHIP PERFORMANCE MONITORING SYSTEM WITH STATISTICAL LEARNING

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Abstract *– Promoting a sustainable maritime transportation concept, the International Maritime Organization (IMO) has also launched the theme of World Maritime Day 2017 entitled "connecting ships, ports and people". To achieve safety, security, and environmental related expectations, monitoring of the performance along with the key operations is become a critical expectation. This paper initiates a framework including data sources, alternative methods, literature and industrial survey protocols to conduct ship performance monitoring studies. Theoretical models, statistical models, and hybrid models are discussed in detail along with the study. Besides the required research potential, this study identifies the existing challenges and opportunities of the model proposal. The developed framework guides to the modelling and demonstration studies on ship performance monitoring.*

Keywords *– ship performance management, statistical learning, ship operation management.*

MOTIVATION

Maritime has been one of the most important international transportation mode that responsible for over ninety percent of global trade. In order to remain the sustainable international transportation mode, International Maritime Organization (IMO) has launched the concept list that aspire to establish a sustainable maritime transportation. The list consists of the safety culture and environmental stewardship; education and training in maritime professions, and support for seafarers; energy efficiency and ship-port interface; energy supply for ships; maritime traffic support and advisory systems; maritime security; technical co-operation; new technology and innovation; finance, liability and insurance mechanisms; and ocean governance. The concept has a positive impact on maintaining a light on the issues to be discussed in the maritime industry in the forthcoming periods. Furthermore, there are increasing pressure on the maritime shareholders (especially ship owners and operators) to improve their operational decisions in terms of reducing the fuel consumption and/or maximizing profit. Since the rising fuel price has an unfavorable effect on the operating cost, improving fuel efficiency is considered as a key aspect to remain competitive [14].

IMO has implemented new amendments on the International Convention for the Prevention of Pollution from Ships (MARPOL) to restrict the greenhouse gases (GHGs) emission from ships. To illustrate; Energy Efficiency Design Index (EEDI) for new ships and the Ship Energy Efficiency Management Plan (SEEMP) for all ships, Energy Efficiency Operational Indicator (EEOI), which is a voluntary technical measure for ships in operation. Hence, evaluation a ship performance is become a necessity with respect to improve the ship operational management and achieve regulatory compliance [4].

To specify the ship performance monitoring advantages on a ship, following examples are highlighted. The operational real time optimization, maintenance purposes, evaluating technological interventions, operational delivery plan optimization, fault analysis, charter party analysis, vessel benchmarking, and inform policy are some of them. To illustrate, ship performance monitoring also generates fundamental conditions to inform authorized parties to prove complying with regulations and conventions, such as; Monitoring, Reporting and Verification (MRV) regulation [2].

Even if the several ship performance monitoring models that have been utilized, new technological developments (electronic logbooks and wireless data transmission from ships) and advance statistical methods may improve the existing models accuracy. Therefore, there is a need for new ship performance monitoring models that based on the advance statistical models and automatic data collection systems.

As indicated above, ship performance monitoring is an increasingly growing research area since it has a huge potential to improve wide range of aspects in maritime industry. Thus, motivation behind this study is to proposing a ship performance monitoring system that enable to evaluate a ship performance, and improve the operational ship performance to contribute sustainable maritime transportation. The rest of this paper is organized as follows: The current section emphases the significance of the ship performance monitoring and the motivations behind the study. At the second section, theoretical background of the ship performance monitoring is comprehensively examined. Proposed research framework is introduced at the third section. Potential and expected impacts of the proposed research in maritime industry is underlined at the final section.

THEORETICAL BACKGROUND

Ship performance monitoring related studies are divided several sub-section with respect to the utilized model. Theoretical models (physical / white box / deterministic) are based on physical behavior of a ship system. Statistical (black box) modelling is mainly driven by data to determine model parameters and the relations among them. The hybrid models (grey- box) combine both methods (white box and black box) to improve the models accuracy [2]. According to the [9] trend analysis and system identification also eligible models that might be used for ship performance monitoring. Trend analysis covers long-term performance analysis that trend curves is the simplest form of performance analysis. System identification is mainly based on the special periodic maneuvers to obtain information about the ship capabilities, which are comparable with the trial runs. Ship performance can be monitoring with numerous ways that taking advance of the meaningful indicators, such as; fuel consumption, ship speed vs. fuel consumption, ship speed vs. delivered power, and RPM vs. torque etc. Since each indicator have its own characteristic, it is important to note that comparing the indicators may cause misinterpretation [7].

There are several studies that based on the theoretical models. [7] has used the theoretical models for fuel oil consumption monitoring and trim optimization program. [1] has taken advantage of the theoretical models for added resistance in wind and waves and the effect of rudder angle and shallow water in ship performance monitoring. [9] have conducted an investigation to develop an advanced ship performance monitoring and analysis system that support real-time ship performance monitoring. [15] have presented the main steps for the development of a multi-physic simulation platform for a twin-screw ship in 6 degrees of freedom, taking into account the complete propulsion system including automation effects. [13] have carried out a study that aimed to prediction of ship operational performance for Suezmax and Aframax Oil Tankers. The study mainly based on the semi-empirical ship operational performance prediction model. [8] have proposed the use of Speed–Power curves with the multiple linear regression model for fuel consumption monitoring. [20] have conducted a research that evaluate a bulk carrier ship performance, which based on the onboard measurement system.

Statistical models also have been widely used in the ship performance monitoring. One of the first statistical based ship monitoring studies have been conducted by [12]. The study clearly shows that many variations can be reduced by using multiple regression techniques. [16] have compared Artificial Neural Networks (ANN) and statistical linear and non-linear regression models, in terms of accuracy of fuel consumption prediction. [18] have compared Gaussian Processes (GP) and ANNs in terms of the predicting the ship fuel consumption and speed from a set of measured features. [19] have implemented a time-delay neural network to predict the response of a range of dynamic variables (speed, trim, draught, and heading) to a change in control variable (pitch, rudder angle, current, headwind and crosswind).

In the grey-box modeling perspective, [11] have implemented a model for ship operational optimization. The study has investigated the two different ways of combining white and black box models; series and parallel. [3] have investigated the sources of uncertainty in performance measurement, and present a method to quantify the overall uncertainty in a ship performance indicator based on the frame work of the "Guide to Uncertainty in Measurement using Monte Carlo Methods". The study has compared the two major data acquisition strategies, continuous monitoring and noon-report, which is a daily report from ship to shore that consist of the data provides the vessel's position and other relevant standardized data to assess the ship performance. [5] have examined the problem of predicting the fuel consumption of a vessel in real scenario based on data measured by the onboard automation systems. The study goal is achieved by exploiting three different approaches: white, black and gray box models. [6] have utilized the advance statistical approaches for the same problems of predicting the fuel consumption and providing the best value for the trim of a vessel in real operations based on measured data gathered by the onboard automation systems. The research has used the Regularized Least Squares (RLS), the Lasso Regression (LAR), and the Random Forrest (RF) models.

Although the all models have offer valuable potential to improve the ship operational management, reduce the fuel consumption, and achieve regulatory compliance; there are several drawbacks that researcher have mentioned about these models. Considering the trend analysis; without paying attention to data quality and uncertainties in the data points, it might be easily cause to misleading conclusions. Despite the potential interaction, system identification techniques have not gained practical interest since its required special maneuvers, still in development phase, and moreover predicts the resistance lower than the traditional techniques [9]. There are also several weaknesses of theoretical models, such as; interaction effects between components of added resistance are not taking into account, and models not validated with data for the ships to which they are applied [2]. The statistical models disadvantages are mainly difficult to detect the significance of input variables and to understand the actual physical relationships between variables.

Despite the ship performance monitoring potential to improve numerical aspect of the shipping industry, limited researches on ship performance monitoring have been undertaken so far. Particularly, the researches mainly focused on theoretical and grey box models. To clarify the literature studies tendency, Table 1 chronologically marked the applied statistical learning methods that can be used for ship performance monitoring. According to the Table 1, theoretical based models are the most preferred models and generally used with the basic statistical models. The table also pointed out that researcher have not taking advantage of the advance statistical models in the ship performance monitoring. Only basic statistical models have been utilized (LR or MLR). Thus, researchers and practitioners may improve the ship performance monitoring models with regarding to using the advance statistical models.

Even if the statistical models have some minor disadvantages, dynamic working environments require the taking into consideration to utilize advance statistical models. Advanced statistical models can reveal relations in the dynamic working environment so it’s become easy to interpret any complicated working environment. Moreover, non-linear statistical models can provide better accuracy prediction of dynamic working environment. Therefore, the study is aimed to develop a ship performance monitoring model that based on the advanced statistical models to contribute shipping industry and literature.

Table 1: Review of applied statistical methods on ship performance.

Reviewed Studies	Applied Methods													
	Regression		Regularization Based Regression		DR Based Regression		Non-LR	Tree-Based Methods			Non-linear ANN	Monte Carlo	GMMs	PCA	Other
Author /Year	LR	MLR	Ridge	Lasso	PCR	PLS	GAMs	Bagging	RF	Boosting					
Eljardt, 2006															x
Leifsson et al. 2008											x				x
Petersen and Larsen, 2009											x				
Aas-Hansen, 2010	x	x													x
Hasselaar, 2011	x	x													x
Petersen et al., 2012-a											x		x		
Petersen et al., 2012-b											x				x
Mak et al., 2014															x
Martelli et al., 2014															x
Erto et al., 2015		x													x
Lu et al., 2015															x
Coraddu et al., 2015			x												x
Aldous et al., 2015												x			
Sasa et al., 2015		x													
Perera, 2016													x	x	
Coraddu et al., 2017				x					x						x
Perera and Mo, 2017													x		x

PROPOSED RESEARCH FRAMEWORK

Taking into consideration the IMO sustainable concept (especially environmental stewardship, energy efficiency, and new technology and innovation) and new ship operational management requirements, the aim of the study is to propose an outline for advance ship performance monitoring model for merchant shipping to evaluate ship performance with high accuracy. The proposed ship performance monitoring outline will be mainly based on the advance statistical learning approaches. Moreover, experienced specialist opinion also might be included in order to clarify the linear or nonlinear relation between the variables and parameters if needed. Statistical learning approaches heavily depend on the data quality, therefore; it is required to using the real shipping operational data that gathered from data acquisition systems and/or signal processing techniques on board ships. Engine, propeller and hull performance under the environmental, loading and operational conditions are the main components of the ship performance. It is essential to obtain the all these shipping operational and environmental data at the same time, such as; shaft torque, rudder angle, ship speed through water, water depth, engine speed, wind speed and direction, ship speed over ground, water depth, course over ground, ship motion, heading. The environmental (sea state, wind speed, sea/air temperature, etc.), loading effects on a ship performance is complicated to quantify in combination, due to the characteristics of all interconnectivity. Using the advance statistical learning models can help to explain the how ship performance influenced under different circumstances. Tree-Based Methods, Regularization Based Regression, and Dimension Reduction Regression etc. methods are some of the qualified advance statistical models that can be utilized in the ship performance monitoring. Figure 1 represents the proposed model framework.

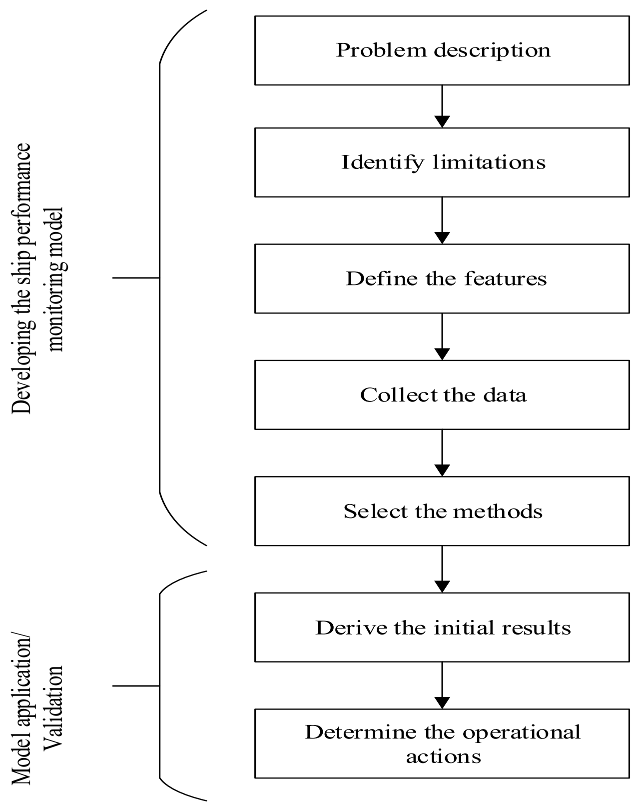

Figure 1: Initial framework of the proposed model

CONCLUSION

As the IMO pursues the sustainable transportation concepts and ship operational requirements demand reducing a ship fuel consumption and/or maximizing profit, monitoring ship performance is the key issue at this perspective. Even if the shipping literature exemplifies several ship performance monitoring model, the study is aimed to propose advance statistical based solution to ship performance monitoring problem. Besides, new data gathering technologies (electronic logbooks and wireless data transmission from ships) provide valuable opportunities that wide range of reliable ship operational data become available. Therefore, the study is aimed to investigate fundamental research for the ship performance analysis via the advanced statistical methods. Considering the reliable ship operational data is precondition for ship performance monitoring, improved data collection methods have been considered. In order to optimize ship operation, ship operation characteristic and important variables, outputs, and their relation must be determined. Therefore, this study has an immense potential to contribute both shipping literature and industry.

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THE IMPACT OF BUSINESS ANALYTICS APPLICATIONS ON SUPPLY CHAIN PERFORMANCE: A LITERATURE REVIEW

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Abstract – *The discipline of supply chain management has deep roots in analytical mastery. Companies that have excelled in this area have a decades-long history of using quantitative analysis to optimize logistics. Analytics took a great leap forward when companies began using them to improve their external processes- those related to managing and responding to customer demand and supplier relationships. The widespread use of digital technologies has led to the emergence of big data business analytics as a critical business capability. Many companies in a variety of industries are enhancing their customer relationship management (CRM) and supply chain management (SCM) capabilities with advanced analytics and they are enjoying market-leading growth and performance as a result. The aim of this study is to make a literature review based on Science Direct and to highlight the evolving nature of the SCM environment using a taxonomy which is based on the keywords related to the use of descriptive, predictive and prescriptive model at strategic, tactical and operational decisions in each stage of Supply Chain Operations Reference (SCOR) model process performance areas (Plan, Source, Make, Delivery, and Return. By this way, the areas that require further research to embrace the trends and to make recommendations to supply chain managers are highlighted. Our research reveals that the majority of investigated papers fall in the area of corresponding to the use of business analytics in "Sourcing" decisions especially at strategic level. Additionally, the major types of these strategic sourcing decision papers are prescriptive. In fact, prescriptive analytics-related papers are also dominant in all decision levels of "Make" and "Delivery & Return" stages of SCOR.*

Keywords – Business Analytics, Supply Chain Analytics, Big Data, Supply Chain Performance Management, Supply Chain Operations Reference (SCOR) Model

INTRODUCTION

The amount of data produced and communicated over the Internet is significantly increasing, thereby creating challenges for the organizations that would like to reap the benefits from analyzing this massive influx of big data. This is because "big data" can provide unique insights into market trends, customer buying patterns, and maintenance cycles, as well as into ways of lowering costs and enabling more targeted business decisions.

The widespread use of digital technologies has led to the emergence of big data business analytics as a critical business capability to provide companies with better means to obtain value from an increasingly massive amount of data and gain a powerful competitive advantage [18]. The way to keep up with this increasing variety of data sources is through better use of big data analytics [47]. Davenport and Harris provide a definition of analytics as follows: '*By analytics we mean the extensive use of data, statistical and quantitative analysis, explanatory and predictive models, and fact-based management to drive decisions and actions*' [26].

For organizations the use of basic descriptive statistics is fairly straightforward, but companies competing on analytics look well beyond basic statistical analysis. One of the major trends over the last number of years that affects companies in every sector of the economy is the realization for the need to move towards more accurate, data-driven insight to achieve effective decision making. Court highlights the growing value of advanced analytics: "Advanced analytics is likely to become a decisive competitive asset in many industries and a core element in companies' efforts to improve performance [25]. Waller and Fawcet define Advanced Analytics *as the scientific process of transforming data into insight for making better decisions* [104].

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Lustig et al proposed a classification of advanced analytics in three main sub-types [68]. 1) *Descriptive analytics* answer the question of "*what happened?*" or "*what is happening?*" Descriptive analytics derives information from significant amounts of data. These are the data analysis made to describe a past business situation in a way that trends, patterns and exceptions become apparent. The first level of analytics explores what has occurred as a way to gain insight for better approaching the future. Descriptive analytics prepares and analyses historical data, and identifies patterns from samples for reporting trends. 2) *Predictive analytics* answer the question of "*what could happen?" or "what will be happening?"* Predictive analytics analyses real time and historical data to make predictions in the form of probabilities about future events. They encompass technology able to learn from data, based on the machine learning techniques and other computational algorithms of data mining. Predictive analytics are typically algorithmic-based techniques. Predictive analytics predicts future probabilities and trends, and finds relationships in data that may not be readily apparent with descriptive analysis. 3) *Prescriptive analytics* answer the question of "*what should be happening?" or "what is the best outcome given a set of circumstances?"* Prescriptive analytics use predictions based on data to inform and suggest proposed sets of actions that can serve to take advantage or to avoid on a particular outcome. Prescriptive analytics derives decision recommendations based on descriptive and predictive analytics models and mathematical optimization models. They also include the study of addressing variability on the expected outcomes by what/if scenario analysis or game theory. Prescriptive analytics are mainly associated with optimization and simulation, and have special relevance in contexts of uncertainty (i.e. where deterministic algorithms are infeasible) relying on stochastic computational programming of random variables. Prescriptive analytics evaluates and determines new ways to operate, targets business objectives, and balances all constraints.

The impact or potential impact of big data business analytics has been widespread in many different sectors, and certainly also the Supply Chain Management (SCM) and logistics area. Analyzing enormous amounts of information from disparate databases provides supply chain managers with the ability to improve supply chain performance. [47]. The application of advanced business analytics in SCM derived in the appearance of Supply Chain Analytics (SCA), a subset of technologies part of the extended supply chain and the precedent of what big data business analytics is considered today in SCM. Companies highly expect to capitalize on big data business analytics in logistics and supply chain operations to improve the visibility, flexibility, and integration of global supply chains and logistics processes, effectively manage demand volatility, and handle cost fluctuations. SCA are tools and techniques that are dedicated to harnessing data from a wide range of internal and external sources to produce breakthrough insights that can help supply chains reduce costs and risks whilst improving operational agility and service quality. SCA focuses on analytical approaches to make better decisions regarding material flows in the supply chain and to make decisions that better match supply and demand [90]. Descriptive SCA applications center on the use of data from global positioning systems (GPSs), radio frequency identification (RFID) chips, and data-visualization tools to provide managers with real-time information regarding location and quantities of goods in the supply chain. Predictive SCA centers on demand forecasting at strategic, tactical, and operational levels, all of which drive the planning process in supply chains in terms of network design, capacity planning, production planning, and inventory management. Finally, prescriptive SCA focuses on the use of mathematical optimization and simulation techniques to provide decision-support tools built upon descriptive and predictive analytics models [90].

SCA describes a new paradigm where models have to be proactive to data instead of reactive. When the focus is on logistics and supply chain strategy, SCA is applied in sourcing, supply chain network design, and product design and development at the strategic level. For tactical/operational level decisions, SCA involves analyzing and measuring supply chain performance on demand planning, procurement, production, inventory, and logistics. Hence, SCA is useful for improving organizations operations efficiency, measure supply chain performance, reduce process variability, and implement the best possible supply chain strategies at the tactical and operational level [105]. In the strategic phase of supply chain planning, SCA plays a vital role. It has been applied to help companies make strategic decisions on sourcing, supply chain network design, as well as on product design and development. In the operational planning phase, SCA has been used to assist management in making supply chain operation decisions, which often include demand planning, procurement, production, inventory, and logistics [105].

Wang et al reviewed and classified the literature on the application big data business analytics on Logistics and Supply Chain Management (LSCM), based on the nature of analytics (descriptive, predictive, prescriptive), and the focus of the LSCM on strategic, tactical and operational levels [104]. The study highlights the role of SCA in LSCM, and denote the use of methodologies and techniques to collect, disseminate, analyze, and use big data driven information. Waller and Fawcett proposed definitions of logistics and supply chain predictive analytics [103]. *Logistics predictive analytics* use both quantitative and qualitative methods to estimate the past and future behavior of the flow and storage of inventory, as well as the associated costs and service levels. *Supply chain predictive analytics* use both quantitative and qualitative methods to improve supply chain design and competitiveness by estimating past and future levels of integration of business processes among functions or companies, as well as the associated costs and service levels.

The Supply Chain Operations Reference Model (SCOR) is a process reference model endorsed by the Supply Chain Council as the framework to identify, evaluate, improve, and monitor the performance of supply chain. The model of SCOR is a system for performance measurement at various levels that covers the Supply Chain processes (Plan, Source, Make, Deliver, and Return). In this study SCA is defined as applying different analysis techniques on the data to give the answers of the questions or solve the problems related to four spots of SCOR.

Chae and Olson proposed a framework for understanding how business analytics can support supply chain organizations [12]. Firms need to possess the analytical capability to handle four supply chain processes- Plan, Source, Make, and Deliver. These four processes have significant roles in facilitating supply chain activities and improving the overall business performance. *Analytical capability for the Planning process*: Analytical IT resources can play two major roles in the Plan process: demand planning and supply planning. Demand planning is a critical function, as it aims to predict future demands and, thus, predictive data mining techniques, including time series and causal analysis, are useful for forecasting sales volumes and also for pro-ling potential consumers accurately. In addition, prescriptive analytics such as stochastic optimization models are useful for supply chain planning. Price optimization using both predictive and prescriptive analytics is also important in demand planning. The majority of analytical IT for supply chain planning embeds prescriptive analytics capabilities. In particular, linear programming-based optimization is popular in APS systems. Additionally, predictive analytics using genetic algorithm, neural network, and fuzzy programming techniques can be effective for developing supply planning and synchronizing production, source, and demand. *Analytical capability for the Sourcing process*: The primary role of analytical IT for sources lies in “improving inbound supply chain consolidation and optimization". There is a strong application for the use of analytical IT to support supplier selection within supply chains. IT with prescriptive analytics has long been a key enabler of manufacturer's sourcing-related decision making. Predictive analytics techniques are increasingly available these days for intelligent material planning, inventory management, and supplier relationship management. All data mining tools have potential to support every application area. *Analytical capability for the Making process*: IT resources can potentially play a role in various areas such as predicting machinery failure, identifying anomalies in production processes, and discovering hidden patterns and potential problems. There are many real-world applications for prescriptive and predictive analytics in the processes, including aluminum processing, semi-conductor manufacturing, electronic assembly, and DNA manufacturing. Specifically, prescriptive and predictive analytics techniques such as Genetic Algorithm are useful for various production-related planning problems such as lot-sizing, lot-scheduling, and optimizing the sequence of orders in manufacturing line. *Analytical capability for the Delivering process*: The role of BA is to improve the efficiency and effectiveness of outbound material flow by delivering products to customers and markets more efficiently. This BA application is also called intelligent order management or “logistics intelligence". Predictive analytics are helpful in analyzing and segmenting orders and deliveries in terms of different measures (e.g., profitability, location, costs). Prescriptive analytics models using forecasting methods can help predict future orders and delivery demands by different categories (e.g., countries, regions, distribution centers).

Trkman et al. investigated the relationships between business analytics in supply chain management and the performance in the SCOR areas of Plan, Source, Make, and Deliver, considering Information System Support and Business Process Orientation as moderators of this relationship [97]-[98]. The authors define Business Analytics as a group of approaches, organizational procedures and tools used in combination with one another to gain information, analyze that information, and predict outcomes of problem solution any of the four areas of SCOR. Examples of the potential use of analytics in various areas include: *In Plan*: analyzing data to predict market trends of products and services; until recently, these have often been done in the form of monthly and yearly reports by marketing and finance departments. *In Source*: the use of an agent-based procurement system with a procurement model, search, negotiation and evaluation agents to improve supplier selection, price negotiation and supplier evaluation and the approach for supplier selection/evaluation. *In Make*: the correct production of each inventory item not only in terms of time, but also about each production belt and batch. *In Deliver*: various applications of BA in logistics management have been made in order to bring products to market more efficiently. Nevertheless, since decisions about delivery are usually at the end of the decision cycle and several companies have outsourced their delivery processes the impact of BA in delivery may be limited.

Souza described different decisions in each of the four SCOR domains – source, make, deliver, and return – that can be aided by analytics [90]. These decisions are further classified into strategic, tactical, and operational according to their time frame, as follows: Strategic decision areas for *sourcing* activities are (1) Strategic sourcing and (2) Supply chain mapping. Tactical decision areas for *sourcing* activities are (1) Tactical sourcing and (2) Supply chain contracts. Operational decision areas for *sourcing* activities are (1) Materials Requirements Planning and (2) Inventory replenishment orders. Strategic decision areas for *making* activities are (1) Location of plants and (2) Product line mix at plants. Tactical decision areas for *making* activities are (1) Product line rationalization and (2) Sales and operation planning. Operational decision areas for *making* activities are (1) Workforce scheduling and (2) Manufacturing, order tracking and scheduling. Strategic decision areas for *deliver and ret*urn activities are (1) Location of distribution/return centers (2) Fleet planning. Tactical decision areas for *deliver and return* activities are (1) Transportation and distribution/reverse distribution planning and (2) Inventory policies at locations. Operational decision areas for *deliver and return* activities are (1) Vehicle routing for deliveries and (2) Vehicle routing for return collections. A fifth domain of the SCOR model – *plan* – is behind all four activity domains. Furthermore, a key input of the supply chain planning process is demand forecasting at all time frames: long, mid, and short term with planning horizons of years, months, and days, respectively.

Souza also provided a summary of analytics techniques used in supply chain management in terms of the four SCOR domains of source, make, deliver, and return [90]. The applications are categorized in terms of descriptive, predictive, and prescriptive analytics and along these four domains of SCOR model, as shown in Table 1.

Table 1. Analytic Techniques Used in Supply Chain Management [90]

Analytics Techniques	Source	Make	Deliver	Return
Descriptive	• Supply chain mapping	• Supply chain visualization		
Predictive	• Time series methods (e.g., moving average, exponential smoothing, autoregressive models) • Linear, non-linear, and logistic regression • Data-mining techniques (e.g., cluster analysis, market basket analysis)			
Prescriptive	• Analytic hierarchy process • Game theory (e.g., auction design, contract design)	• Mixed-integer linear programming (MILP) • Non-linear programming	• Network flow algorithms • MILP • Stochastic dynamic programming	

This study intends to identify analytics types (i.e. Descriptive, Predictive, and Prescriptive) and techniques that are effective at strategic, tactical, and operational decision levels in SCOR performance areas, namely Plan, Source, Make, Deliver, and Return. For this purpose we mainly revisited two aforementioned studies; (1) the study of Wang et al. [104] which classifies analytical methods used in strategic and operational application areas of logistics and supply chain management according to descriptive, predictive, and prescriptive types, based on a comprehensive literature search, and (2) the study of Souza [90] which identifies strategic, tactical and operational level decision areas in SCOR processes and analytical types and techniques that are effective in SCOR performance domains.

This paper contributes on classifying in further details, supply chain analytics types and techniques used in various decision levels of each SCOR performance domains, by combining aforementioned studies and extending related literature review.

In the next section, based on our literature review, we classified recent studies according to business analytics types use in various decision levels in SCOR performance domains, as appropriate for the purpose of this study (Table 2).

LITERATURE REVIEW

Table 2. Combined Literature Review on Supply Chain Analytics and Classification of the Studies by SCOR Performance Domains and by Types of Analytics.

		SCOR Performance Domains									
Decision Level		PLAN	SOURCE			MAKE			DELIVERY & RETURN		
			Strategic	Tactical	Operational	Strategic	Tactical	Operational	Strategic	Tactical	Operational
Decision Domains [12]-[90]-[104]-[82]		*-Demand Forecasting and Planning*	*-Strategic Sourcing -Supply Chain Network Design*	*-Tactical Sourcing / Procurement -Supply Contracts -Supply Risk Management*	*-Materials Requirement Planning -Inventory Replenishment Orders*	*-Location of Plants -Product Line Mix at Plants -Product Design and Development -Production Process Improvement*	*-Product Line Rationalization -Sales and Operations Planning (S&OP)*	*-Workforce Scheduling -Manufacturing, Order Tracking, and Scheduling*	*-Location of Distribution Centers -Location of Return Centers -Fleet Planning -Logistics Outsourcing*	*-Transportation and Distribution Planning -Inventory Policies at Locations -Reverse Distribution Planning*	*-Vehicle Routing for Deliveries -Vehicle Routing for Returns Collection*
Analytics Types and Techniques	Descriptive	[24]-[53]-[16]		[74]	[54]	[79]	[52]				
		- Supply Chain Mapping				*- Supply Chain Visualization*			*- Supply Chain Visualization*		
	Predictive	[66]-[88]-[9]	[46]-[64]-[86]-[14]-[23]		[40]-[4]-[28]	[5]-[67]-[91]-[92]	[107]-[22]				[102]
		- Time Series Methods (e.g., Moving Average, Exponential Smoothing, Autoregressive Models) - Linear, non Linear, and Logistic Regression Analysis - Data-mining Techniques (e.g., Cluster Analysis, Market Basket Analysis) - Neural Network - Fuzzy Programming - Generic Algorithm				*- Time Series Methods (e.g., Moving Average, Exponential Smoothing, Autoregressive Models) - Linear, non Linear, and Logistic Regression Analysis - Data-mining Techniques (e.g., Cluster Analysis, Market Basket Analysis)*			*- Time Series Methods (e.g., Moving Average, Exponential Smoothing, Autoregressive Models) - Linear, non Linear, and Logistic Regression Analysis - Data-mining Techniques (e.g., Cluster Analysis, Market Basket Analysis)*		
	Prescriptive	[32]-[17]-[37]-[15]-[8]	[95]-[99]-[43]-[70]-[75]-[45]-[76]-[56]-[57]-[3]-[72]-[38]-[60]-[96]-[7]-[11]-[80]-[29]-[48]-[84]-[39]-[51]-[89]-[13]	[41]-[10]-[55]-[6]	[108]	[73]-[87]-[93]-[42]-[61]-[69]	[21]-[30]-[20]-[59]-[63]	[83]-[65]-[85]-[105]-[106]	[50]-[33]-[44]	[27]-[35]-[31]-[34]-[77]-[36]	[78]-[62]-[58]-[71]
		- Analytic Hierarchy Proces (AHP) - Game Theory (e.g., Auction Design, Contract Design) - Linear Programming-based Optimization - Stochastic Optimization Models				*- Mixed-integer Linear Programming (MILP) - Non-linear Programming*			*- Mixed-integer Linear Programming (MILP) - Network Flow Algorithms- Stochastic Dynamic Programming*		

FINDINGS AND CONCLUSIONS

In this study, which is based on a literature review, 88 studies on analytics applications in supply chain processes were revisited. In these studies, it was determined that 11 of the analytical applications were used in Planning phase of SCOR model, 39 were in Sourcing phase, 24 were in Making phase, and 14 were in Delivery & Return phase. When these studies are examined in terms of analytical types, it has been determined that 7 analytical applications are Descriptive type, 18 applications are Predictive type, and 63 applications are Prescriptive type (Figure 1).

As shown in Figure 1; (1) the operational area where analytical applications are most used is “Source”. This is followed by “Make”, and “Delivery” respectively. (2) Prescriptive analytics are the most commonly used analytical type in all areas of SCOR and Descriptive analytics are the least used analytical type. (3) In the planning process affecting all other areas, all three analytical types (Descriptive, Predictive, and Prescriptive) are used at almost the same level. (4) Logistics-based decisions in the “Delivery & Return” process seem to be based solely on prescriptive analytics.

It has been observed that 54 of these analytical applications were effective at the Strategic decision level, 19 at the Tactical decision level and 15 at the Operational decision level.

Figure 2 shows that the decision area that is most benefited from advanced business analytics is Sourcing decisions at Strategic Level. The vast majority of analytics types used in these strategic sourcing decisions are prescriptive. As can be seen in Figure 3, prescriptive analytics are effective at the same level in all decision levels of “Make” domain of SCOR. Predictive analytics, however, seem to be relatively less effective in strategic and tactical decisions. Finally, prescriptive analytical techniques seem to be influential in all strategic, tactical and operational decisions on “Delivery & Return” processes (Figure 4).

Findings from this study highlight the impact of advanced business analytics applications on supply chain performance in the context of SCOR domains and provide some insights as to the analytics types and techniques that will be effective in strategic, tactical and operational decisions of supply chain managers. This study provides a general framework for analytical types in SCOR performance domains. We have also several suggestions for future research.

1) Our study can be extended by elaborating on the techniques used in analytical applications. In this way, the analytical techniques that provide the greatest benefit in each category and at each decision level can be determined.

2) Future research can include best practices and case studies in order to acquire the complete view of how business analytics affect various areas of the supply chain performance.

3) We also believe that it would be beneficial to have an empirical study to be done separately on manufacturing companies and logistics service providers.

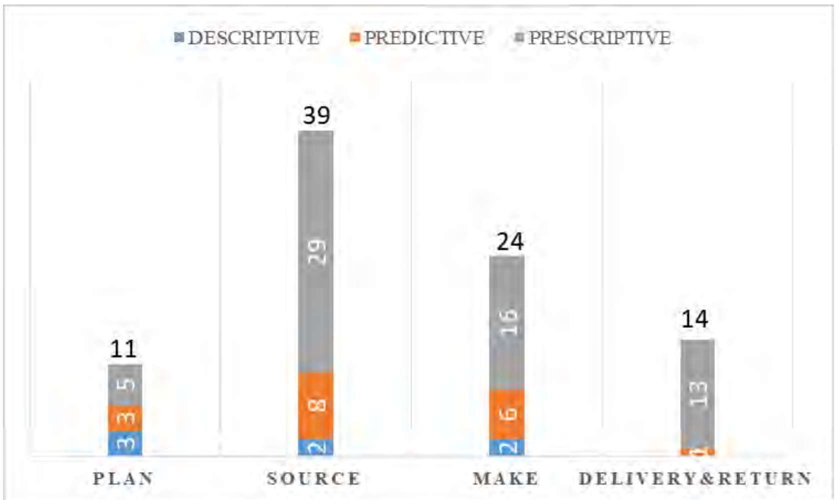

Figure 1. Types of Analytics Applications by SCOR Domains

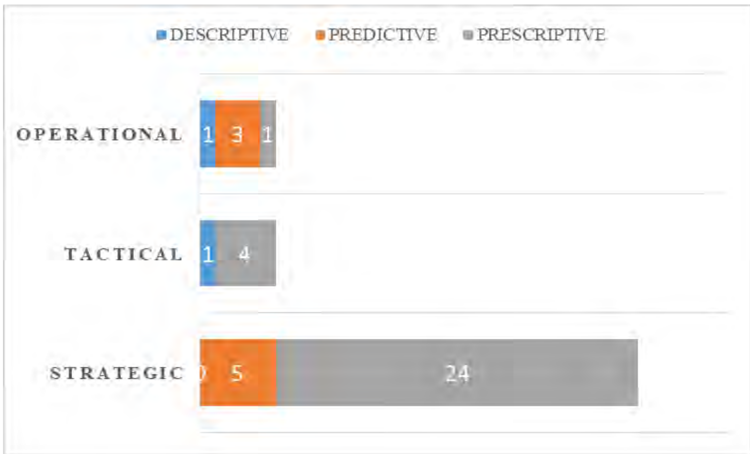

Figure 2. Types of Analytics Applications in SCOR Performance Domains by Decision Levels SOURCE

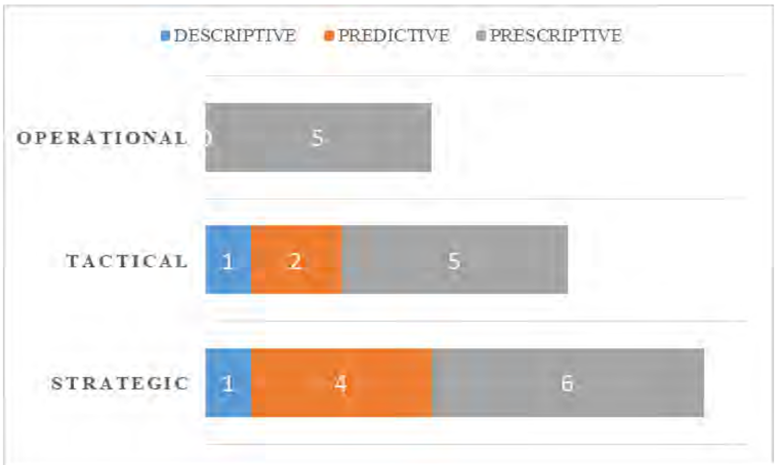

Figure 3. Types of Analytics Applications in SCOR Performance Domains by Decision Levels MAKE

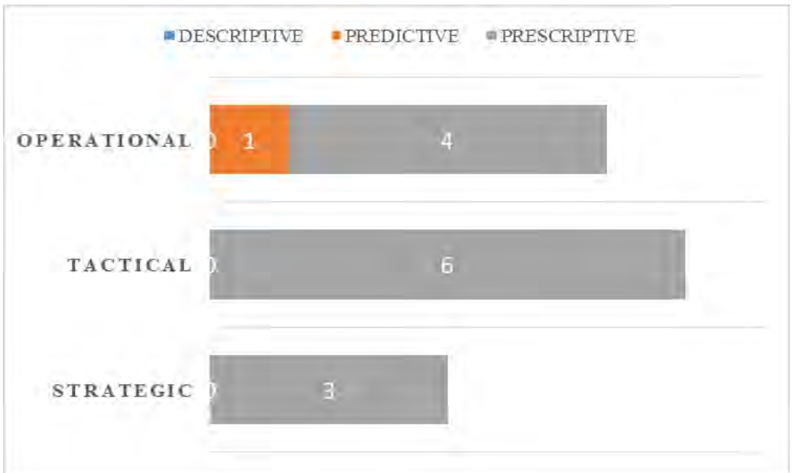

Figure 4. Types of Analytics Applications in SCOR Performance Domains by Decision Levels DELIVERY & RETURN

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APPLICATION OF EFQM EXCELLENCE MODEL TO REVIEW THE ORGANIZATIONAL STRUCTURES IN TURKISH SHIP RECYCLING INDUSTRY

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Abstract *− Currently, Turkey is the fifth larger ship recycling country in the world and has big demand to achieve some industry based specific problems such as poor working conditions, financial limitation, environmental sensitivity, organisational management etc. Therefore, current situation of Turkish ship recycling industry, advantages & disadvantages in comparison with other ship recycling countries must be identified clearly. Later, solutions and reformatory measures must be discussed. To do this, this study adopts the European Foundation for Quality Management (EFQM) framework and review relevant studies on ship recycling; also a brief survey in accordance with EFQM criterion scheme is conducted. The revealed field investigation results have pointed the needs for improvement in both managerial and operational levels (i.e. leadership, processes, etc.). The findings are also supported with the RADAR logic (Results, Approach, Deployment, Assessment and Refinement) to produce effective solutions. Consequently, the research has extended the EFQM-RADAR approach to maritime industrial development and sustainability. Furthermore, the similar approach might be followed to measure the organizational improvements in other maritime stakeholders such as shipping companies, shipyards, ports & terminals, etc.*

Keywords *−EFQM model, maritime industry, ship recycling, RADAR logic*

INTRODUCTION

Steel is the most recycled material in the world and widely used by many industrial fields. Besides, steel is potentially 100% recyclable [1]**.** In other words, steel is theoretically can be reproduced endlessly without loss of quality [2]. Recycling of steel is acknowledged as one of the most environment friendly activity, for instance; an amount of 7400MJ energy is required for obtaining 1 ton of steel from hematite ore, while it is required 1350MJ energy when obtaining from steel scrap. In addition, 2200 kg of carbon dioxide releasing reduces to 280 kg by means of recycling [3].

From another angle, steel recycling also provides significant contributions to the environment such as; 86% air pollution reduction, 76% water pollution reduction and 40% water usage reduction [4].

In maritime industry, recycling of ship is another source for steel scrap production. However, "ship recycling" is one of the most difficult recycling activities on several counts when compared with the other industrial fields. Breaking apart an object like a "ship" is much harder than thought due to their non-geometric dimensions, bulky sizes, weightiness and -hard to be settled- constructions that require very complex processes to be dismantled. Recent years, ship recycling came under scrutiny with poor working conditions, human health and environmental issues, when considering it is a labour-intensive industry. As an illustrative case, two major explosions took place at the ship breaking yard Alang (India) in 2003. Eight people died on a tanker ship and twelve people died on a container ship; both of them due to explosions [5]. In addition, ninety workers died between the years of 2005 – 2012 just only in Chittagong, Bangladesh [6]. Further; 348 workers died between the years of 1991 – 2007 in Alang, India [7]. Besides, there are also deaths implicitly due to occupational diseases such as lung cancer or asbestos related diseases. In this respect, concerned authorities have attempted to solve relevant matters and they decided to adopt Basel convention in 1989 [4]. Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal was adopted in 1989 and came into force in 1992 in response to toxic waste trading to developing countries from abroad. In the 1980s, environmental regulations in the developed nations had led some operators to seek cheaper disposal alternatives for hazardous wastes in less developed countries, where environmental awareness and regulations were substandard. Due to increasing public resistance and voices from responsible organizations, a diplomatic conference held under the UNEP (United Nations Environment Programme) in Basel (Switzerland), where the convention was adopted. After entering into force in 1992, the convention has seen several significant developments. The ban amendment addressed for prohibiting exports of hazardous wastes was adopted by the third meeting of the COP (Conference of the Parties) in 1995. Then Technical Working Group of the convention agreed on a list of specific wastes that identified as hazardous or non-hazardous, was adopted in 1998. With the purpose of minimizing hazardous waste, the protocol on Liability and Compensation was adopted in 1999 to establish rules on liability and compensation for damages including incidents occurring during export, import or disposal. As a major milestone, COP 6 agreed on "Strategic Plan for the Implementation of the Basel Convention" for the period of 2002- 2010, to support the developing countries and countries in transition in implementing the provisions of the Convention to achieve environmentally sound managent of hazardous waste. Additionally, the HK (Hong Kong International Convention) for the Safe and Environmentally Sound Recycling of Ships was adopted in May 2009. The convention was aimed at ensuring that ships, when recycled after reaching the end of their life cycle, do not pose any unnecessary risk to human health and safety or to the environment [8].

According to HK, ships -that comply with the requirements of the Convention- are required to have an initial survey to verify inventory of hazardous materials only by authorized ship recycling facilities [9]. Hence, working conditions were expected to gain improvement at some level by these standards of the convention.

In addition to the above mentioned concerns, ship recycling industry also faces with financial challenges. There are some dominant factors in the market such as freight rates and steel market, which directly affects the offering prices for obsolete vessels and margin of profit. According to the total ship recycling volumes, the countries will be as follows respectively from largest to the smallest; India, Bangladesh, China, Pakistan, Turkey and others [4]. As it is known, importing materials and goods from foreign countries increase fragilities in nation's economies. Turkey is a country that already stands as one of the "fragile five" economies in the world with Brazil, India, Indonesia and South Africa [10]. Additionally, Turkey is the largest steel scrap importer country in the world by an enormous margin [4]. **Table 1** illustrates the main steel scrap importing countries to have better understand about the subject.

Table 1: Main steel scrap importing countries (in million tones) [4].

	2007	**2008**	**2009**	**2010**	**2011**
Turkey	17141	17415	15665	19192	21460
Korea Rep.	6887	7319	7800	8091	8628
China	3395	3590	13692	5848	6767
India	3014	4579	5336	4643	2929
Taiwan	5418	5539	3912	5364	5328
USA	3692	3571	2986	3775	4003
EU-27	5142	4809	3270	3646	3676
Malaysia	3688	2293	1683	2292	2050
Indonesia	1260	1899	1484	1642	2157
Canada	1435	1674	1408	2226	1911
Thailand	1805	3142	1323	1282	1877

For this reason, development of the ship recycling industry in Turkey plays an important role as a magnificent steel scrap source. Thus, Turkish ship recycling industry must be developed with innovation techniques to refrain steel scrap importing and gain economic benefits. Even so, with geographic position and promising facilities in the world, Aliaga ship recycling zone has big potential to reach desired level. In order to achieve industrial objectives, roots of various problems must be identified thoroughly and the weakest points need to be improved elaborately. Therefore, in this study, the EFQM excellence model has been applied to Turkish ship recycling industry on the purpose of investigate, identify and suggest corrective improvements to eliminate critical sector weaknesses. The RADAR logic (Results, Approach, Deployment, Assessment and Refinement) has been used as a tool for demonstrating detailed analysis of the industry in a lot of ways.

LITERATURE REVIEW

This chapter provides a comprehensive review on academic studies, key research projects, and industrial studies focusing ship recycling industry development. In academic studies, environmental studies are become prominent about the ship recycling. Almost all ship recycling zones have been studied and examined by researchers to reveal magnitude of the environmental impacts. For instance, a study has been conducted to analysis solid wastes in a very large ship recycling in India [11]. **S**olid waste in two regions; Alang and Sosiya have been analysed. For these two regions, 10kg/m^{2}and more than 15kg/m^{2}solid wastes were founded, respectively. In the same regions, a similar study investigated heavy metals, hydrocarbons and other pollutants, as result; significantly hazardous values of materials have been identified for environment [12]. Besides, an analysis has been made in the same zone and found out; almost no vegetation left in the coastal beach, the population and diversity of marine species decreased some fish species already disappeared, noise pollution raised, agricultural activities get harmed since the industry began [13]. Moreover, In Sitakunda (Bangladesh), negative impacts of the ship breaking yards highly examined and harmful substances put emphasis [14].

Such researches were also executed in Turkish coastal. As an environmental case study, in order to measure contamination of heavy metals and other pollutants, an analysis have been conducted [15].

As consequence, Aliaga has been found as already polluted with heavy metals such as Hg, Cd, Pb, Cr, Cu, Zn, Mn and Ni. For a similar study, see also [3].

Apart from the environmental studies, human health issue has also been highlighted. In order to estimate the potential maximum heavy metal exposure to ship recycling workers at Alang, India, a study has been investigated to reveal how much hazardous ship recycling activities when correct methods are not utilised [16].

Also, in Taiwan, increased risk of cancer among ship breaking workers caused by asbestos release is put emphasis [17]. However, despite this underwhelming results, hazardous impacts of ship scrapping activities can be minimised, if correct steps are taken [18]. To achieve this**,** innovative approaches can be integrated. A pilot model project highlighted as utilisation of water jet cutting technique, which provides major advantages on preventing toxic gases generation and explosion risk during the operation [19]. Furthermore, a detailed Ship Recycling Recommender system has been proposed with the intention of helping the relevant stakeholders by recommending them “best practices” idea [20]. In addition, a holistic approach to the status of ship recycling with a new ship recycling design is possible to implement [21].

There are also financial analysis based studies such as investigating the ship demolition market to insight the basic dynamics with applying econometric model fed by a unique data set is conducted [22]. Scrapping market of ships could be effected by many factors just as ship types, vessel age, vessel size, earnings, second hand ship prices, ship building prices and scrap prices. In attempt to show this, market position of the top five ship recycling countries has also been studied [4].

Research projects, majority of them funded by EU, in the ship recycling put emphasis mostly on safety and environmental issues. A European project so called as Shipmates [23], which aimed to provide a smart route for technologically enhanced and environmentally friend ship recycling activities. In Life+ program, Recyship project [24] was supported to deal with the matters of occupational safety, health and environmental protection on ship scrapping activities. Moreover, ShipDismantl project develops optimal ship dismantling design, restructuring the yards, and developing decision support systems [25]. Another decision support tool database is conducted in DIVEST project to prevent operational accidents and reduce relevant risks. Creating an accessible information exchange with the stakeholders and supporting training programs were in the main targets of the project [26]. In Turkey, a similar project was conducted namely Ship DIGEST, which aimed to establish knowledge transfer from Europe to Turkey in order to ensure more reliable working conditions and skilled employees for safe and environmentally friendly ship dismantling operations [27].

Industrial studies on ship recycling gained momentum due to increased awareness towards industry's problems in the nations. The first attempt at addressing the matter was adopting the Basel Convention in 1989, which entered into force in 1992 to protect human health and the environment against detrimental effects of hazardous materials. Furthermore, it has precautions in response to toxic waste trading to develop countries from abroad [28]. In 1995, a Joint Working Group on ship recycling has been established by IMO (International Maritime Organisation) to prevent duplication of work and overlapping of actions between the parties. The joint group has concluded a couple of meetings and discussed the state of affairs in the ship recycling [29]. The IMO's active role on the ship recycling was first raised at the 44th MEPC (Maritime Environment Protection Committee) in March 2000 in order to investigate ship recycling activities. Then "Guidelines of Ship Recycling" was adopted at MEPC in July 2003[30]. In 2004, ILO (International Labour Organisation) adopted "Safety and Health in Shipbreaking: Guidelines for Asian countries and Turkey" to ensure safe work in shipbreaking and to assist shipbreakers and competent authorities in order to implement the relevant standards of ILO. These guidelines have the characteristics of recommendation (they have no enforcement) for selected Asian countries and Turkey [31]. As a NGO, the Shipbreaking Platform was established in 2005 to prevent toxic obsolete vessels from beaching in developing ship-recycling countries. Besides, Greenpeace is one of the member organization of Shipbreaking NGO Platform since September 2005 and one of the observers of IMO Working Group on ship recycling [32],[33]. European Union (EU) adopted a community strategy on "An EU Strategy for Better Ship Dismantling" on 19 November 2008, in addition to their indirect efforts. The strategy proposes a number of precautions to enhance ship-recycling conditions in order to contribute implementation of international conventions [34]. Until 2009, industrial studies kept working at some level from above-mentioned organizations and recently, the HK was adopted with contribution of IMO Member States, several ship recycling NGOs, ILO and the Basel Convention Parties. In operational level, ship recycling yards will be required to provide a "Ship Recycling Plan", determine the procedure for each ship to be recycled, depending on its characteristic particulars and its inventory. Parties will be required to take effective precautions to ensure that ship recycling facilities under their jurisdiction comply with the HK Convention [30].

According to the literature review, the most of the studies are about job safety and environmental issues in order to give scientific response to the concerning issues. Despite the many studies about ship recycling's environmental impact; there are too few studies about enhancing process techniques and workflow, such as the pilot study of [19]. There are also very few studies about interrogating the international conventions and deficiencies elaborately. Despite HK has many beneficial points, there are still uncertainties in published rules [8].

PROPOSED APPROACH

To review and enhance an industrial process, relevant operations and management activities; there are various methods in the literature including quality management methods, multi criteria decision making methods and other approaches. The one of the main objectives of this research is establishing a sustainable quality management tool to the industry. As the Turkish ship recycling industry has close relationships with the European Union countries, utilised approach was chosen to be in harmony with European quality management vision. So; EFQM excellence method has been decided as the most proper approach to be utilised for such situation.

In September 1988, 14 European Business Leaders signed a "Letter of Intent" under the presidency of Jacques Delors (President of the European Commission between 1985 and 1995) to improve competition of European businesses. Afterwards, the European Foundation for Quality Management was founded in October 1989 by subscription of 67 European business leaders to this action. A team of experts from industry and academia has been in charge to develop EFQM excellence model that could be applied to any organization regardless of size or sector. First implementation of this model has been made in 1992 to support the assessment of organizations in the European Quality Award. The model has evaluated with global market experiences over 25 years and from both public and private sector participated in EFQM Excellence awards including most famous and less-known organizations in the world. From past to present, these mechanisms aim to support organizational excellence [35].

The EFQM model is a practical tool that could be use in variety of ways for organizations. The framework of the model has nine main criteria, which are taken into consideration when conducting self-assessment. Five of these criterions are "enablers" and four are "results" as indicated in **Figure 1**. The "enablers" cover the organization's working style and efforts to achieve its objectives, and "results" cover how much success the organization on making realize of this. Therefore, "results" are caused by "enablers" and correct analysis of the results would increase the organization's capability on its journey of excellence. Excellent organizations use comprehensive performance and perception indicators to monitor those abovementioned efforts and achieve successful results [35].

In EFQM concept, the RADAR is used as a practical tool and a dynamic assessment frame, which ensures a structural approach to examine the performance of any organization. RADAR indicates that an organization must consider these aspects; i) Identifying the indispensable results as a part of the strategy, ii) Planning and creating approaches that integrated with each other for achieve current and future results, iii) Deploying the approaches to secure the application, assessing and enhancing based on monitoring, analysing and continuous learning activities of obtained results. There are five main aspects of RADAR; three of them (Approach, deployment, assessment & refinement) relating to assessment of inputs and the rest of them (relevance & usability, performance) relating to assessment of results. At the same time, performance that related to main results is compared with external organizations. Clear and positive relationship between inputs and outputs indicates that the organization maintains its good performance for the future [36].

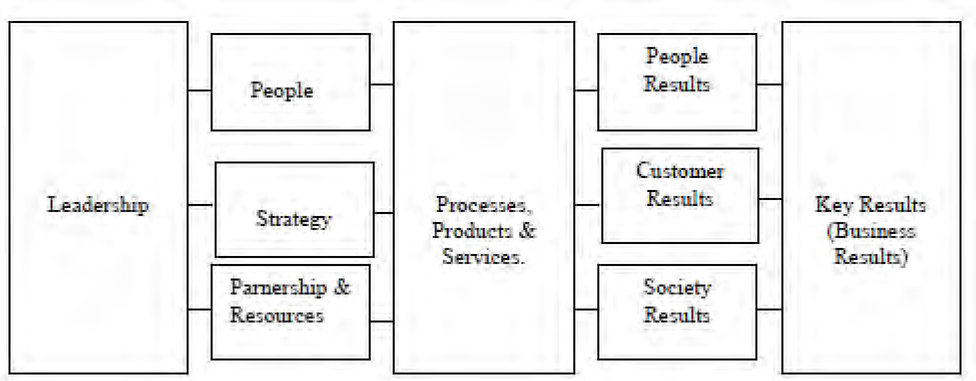

Figure 1. EFQM main criteria [35].

Many studies have been conducted to measure and contribute organizational structures' excellence level. The EFQM excellence model has been applied to large spectrum of various fields since its intention. Illustrative cases are shown below in order to have insight for different application fields of the EFQM such as business. As a contribution to this area, a strong relationship between EFQM excellence model and organizational commitment has been revealed by applying the EFQM model to Turkish Quality Award winners' employees in 2004 [37]. In addition to this, a study is proposed based on a new analytic hierarchy process and EFQM Model to improve business performance excellence via excellence award scoring system [38]. In addition, various applications can be cited in literature, see also; [39], [40], [41], [42], [43].

The framework consists of three main elements as; model, application and results. The "model" is based on a field survey approach that derived from both EFQM model and ship recycling industry. In other words, field survey is created by adapting the EFQM model to ship recycling industry in consideration with RADAR logic. As the second stage of the framework, the "application" is conducted based on the new originated field survey approach. The field survey is carried out through two different perspectives to have more accurate insight towards results. Demonstration is obtained through responses, comments, approaches, opinions and judgments of both academic and industrial perspectives. In the light of the demonstration, findings are discussed accordingly.

DEMONSTRATION& DISCUSSION

Application of the EFQM Excellence model to the Turkish Ship Recycling Industry aims to reveal that; how much excellent the current industrial activities, which parts of the work stream are stronger or weaker and what should be done through permanent improvements to reach desired excellence level and sustainable development. Hence, the main goal is to ensure sustainable development of ship recycling industry via organizational excellence.

Table 2. Coefficients and maximum points of RADAR logic [44].

Criterion	Coefficient	Maximum Points Awarded	Maximum Total Points
1. Leadership	x1.0	100	
2. Policy and Strategy	x0.8	80	
3. People	x0.9	90	500
4. Partnerships& Resources	x0.9	90	
5. Processes	x1.4	140	
6: Customer Results	x2.0	200	
7. People Results	x0.9	90	500
8. Society Results	x0.6	60	
9. Key Results	x1.5	150	

The calculations of excellence rate have been made through RADAR logic's excellence points. Besides, awarded scores that obtained in the calculation of enablers and results matrix have been multiplied their main criteria coefficients. The coefficients, maximum points and the way of calculation for maximum total points are shown in the **Table 2.**

Obtained responses, opinions and comments from the respectable experts from academia and industry transformed into tangible data. Distribution of those data and average of all data is illustrated in **Figure 2** according to main criteria of the EFQM in comparison with each other of two survey responder groups. The both groups create a discussion consensus and chose one result on behalf of the consensus for the each EFQM sub-criterion assessment survey questions. The industrial consensus consists of 12 persons including two ship recycling company owners, eight managers and two workers. The academic consensus consists of 7 persons including one professor, two associated professors, two lectures and two research assistants. According to the comparison results, excellence rates from academic remarks are lower than the industry's remarks for all criteria. It reflects clearly the differences between two different perspectives.

"People" and "people results" criterion have taken the best excellence rates from the experts. Their excellence rates are respectively; 67.48% and 71.65%. It means the Turkish Ship Recycling Industry cares about their employees when comparing with the other aspects of their activities. Besides, the industry is achieved some good results already, as "People results" has higher excellence rate than the "People" criterion (an enabler criterion). "People" and "People Results" are shown in the **Figure 3 and 4**.

Human resources department is the best aspect in the people criterion, despite a divergence between the responses of academia and industry. Besides, the industry is good about ensuring of training & development services for their employees.

However, employees are not getting rewarded as they had expected, but the situation is not that poor and still improvable. Training & development is answered back to the given efforts about this area according to the "people results" criterion.

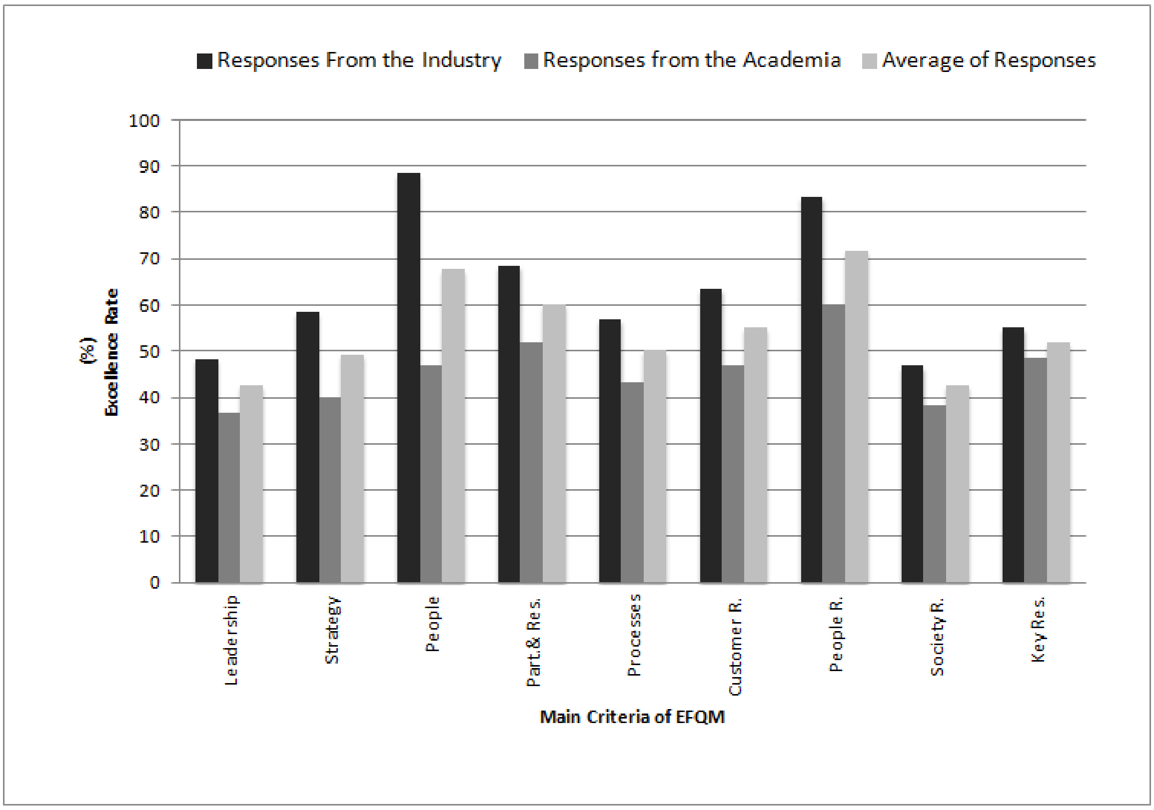

Figure 2. Comparative illustration of the excellence rate results.

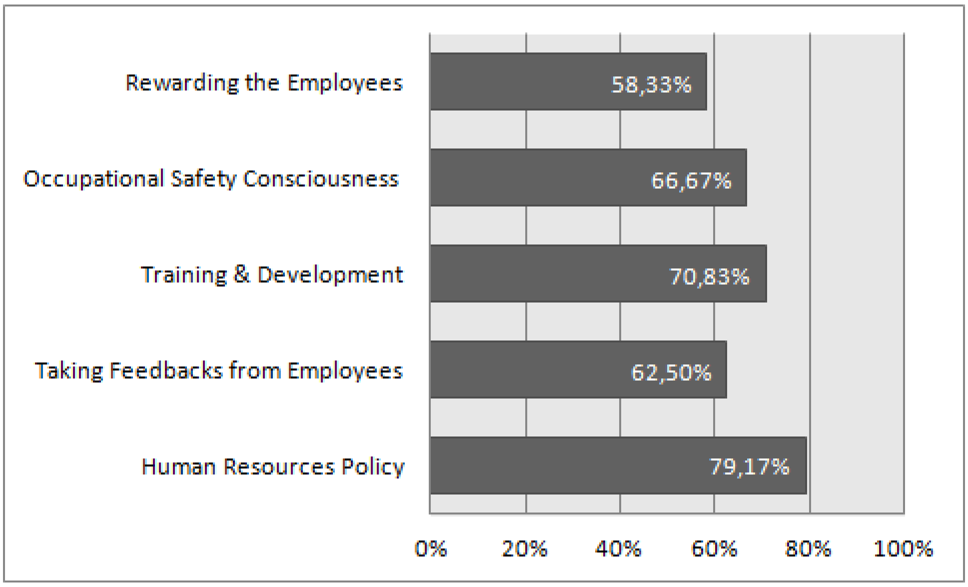

Figure 3. Excellence rates of the people criterion.

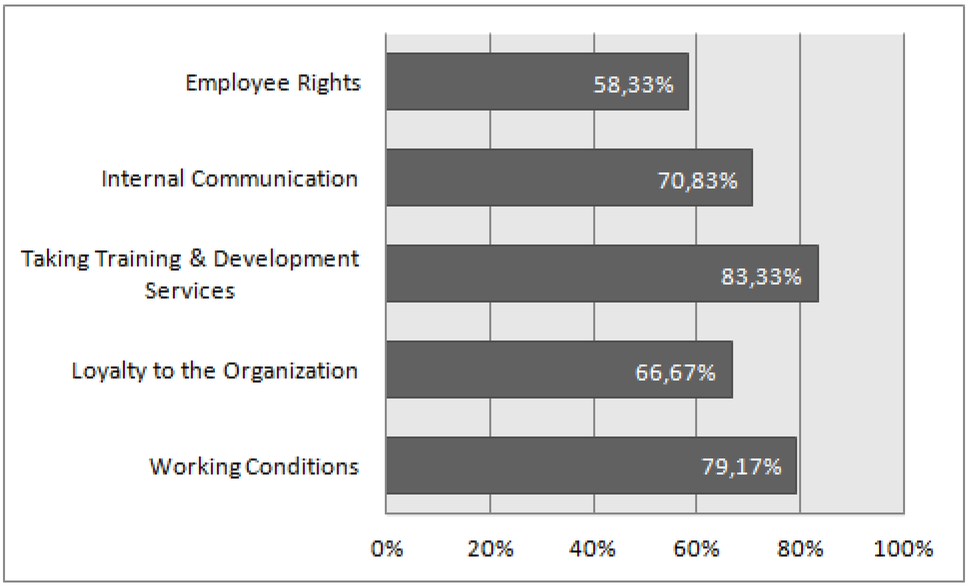

Figure 4. Excellence rates of the people results criterion.

Working conditions are appeared to be in course of improving and internal communication is conducted just sufficiently. Employee rights area is not poor but it is open for development. Employees are quite loyal to their organizations and it is helping to increase total experiences of the employees. "Leadership" and "society results" criterion have taken the lowest excellence rates from the experts, which are respectively 42.48% and 42.50% shown in the **Figure 5.**

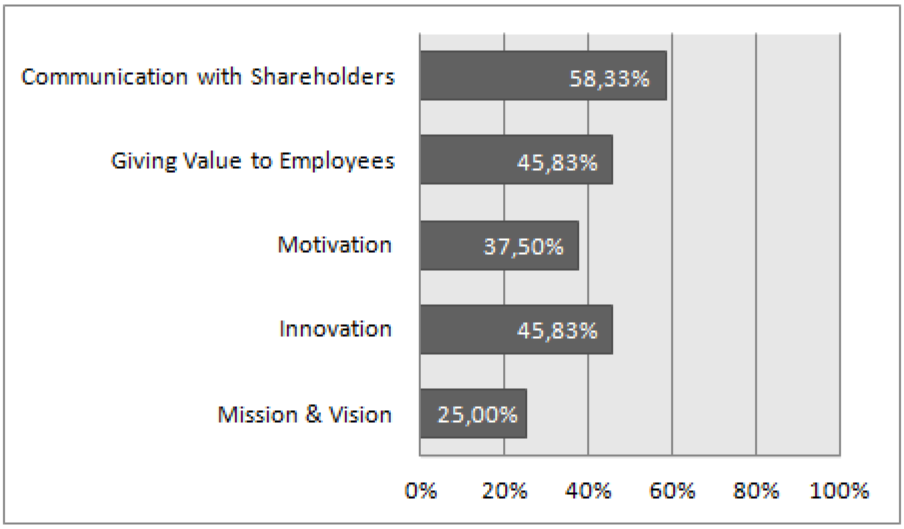

Figure 5. Excellence rates of the leadership criterion.

However, the best skill of the leadership is communication with the shareholders. Other items are also at poor level; leaders struggle to motivate their employees despite they make more effort on giving them value. They are also unsatisfied on the monitoring and bringing innovations to their organizations. Excellence rates of the society results are as it is shown in **Figure 6.**

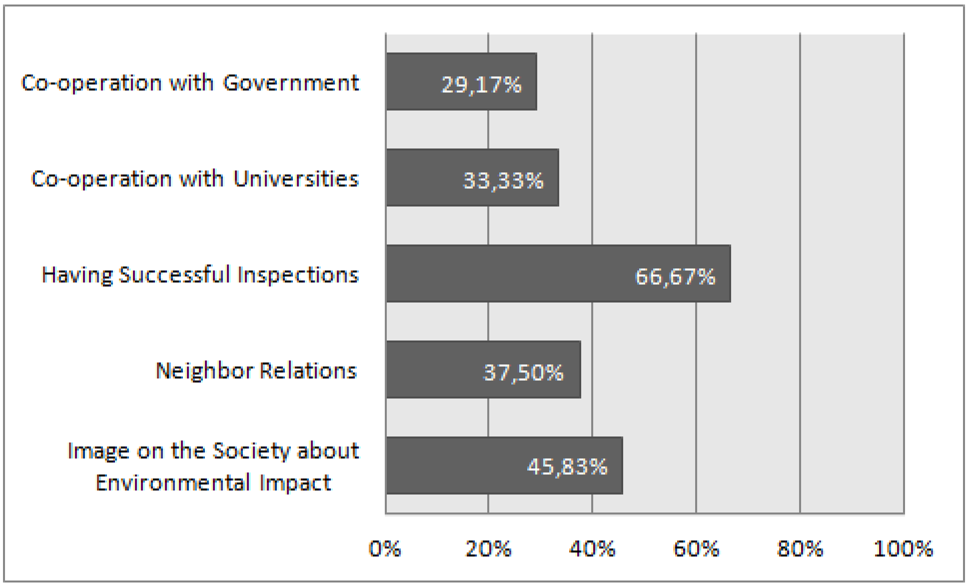

Figure 6. Excellence rates of the society criterion.

Strategy is just another criterion that the industry could not show success. As in the **Figure 8**; the organizations are not ready to make swift changes on their policy or strategy in the cases of unexpected negative situations. Additionally, they are unable to detect those risks due to many changeable dynamics in the market that they cannot dominate. They are not that poor on identifying strategic priorities and it is the only promising area in the strategy criterion despite the lack of innovative movements.

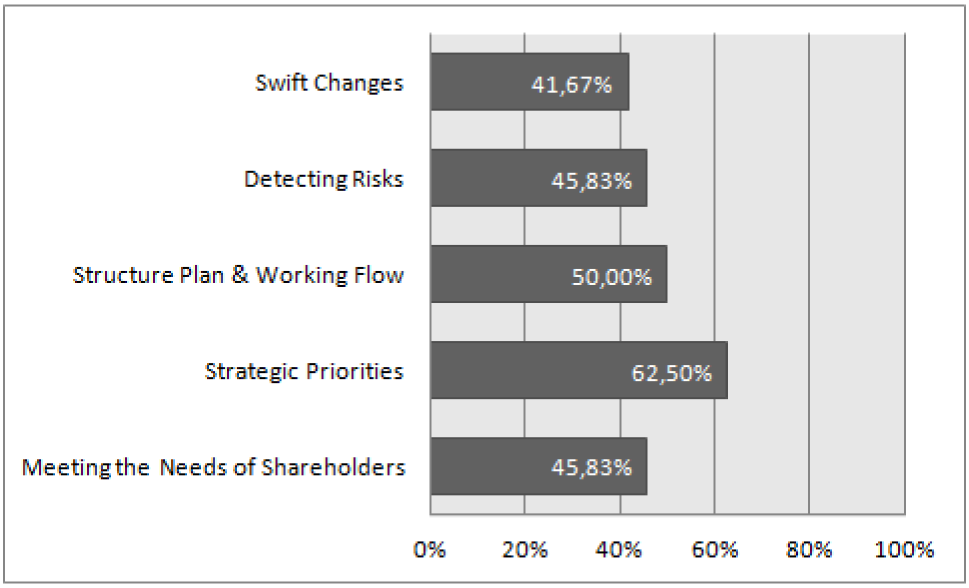

Figure 7. Excellence rates of the strategy criterion.

Partnerships & Resources criterion is the third best criterion of the industry with around 60% excellence rate **(Figure 8**). The organizations are promising on increasing their worker's total experience and it is matching with the loyalty of the employees, as it has satisfying value in the people results. They are taken feedbacks from shareholders and make effort for advancement in relevant issues. The industry could be considered as satisfying on environmental issues but there is still a long way to reach excellence in this area. As dependent to the poor capability on innovation; technologic infrastructure is not good enough. Financial control rate is insecure and it means the industry is struggling with economic problems.

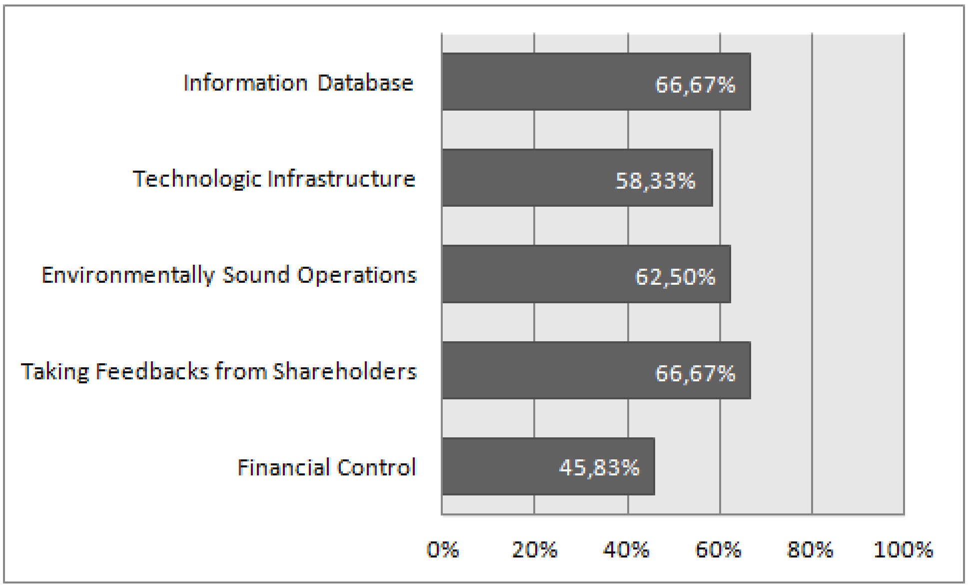

Figure 8. Excellence rates of the partnerships & resources criterion.

Processes criterion has 50% excellence rate and it is shown in the **Figure 9**. According to the excellence rates of the question areas; the organizations are capable to plan their processes but they seriously have inabilities when it comes to optimize them. They care about international conventions but there are still some matters that need to be solved sustainably for the upcoming conventions. They are also not good at the point of reducing inconveniences permanently.

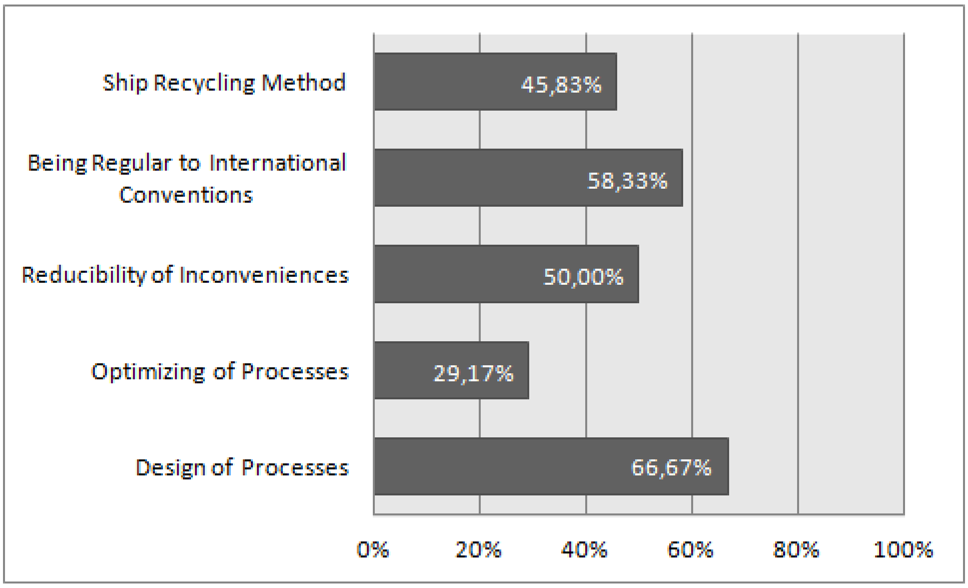

Figure 9. Excellence rates of the processes criterion.

"Customer results" is an above average criterion in the survey **(Figure 10).** The ship recycling organizations are supporting their customers and brokers at good point. They are also better than the other ship recycling nations on confidence about occupational accidents. They are aware of why they are to be chosen, however they do not care much their images and reputation in the sector. Key results have around 51.5% excellence rate is shown in the **Figure 11**. The Turkish Ship Recycling Organizations have good results about increasing their ship scrapping volume.

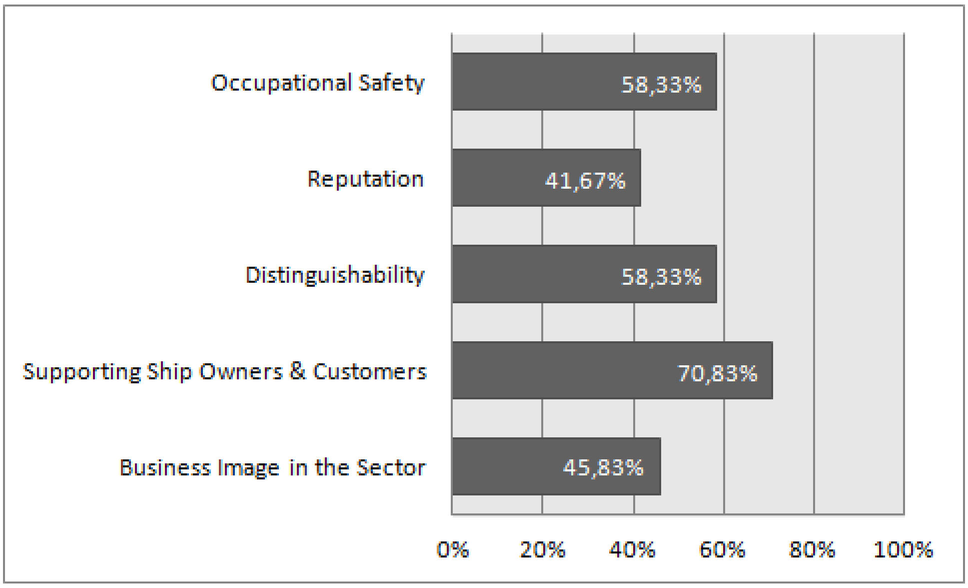

Figure 10. Excellence rates of the customer results criterion.

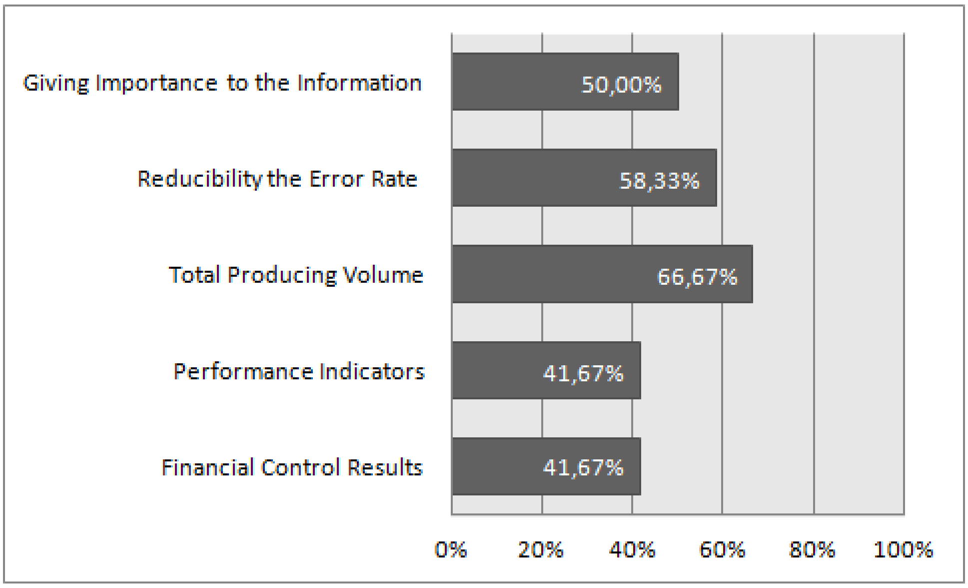

Figure 11. Excellence rates of the key results criterion.

As it is shown on the **Table 2**, excellence rates are transformed into the excellence scores with respect to the RADAR logic coefficients. Maximum total scores are ‘500’ points for both enablers and results. (Total maximum point is ‘1000’). Here, the Turkish Ship Recycling Industry’s excellence rate is 54.40% which is an overall rate that giving ideas from a large perspective.

Besides, the rates of the results criteria (55.49%) and the enablers criteria (53.30%) have closer excellence rate values; in other words, the results are consistent at this sight. To illustrate, **Figure 12** show the distribution of judgments from the academia and industry with respect to the responses given for the survey.

Table 3. RADAR analysis results.

	Criterion	Excellence Rate (%)	RADAR Coefficients	Scores	Total Scores of Enablers and Results	Total Excellence Score
Enablers	Leadership	42.485	1.0	42.485	266.528	544.014
	Strategy	49.150	0.8	39.320		
	People	67.485	0.9	60.737		
	Part.& Res.	59.985	0.9	53.987		
	Processes	50.000	1.4	70.000		
Results	Customer R.	55.000	2.0	110.000	277.486	
	People R.	71.650	0.9	64.485		
	Society R.	42.502	0.6	25.501		
	Key Res.	51.667	1.5	77.500		

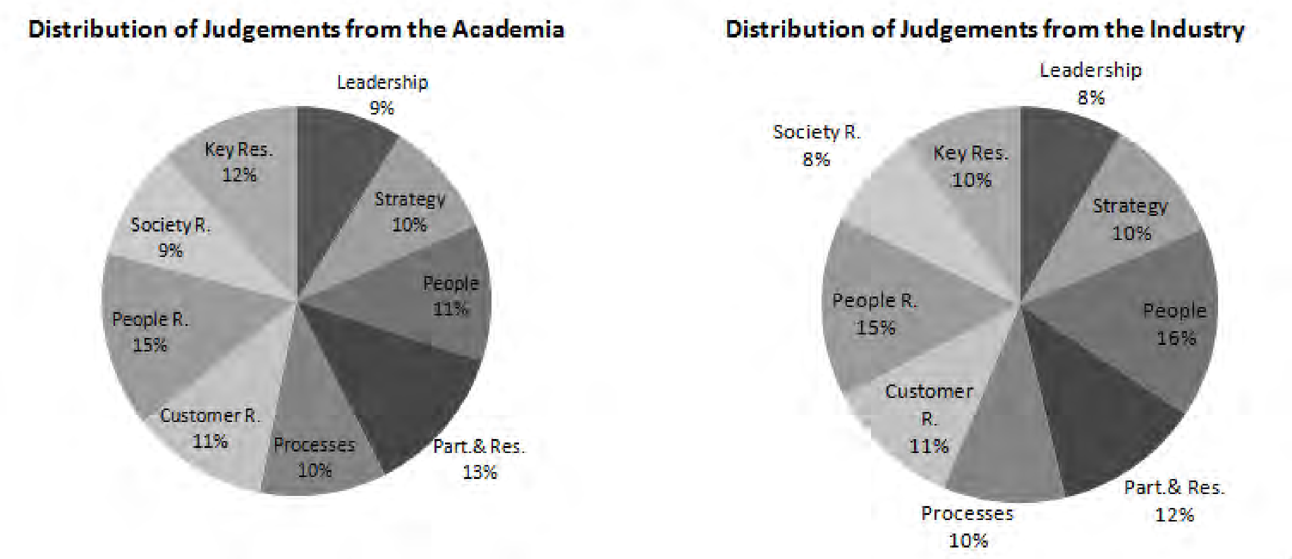

Figure 12. Distribution of judgments from the academia and the industry.

CONCLUSION

This study investigates the current situation of the Turkish ship recycling industry and reveals the weak and strong points, as well as offer solutions in the EFQM's perspective. A ship recycling industry EFQM based survey has been originally adopted and successfully conducted. Considering the analysis results, the following items are summarized to improve the ship recycling activities in the region:

- Poor leadership and mission & vision skills are the weakest areas of the industry. Sector could not dominate the market and tries to survive under many uncertainties. Like employees, leaders also should take some education programmes to gain personal development about organizational management.
- Current ship recycling method restricts the innovative movements as it is seen in the area of "optimizing of processes". Despite the currently used ship recycling method, Turkish ship

recyclers standas environment friendly, when comparing with the India, Bangladesh and Pakestan. Switching to the dry-dock method is needed for further development.

- The industry is satisfyingly ready to the upcoming HK as it stands as a very important finding. The rating of "environment friendly" is at satisfied level despite currently using unfavourable ship recycling methods. If the method changes and enhances, the industry would gain more advantage with the HK.
- Co-operation between industry and the government is weak. The government should provide long term credits or subventions to support ship recyclers for making considerable improvements such as switching to the dry dock method.
- Neighbour relations still undeveloped and could cause some problems about waste management. There are also some disagreements are risen up about waste management due to lack of authority of the local governmental organization.
- Ship recyclers tend to hide information from academicians or relevant experts due to probability of some of their mistakes could be exposed. Stronger connections should be established with the industry. The organisation leaders must be encouraged to be more transparent on information sharing thus tangible results could be achieved by tangible data.
- The best result of the study is about ship recycling workers. With the recent training projects between Turkey and EU "Taking Training & Services" is at satisfying level. When comparing with the other ship recycling nations' facilities; working conditions could be considered also as good enough. The leaders are failed to encourage and reward them, mentioned improvements or another actions to be taken to increase their management quality.
- Aliaga ship recycling zone has reached its maximum capacity already with 23 different companies [44]. Company merging could be a solution in shortest term. Besides, another ship recycling zones are needed in order to dismantle larger obsolete vessels.

The study has a contribution to the literature via initiating a self-assessment with EFQM model in ship recycling industry. There are many applications of the EFQM to the study areas of medicine, employee motivation, safety & security, education & training, construction sector, tourism etc. However, there are not many applications in the maritime field. The demonstration results are useful to remedy the gaps of region to become ship recycler of the Europe, as a suggested maritime policy. Furthermore, application of the EFQM model to specific organizations to support the integration of advanced ship recycling methods, convention requirements and innovations into industry can be studied.

The research has been resulted as expected but gives more detail about the Turkish ship recycling industry situation. For instance, environmental awareness and working conditions were expected because Turkey has already begun to implement requirements of the HK Convention. The actual benefits of the convention could be seen in the next years more clearly.

The limitation of the study is that the industry is very specific and small scaled sector thus that makes it very difficult to create a broad participated consensus groups. Besides, some of the industry managers were reluctant to share detailed information as they consider privacy policy of their organisations.

For further studies, European ship recycling methods, techniques and innovations could be examined in order to reveal differences between Turkish and European ship recycling industry. Therefore, an advanced European ship-recycling model may be implement to Turkey as a "ship recycler of the Europe" due to Turkey's geographic location and its better appearance about human health and environmental issues. Besides a new or modified ship recycling assessment model could be designed if new conventions entry into force based on EFQM excellence model. Moreover, EFQM model could be applied to just one ship recycling organization to establish sustainable excellence model for one organization, which could be the best guide for other ship recycling organizations.

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INVESTIGATION OF COST CONCEPT IN AIR CARGO MANAGEMENT IN THE CONTEXT OF TURKEY

İlhan ATİK[1]

Abstract – *In accordance with the developing commercial activities of our country in recent years, there is a steady increase every year in transportation modes. However, among these modes, the aviation sector is constantly showing the greatest growth potential. The aviation sector in the world and in our country is a sector in which large investments are made by using material resources at a considerable level but profit is obtained at low level in global competition. Businesses operating in this sector have to manage their cost elements without compromising the high quality they have in order to compete and profit. Cost classification in the sector can be done in various ways for different purposes. However, in all airline companies, cost information is needed when the profit and loss related to the main activities can be evaluated separately from other activities. It also uses cost information to evaluate investment decisions such as aircraft purchases or a new line to be added to the flight network. Cost information plays an important role in determining the pricing policies they apply. In this study, the development in the aviation sector will be examined considering the position of our country in world trade and transportation networks. In addition, cost elements of the air cargo will be evaluated. Also, it is tried to put forward the role played by the air cargo management to gain the competitive advantage of our country.*

Keywords – *Air Transportation Models, Cost, Logistic, Transportation.*

INTRODUCTION

In the global economy, every $100 of output produced and every 100 jobs generated by air transport trigger additional demand of some $325 and 610 jobs in other industries[1].

Air cargo transportation, which provides high added value to other sectors and is one of the important components of economic development; has gained significance despite its high cost due to the fact that speed and time factors stand out with globalization. By definition, "Air cargo transportation"; in accordance with the ICAO and IATA rules governing international aviation activities and by taking into account the country and carrier restrictions, is the packaging and labeling of goods except for mail and baggage, proper preparation of documents and shipment by air [2].

Air transportation is the basis of aviation activities. From airport construction, maintenance improvement, air traffic activities to ground services, all operations are carried out in order to ensure that air transport is safe, secure and effective [3].

International trade has reached high economic values due to the rapid development in the information sector and the increase in the effectiveness of the organizations that regulate global trade. Logistics activities have a very critical value when the trade is effectively carried out. The "transport" issue, which has an important financial asset in logistics activities, is one of the most important problems in the development of global trade. In this context, transportation costs are dwelled on, considering that the reduction of the transportation cost, expressed in "Squares Rule" or "Lardner Rule" used in transportation and commerce, may increase the market of the products to 4 times the market area [4]. Over time, due to the decrease in passenger income and the satisfaction of passenger demand in the market, airlines have moved to the cargo market. Worldwide increase in cargo volume has increased the importance of effective management of cargo capacity in aviation.

In this study, the characteristics of the air cargo transportation and the enterprises operating in this sector will be examined first, considering the position of our country in the world trade and transportation networks and then the costs involved in the air cargo activity will be tried to be expressed and then an evaluation will be made in terms of air cargo transportation by introducing the position of our country in the world civil aviation sector.

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CHARACTERISTICS OF AIR CARGO TRANSPORTATION AND OPERATIONS

Effective cost management in global markets is important for businesses to gain competitive advantage. When the cost elements of logistics activities, which have a significant share in the transactions subject to the trade, are detailed, transportation activities within the sub-components constitute 45% of the total cost, while storage constitutes 26%, management costs 9% and storage 20% [5].

When transportation modes are compared in terms of fixed and variable costs, air transportation requires high investment in terms of fixed cost as presented in Table 1 and variable cost shows a flexible structure depending on actual traffic.

Table 1: Comparison of Transportation Modes In Terms Of Fixed and Variable Costs.

TRANSPORTATION MODE	COSTS	
	Fixed Costs (Terminal, infrastructure, road maintenance etc.)	**Variable Costs** (Fuel, labor, repair etc.)
Railway	Very High	Low
Highway	Low	High
Maritime	High	Very Low
Airway	Very High	Flexible
Pipe line	Highest	Lowest

Operational features of transport modes; Speed (time spent on board), availability (ready to service), reliability (timely departure and arrival, regularity), frequency (number of transfers), capacity (the ability to meet all transport requirements) and cost [6].

When transportation modes are classified according to these characteristics in Table 2, it is considered that road transport is the most common mode of transport, the fastest mode of transport is air transport, and maritime transport is the ideal mode for transporting large and bulky goods.

Although air cargo transportation is the most expensive type of transportation, due to inflation, air cargo freight rates have been falling for the past 30 years and this has positively affected air cargo demand. Estimates that transport prices will be further reduced in the future are reflected in the positive direction of the sector [7].

Table 2: Sorting of Transport Modes by Operational Features

Features	Railway	Highway	Seaway	Airway	Pipe Line
Speed	3	2	4	1	5
Availability	2	1	4	3	5
Reliability	3	2	4	5	1
Capacity	2	3	1	4	5
Frequency	4	2	5	3	1
Cost	3	2	5	1	4

Today, air cargo operations are used to transport many valuable but light products from precious metals, microelectronics, medicines to live animals and dangerous goods. These enterprises are located in the global market, taking into account traffic rights, environmental factors, procedures, performance standards and customs procedures.

In global trade, the concepts of speed and security required for goods to reach the market from the producers and to reach the consumers from the market are successfully achieved with air cargo transportation. Considering that international transportation lines are particularly important in the investment decision for 52% of businesses today, it is clear how important air cargo transportation is for different industries [8].

Features of air cargo transport in general can be listed as speed and security, usual one-way transportation, the type and volume of the goods transported, high labor force, aircraft purchase / lease and fuel cost, intense competition and advanced technology.

Due to the unidirectional transport of air cargo, it is an important cost factor to make demand forecasts. According to the characteristics of the commercial zone, goods are carried by passenger aircraft as well as cargo aircraft. While the approximate 19% of the international cargo traffic in 1960 was transported only by cargo-carrying aircraft [9], 66% of international cargoes are now carried on combined transport aircraft.

Air cargo operations carry the goods they deliver in a faster and safer way than other transport systems. Air cargo operations are generally organized as marketing, sales, operations and administrative services.

Marketing and sales departments are the departments where the customer service needs are harmonized with the given transportation service. Marketing units analyze the market needs by taking into account the aircraft fleet that the operator owns and produce the strategies of being present in the market. This section is responsible for all activities related to real customers, whether they are potential or not. The operation department is the department where air cargo operations are carried out. This section is where the basic cost areas of the business take place, where profit and loss occurs, where work is most intense, and where support and additional work related to transportation services are made. Enterprises operating in the sector where the competition is intense, high fixed capital is used and low profit margins exist must be operationally well organized [10].

Administrative services refer to activities in general subject areas such as human resources, procurement, transportation, and subsistence related to the activities carried out as in all other businesses. Air cargo transport has its own unique sectoral problems as it is in other transport modes. These include sensitivity to economic fluctuations, sensitivity to national and international policy and trade agreements, national fuel politics, dangerous cargo problems, cargo alliances and other problems.

AIR CARGO COST ELEMENTS

With the globalization of the world economy, customers' expectations for faster and more reliable deliveries have led to increased competition in air and cargo traffic for air cargo direction products with short shelf life and the development of air bags. Increased air traffic due to commercial integration between the European Union and the USA, increase in capacity by producing aircraft suitable for cargo transportation and decrease in labor costs due to more efficient use of labor have resulted in an increase in air cargo transport and a steady decline in revenues.

Airlines carrying both passenger and cargo have faced with great difficulty in classifying passenger costs with cargo. As the costs of these activities are intertwined, it is difficult to separate them. For this reason, it may be difficult to calculate the actual value of the costs realized and determine the cargo part. Fully cargo-carrying airlines and non-scheduled carriers can easily determine their costs.

The increase in oil prices, the most important cost to airline companies, has forced airlines to take new measures. In addition, the airport's departure, departure, parking and security, which are expressed as airport fees, it is a significant cost element in the fees charged for noise and emissions in cities. Another cost item for air cargo carriers is the costs associated with air traffic services. Air traffic services are airport services that inform air travelers about the route they must follow during their landing and departure. The primary impact of these services on costs is through delays in flight and inefficient route assignments. Another important cost in this line of work is labor costs. The factors of labor costs are, in general, the number of workers, salaries and ancillary benefits, the insurance and health costs of the workforce, the obligations of the contracts with the unions, the cost of the senior workforce and training costs.

In general, the definition of the cost concept is the monetary statement of the intermediate goods and components used to the product. The "cost" phrase refers to the burden of operating the inputs that are often presented in the form of a particular commodity, service. Generally, there are two sources of costs for an operator's goods and services. The first is the variable costs and the second is the fixed costs. The costs incurred in carrying out activities in the aviation sector as well as in other sectors are a very important factor in the operational strategy and the decisions to be taken. ***The cost;*** product or service price is generally needed for planning and decision making purposes for ***three reasons*** [11]. When these causes are examined, ***first;*** it is necessary for airlines to gain efficiency in management decisions by seeing the total cost in detailed expense classes. Thus, the changes and trends that may arise over time in costs can be predicted, and the costs related to operations and activities outside the core activity can be measured. ***Second,*** it is the decision to invest because the cost element will come to the fore as an important variable when evaluating the financial aspect of the aircraft fleet and the decision to extend flight points. ***Third*** one is the main determinants of the cost of tickets and transported goods. In the aviation sector, profit margins are declining steadily over the years. For this reason, wage levels determined without cost analysis may result in damage [12].

There is no generally accepted cost management. For example, an expense classification developed for general management purposes may not work as a pricing strategy. In this context, the cost classification specified by ICAO is taken as an example [13]. To this end, as a general practice in cost classification, entities divide total costs into ***operating expenses and non-operating expenses*** [14].

Thus, the actual activity flight and all expenditures made for its realization are determined. **In airline companies, operating expenses can be divided into direct and indirect operating expenses.**

Direct operating expenses are collected in three headings as all expenses related to the flight. These are ***flight operation expenses, maintenance expenses, depreciation and rent expenses.***

- ***Flight operational expenses*** are the largest of direct operating expenses. Scope includes payments to flight crews (salaries, travel expenses, travel costs, insurance and other social security payments) and fuel costs. Fuel costs are related to aircraft leaving the planned route due to aircraft type, flying distance and adverse weather conditions. Fuel costs have historically accounted for 10% to 15% of total operational costs in air transport, with a 20-40% share nowadays. Together with labor and fuel costs, they account for 60% of the operating cost of the air cargo [15].
- ***Maintenance and repair activities*** are important in terms of flight safety in aviation, and expenditures made for each stage of maintenance in ICAO applications are generally aggregated under a single cost item. All facilities, technical and administrative personnel necessary for the realization of maintenance and repair activities and the expenses of the parts which are changed and repaired are evaluated within this scope. Many businesses can also use these costs to compare costs by calculating separately for aircraft types.
- ***Depreciation and rental expenses;*** expresses depreciation and rent of equipment related to flight activity. The depreciation period is usually 14-16 years for large-bodied long-haul aircraft, and 8-10 years for smaller, shorter-haul aircraft. Depreciation and amortization are different according to operating policies. In addition, adding a new line to the flight network, subjecting the flight team to certified training to provide service on a certain type of aircraft by covering under amortization costs are spreading over the years.

Indirect cost of operations; includes station and place expenses, passenger services expenses, tickets, sales and promotion expenses, general and administrative expenses and other operating expenses that are not directly related to the flight collected in five subheadings, expenses that may increase or decrease by the amount of traffic [16]- [17].

- ***Station and location expenses;*** includes the expenses of the ground handling personnel, the maintenance expenses of the vehicle and equipment, the rental fees of the waiting rooms and other airport fees, the expenses related to the insurance and maintenance expenses of the buildings and the equipment.
- ***Expenses for passenger services;*** expenses such as fees for passenger service personnel, accommodation expenses of the flight team, catering services such as food and beverages provided to passengers during flight, overnight accommodation of transit passengers, in the event of a delay or a cancellation, the passengers who miss their voyages will not be able to obtain food or travel in the event of a delay in their stay are assessed under this expense.
- ***Ticketing, sales and promotion expenses;*** includes all expenses arising from ticket, sales and promotion services, commissions paid to travel agencies, all payments made to the staff serving in ticketing, sales and promotion departments and the expenses of their office and office equipment.
- ***General and administrative expenses;*** while general and administrative expenses for the above-mentioned areas are included in costs those which are not participating in this item is considered in this account.
- ***Other operating expenses;*** expenses not included in the above-mentioned expenditure types take place under this expense.

There are 5 different expense items according to the regulation made by ICAO on ***non-operating expenses.*** These are losses arising from the failure to use facilities and equipment, loan interest from bank loans or other debts, losses arising from other entities to which the entity is affiliated, changes in foreign currency exchange rates and expenses arising from financial instruments and other taxes [18].

EVALUATION OF THE MATTER IN TERMS OF TURKEY

The aviation sector, which is one of the biggest contributors to global refinement, has increased its production by accelerating investments by carrying 3.57 billion passengers and 52.2 million tons of cargo in 2015.

The global economic impact of aviation, which provides 62.7 million jobs with its associated business lines, which directly employs 9.9 million people, is estimated at $ 2.7 trillion. The national income of the aviation sector was $ 664 billion in 2015 and 3.5% of the global national income came from the aviation sector [19].

In 2015, 52.2 million tons of cargo has been transported as a total of 5.6 trillion US dollars worldwide. This financial value corresponds to 35% of the total merchandise, which represents only 1% of the cargo weight [20]. Similarly, air cargo has doubled every 10 years since 1970, and this trend is expected to continue at an average growth rate of over 4.2% per annum over the next 20 years, according to Boeing's World Air Cargo Forecast [21]. These expectations are also influenced by the emergence of integrated on-time production, logistics networks, and rapid development of electronic commerce at global level. The average annual growth of air cargo transportation over the past 10 years for the selected regions in Table 3 below, the performance of 2015 compared to the previous year and the growth forecast for the next 20 years are given. Global e-commerce is projected to more than double over the next five years, growing from $1.7 trillion to $3.6 trillion by 2020. Asia will continue to lead the world in average annual air cargo growth, with domestic China and intra-Asia markets expanding 6.2 percent and 5.5 percent per year, respectively. The Asia–North America and Europe-Asia markets will grow slightly faster than the World average growth rate.

Established markets expand slower than developing markets, so North America and Europe air cargo growth rates will be below the world average rate [22].

Table 3: 2015 Air Cargo Growth by Major Market

Region	History 2005-2015 by Percentage	Growth Percentage Year to Year	Forecast 2015-2035 by Percentage
World	2,0	1,9	4,2
Asia-North America	1,9	6,5	4,6
Europe-Asia	2,1	6,5	4,6
Intra-Asia	2,1	1,3	5,5
Europe-North America	0,4	1,8	2,4
Intra-North America	-1,4	2,5	2,2
Domestic China	7,6	4,9	6,2
South Asia-Europe	3,5	-4,1	5,0
Middle East-Europe	3,6	11,1	3,9
Intra-Europe	1,6	5,0	2,2

After the legal regulations that have been made in our country since 2003, the rapidly growing aviation sector with the increase of the airline companies operating in the sector continues to develop as a result of increasing infrastructure and fleet investments, number of connections and air ticket prices. In the period 2003-2015, the rate of growth in the world aviation sector, which is around 5% a year on average, was realized as 15% in Turkey. While employment in the sector in our country was around 65 thousand in 2003, it exceeded 187 as of the end of 2014. In the last twelve years, the total indorsement of the sector by 12 times increase has reached 26.6 billion dollars from 2.2 billion dollars.

According to ICAO's Economic Development, 2016: Air Transport Yearly Monitor report Istanbul Ataturk Airport took the 13th place with 233.228 aircraft landing and departing in the world's busiest airports, an increase of 0.4% was provided when it is compared to the previous year, with the number of passengers, 30.124.371, using the airport took the 14th place despite a decrease of 1.7% compared to the previous year [23], with a total of 918,136 tons carried 88.89% turkey's total air cargoes amounted to 1,032,943 tons by itself [24].

Table 4: Air Cargo Traffic of Turkey (2010-2016)

YEAR	DOMESTIC LINE (TON)	INTERNATIONAL LINE (TON)	TOTAL (TON)
2010	71.218	470.141	541.359
2011	76.268	508.204	584.472
2012	84.431	539.627	624.058
2013	100.097	631.864	731.961
2014	104.941	734.300	839.241
2015	101.447	803.314	904.761
2016	81.587	951.356	1.032.943

Air cargo transportation in Turkey has increased its efficiency by increasing its flight points and cargo transportation has been made to 552 flight points abroad from our country airports. In 2015, the most transported countries and continents have been;

- In the first place European Continent and most of the transportation has been made to Germany in this continent.
- In the second place Asia continent and most of the transportation has been made to China.
- In the third place the Middle East and most of the transportation has been made to United Arab Emirates.
- In the fourth place North America and most of the transportation has been made to United States.
- In the fifth place the African continent and most of the transportation has been made to Nigeria.
- In the sixth place south American Territory and and most of the transportation has been made to Brazil.
- In the seventh place Russia [25].

In our country, the civil aviation sector has 13 air carriers which are cargo or freight forwarders which have 28 cargo aircraft and total cargo capacity of 1.967.820. Air cargo transporters in Turkey are listed as Turkish Cargo which is established within the Turkish Airlines, MNG Airlines Transportation, ACT Airlines and ULS Airlines Cargo Transportation.

Turkey, the world's 18th largest economic power [26]; is in the middle of a region with high market volume when considering geopolitical importance. Our country has the easiest access to the European Union market which has a population of around 600 million and a gross national product of about 18 trillion dollars, the Russian Federation with a population of 140 million and a gross national product of about 1.3 trillion dollars, Africa and the Middle East which has a population of 600 million and a gross national product of about 3.5 trillion dollars.

The following are the issues that may be a problem when the cost of air cargo transportation is examined in terms of our country and the operating companies:

- Strong capital requirements for fleet setup and participation of new aircrafts to the transportation fleet or extra cost of obtaining loans from banks for these,
- The additional cost of using high fuel due to the use of old aircraft in the inventory, the need to pay extra fees due to noise and air pollution to airports in many regions or the necessity to use different routes without using those airports,
- The additional cost of having different types of aircraft in order to take full advantage of the potential in the market by taking into account the different characteristics of the transported cargos,
- The additional cost that can be caused by the economic and political crisis that may be faced at any time on the global and regional level,
- The cost of the delays that can be caused by the situations in which the General Directorate of Civil Aviation, which is the authority in the aviation sector in Turkey,
- Especially the cost of delays in the transit cargo operations which may be caused by lack of legislation, infrastructure and competent personnel,
- Operating costs arising from the fact that airports are not suitable for intermodal transport.

CONCLUSION AND EVALUATION

The contribution of world-wide communication and e-commerce to the development of global trade is increasing day by day. In this process, businesses have focused on low cost and fast goods delivery in order to provide competitive advantage.

As one of the leading economies of the world, Turkey has the opportunity to transport goods to the Asian, European and Middle Eastern markets in the shortest possible time with the lowest transportation costs due to its geopolitical position.

In the increasing foreign trade of our country, although the increase in the transportation of goods by air transport has increased over time, it has not yet reached the desired level. When air cargo cost factors are considered;

- The government is implementing many sectoral incentives. In the same context, financial support should also be provided for fleet installations and new aircraft purchases of air cargo transport companies.
- Establishment of maintenance facilities in different regions of the country to control the operating and maintenance costs of aircraft in the inventories of enterprises.
- Establishment of facilities and vocational high schools that can meet the needs of enterprises in terms of equipment and qualified labor force by the private or the public sector will reduce external dependency in these areas and costs.
- It is very important for the industry to be able to respond quickly to market conditions and to grow the potential appropriately. For this, it is necessary to simplify the bureaucracy and create a structure in which the problems are solved.

- Regulations on customs clearance procedures, regulations and structures that will speed up transit cargo operations on infrastructure and competent personnel should be carried out by the private sector and the public to reach level that can compete with other countries.
- Completion of the infrastructure deficiencies required by existing airports for air cargo operations and creation of infrastructure suitable for intermodal transportation between airway / road / railway and maritime transport are considered necessary for effective solutions.

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SMART TRANSPORTATION STRATEGY SELECTION FOR LOGISTICS COMPANIES

Gülçin Büyüközkan[1], Esin Mukul[2]

Abstract *− Developments in the automotive industry and the associated increase in the number of roads lead to a rapid rise in the number of vehicles, traffic congestion, delays, travel time, resource consumption, environmental problems, and accidents. This need gives way to the concept of smart transportation that shall be supported by appropriately selected strategies for logistics companies. Choosing the right strategy provides access to integrated, secure, efficient, innovative, human and environment-friendly, sustainable and smart transportation networks using that are well integrated with information and communication technologies. Smart transportation strategy selection problem has many conflicting objectives, where different criteria need to be taken into account for deciding on the right strategy. This study approaches the smart transportation strategy selection as an MCDM problem for logistics companies and presents a simple selective approach to solve it. After determining the strategy evaluation criteria, two MCDM methods are used in the evaluation procedure. AHP (Analytic Hierarchy Process) is employed for determining the importance of each criterion and calculating their weights. Then, COPRAS (Complex Proportional Assessment) is applied for evaluating and ranking smart transportation alternatives. Finally, a case study is provided to demonstrate the potential of the proposed approach.*

Keywords − Smart transportation, Strategy selection, Logistics sector, MCDM, AHP, COPRAS

INTRODUCTION

In the transportation sector, sustained economic growth, continuous population growth and increasing urbanization have become decisive factors for the industry's future. The increase in population leads to an increase in mobility requirements both for passenger and freight transport. However, safe, punctual, shorter time and more comfortable transport demands have accelerated the development of transport. Within this framework, concepts such as the operation of transportation types supported by logistics services, the establishment of an efficient transportation infrastructure and the creation of the concept of sustainability that emphasizes safety in transportation types have emerged.

Developments in the automotive industry and the associated increase in the number of roads lead to a rapid rise in the number of vehicles, traffic congestion, delays, travel time, resource consumption, environmental problems, and accidents. These adverse outcomes in the transportation systems require new designing systems that are more efficient, effective, safe and economical. This need gives way to the concept of smart transportation that shall be supported by appropriately selected strategies for logistics companies.

Smart Transportation Systems provide economic, environmental and socially sustainable solutions, in particular by ensuring that information is accessed quickly and efficiently [1]. The objectives of the smart transport system are to provide multidimensional data exchange between human-vehicle-infrastructure-center, to use in accordance with the capacities of the roads, to increase the safety and mobility of traffic, to reduce energy loss by providing energy efficiency [2]. Within the context of smart transport, solutions to major transportation problems can be produced by using advanced information and communication technologies. With smart transportation applications, coordination between different types of transportation can be provided to create ideal traffic conditions and the efficiency and speed of services related to passenger and freight movements can be increased [3].

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Choosing the right strategy provides access to integrated, secure, efficient, innovative, human and environment-friendly, sustainable and smart transportation networks which are well integrated with information and communication technologies. Smart transportation strategy selection problem has many conflicting objectives, where different criteria need to be taken into account for deciding on the right strategy.

Multi-criteria decision making (MCDM) is a powerful tool, which is widely used for evaluating problems containing multiple, usually conflicting criteria. The MCDM is one of the most popular problems in the literature. MCDM refers to find the best opinion from all of the feasible alternatives. Priority-based, outranking, distance-based and mixed methods could be considered as the primary classes of the current methods [4]. One of the most outstanding MCDM approaches is the Analytic Hierarchy Process (AHP) which has its roots on obtaining the relative weights among the factors and the total values of each alternative based on these weights. This study uses the AHP to determine the criteria weights from subjective judgments of the decision maker group [5]. The rating of each alternative and the weight of each criterion, which are calculated using the AHP, are then passed to the Complex proportional assessment (COPRAS). COPRAS is applied to rank and evaluate alternatives in terms of importance and benefit ratings. Criterion values are used to maximize the benefit criterion in evaluating the criterion and to evaluate the most useless criteria for the lowest cost. Compared with other MCDM methods such as AHP and TOPSIS, it is a very simple method to use less calculation time. The method allows evaluation of both qualitative and quantitative criteria.

The objective of this study is to estimate the strategic factors of smart transportation and to choose the best solution for smart transportation strategy in logistics companies. The structure of the paper is as follows: The related studies are summarized in next section. The following section presents the proposed model and methodology for smart transportation strategy selection. A case study is given in latter section and finally the last section concludes the study.

LITERATURE REVIEW OF SMART TRANSPORTATION

Today, smart transportation systems are built on advanced technologies such as computers, communications, and electronics. They are systems which use real-time and up-to-date databases that aim to improve efficiency, security and service quality in transportation. On the other hand, the integration of all transport systems on the technological and institutional basis, which enables people and goods to move from one place to another, is also considered within the concept of smart transportation [6].

Smart transportation systems, in general, can be defined as transportation solutions designed to alleviate the thinking or decision-making burden on people. From this point of view, the first smart transportation application is traffic lights. It is accepted that the beginning of the research period began in the late 1960s and early 1970s. Each of the three leading countries of intelligent transport systems considers their pilot implementation as a milestone. The Electronic Route Guidance System (ERGS) launched in the US in 1969, the CACS (Comprehensive Automobile Traffic Control System) launched in Japan in 1973 and the ARI (Autofahrer-Rundfunk- Information system) are prominent systems of this period [3].

In the literature, Stefansson and Lumsden [7] presented the conceptual model of the Smart Transportation Management (STM) system and analyzed how the included factors change the performance of distribution activities and what management issues are at stake. Kim et al. [8] proposed a reservation-based scheduling scheme for the charging station to decide the service order of multiple requests, aiming at improving the satisfiability of electric vehicles. Synergizing electrified vehicles and mobile information systems in smart transportation are presented by Schewel and Kammen [9]. Khan et al. [10] developed wireless sensor networks for smart transportation solution. Wang and Kexin [11] discussed the benefits and problems of the three solutions of transportation, based on the Transit Priority Strategy in China, including the transportation policy research, smart transportation research, as well as planning and design research. Bacciu et al. [12] analyzed the feasibility of these services in using machine learning for short-term predictions in smart transportation systems. There are many studies about smart transportation in the literature. In this study, a different point of view will be presented using smart transportation and multi-criteria decision making and strategy selection will be made.

PROPOSED METHODOLOGY

The approach proposed in this study consists of three basic steps:

Step 1. Propose a model that will enable logistics companies to make strategy choices about smart transportation

Step 2. Determination of the importance of the evaluation criteria in the proposed model by the AHP method

Step 3. Determine the most appropriate strategy by COPRAS method based on the model proposed for smart transportation for companies operating in the logistics sector

Evaluation Criteria and Model Components

There are many criteria to be taken into consideration in order to integrate smart transport into the existing system in the most accurate way. These criteria are as in Figure 1.

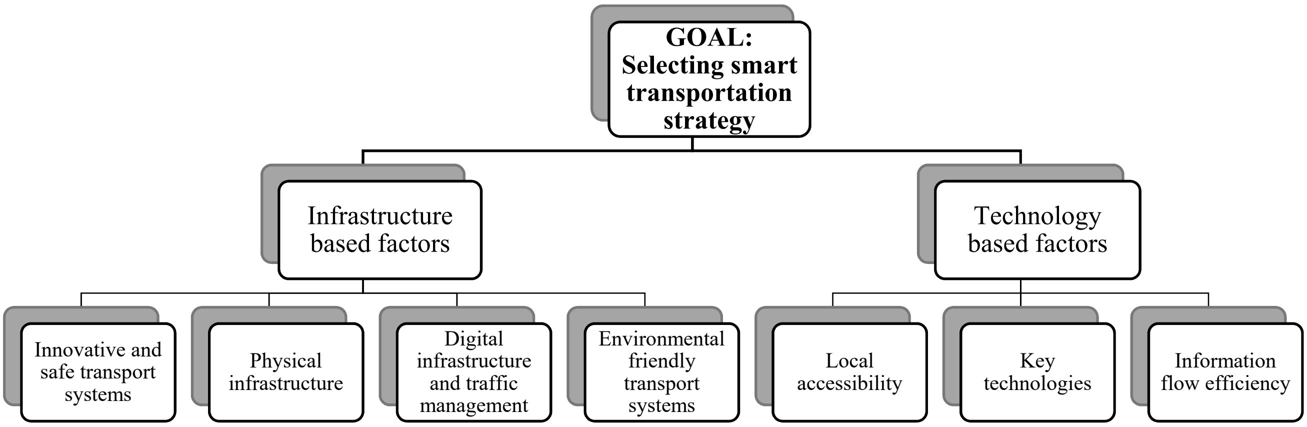

Figure 1. Proposed evaluation model and criteria

Innovative and safe transport systems (C11): A multidimensional, comprehensive, planned and nationwide co-ordinated smart transportation system installation is essential for an effective, innovative and safe transport management. The use of traffic information and management systems, such as smart transportation systems, electronic railway traffic management systems, will increase productivity in infrastructure use [3].

Physical infrastructure (C12): Infrastructure forms the whole of all economic, financial and social activities and forms of production. In general, infrastructure is the backbone of world economies. Transportation services consist of highways, airways, railways, seaway and port services. All transportation services require large infrastructure investments. The transportation services infrastructure requires high fixed costs. The costs of transportation services vary according to the sub-sectors. Some of the costs in highways are road construction costs, repair costs, vehicle operation costs [13]. Also, intelligent infrastructures have the ability to control their own use by intelligently responding to changes in their environment [14].

Digital infrastructure and traffic management (C13): Rapid developments in mobile data communication are generating an increasingly larger supply of individual services and support for the driving task of road users. Short-term opportunities primarily involve improved information provision for road users. In the longer run, this data communication will also be suitable for automated (self-driving) applications. In the years to come, the reality on the road will increasingly be characterized by conventional vehicles operating alongside smart vehicles in traffic. The actual use of new information services and driver willingness to utilize digital support in the task of driving will determine the pace at which new mobility applications will become a part of daily practice [15].

Environmental friendly transport systems (C14): The use of fossil fuels in road transport creates air pollution, and the use of increased motor vehicles also causes noise pollution. Environmental impacts, which are among the major problems of road transport, will lead to bigger problems in the future if measures are not taken [1]. With smart transport systems, it is aimed to reduce pollution rates and create a more environmentally friendly environment.

Local accessibility (C21): Smart transport systems can be used in 3G and 4G mobile phone networks. 3G or 4G wireless environments are especially important in terms of accessibility in urban areas and long roads [3]. In addition, the Accessible Pedestrian Button System, which has the ability to receive location and intersection information via Bluetooth, enables elderly or handicapped citizens to participate in the transportation system safely at intersections within the city [1].

Key technologies (C22): Smart transport technologies integrate telecommunications, electronics and computer technologies with the transportation sector. Some of these key technologies are Global Navigation Satellite Systems, wireless networks, mobile communication tools, RFID, detection technologies etc. [3].

Information flow efficiency (C23): In many countries, metropolitan areas have mobile applications and web applications that provide instant information about the traffic situation. Along with these applications, users can be informed and can easily use intelligent transportation systems. Ports that offer advice and directions from one point to another and route setting applications are also made to inform users [16].

Many strategies can be used to realize the smart transport system to be integrated. In this case, it is important to choose the strategy that will be most successful and the most appropriate for the system. These strategies are as follows:

Planning and integrating strategy: First, smart transport system architecture should be established at the national level. Along with this strategy, organizational arrangements are carried out in order to ensure the systematic planning, coordination, and implementation of the smart transport system. The implementation of legislative arrangements for the implementation and integration of the intelligent transport system is among the foundations of this strategy [17].

Competitive smart transport strategy: The main purpose of this strategy is to increase the awareness of users and practitioners of smart transportation systems. To this end, awareness-raising and promotion activities should be disseminated through public, private and civil society collaborations [17]. The opening of the external market of the information and communication technology industry will provide a strong position in the competitive environment.

Strategy for increasing security and mobility: This strategy focuses on the regulation of smart transport systems in the existing transport and communications infrastructure. With this strategy, traffic management in the urban and inter-city road network is brought up effectively and efficiently [3].

Access facilitation strategy: The availability of the system is important for effectiveness and efficiency. The transport infrastructure should be organized to provide more effective and safe services for the elderly, children and the disabled. At the same time, public transportation fleets must be regulated to provide more efficient [1].

Environmental strategy: This strategy is environment-focused and ensures that all work done is environmentally friendly. With this strategy, it is aimed to develop an environmentally friendly system that will provide energy efficiency. Solutions for reducing emissions in urban transportation are produced [3]. Smart transport systems help reduce vehicle emissions because of benefits such as reducing traffic congestion and allowing private motorists to move to public transport [17].

Determining the Criteria Weights by the AHP Methodology

AHP was developed by Saaty [19] as probably one of the best-known and most widely-used model in decision-making. AHP is a powerful decision-making methodology in order to determine the priorities among different criteria. To make a decision in an organized way to generate priorities we need to decompose the decision into the following steps:

Step 1. Define the problem and determine the kind of knowledge sought.

Step 2. Structure the decision hierarchy from the top with the goal of the decision, then the objectives from a broad perspective, through the intermediate levels (criteria on which subsequent elements depend) to the lowest level (which usually is a set of the alternatives).

Step 3. Construct a set of pairwise comparison matrices. Each element in an upper level is used to compare the elements in the level immediately below with respect to it.

The matrix A is a $m \times m$ real matrix, where m is the number of evaluation criteria considered. Each entry a_{jk} of the matrix A represents the importance of the j^{th} criterion relative to the k^{th} criterion. If $a_{jk} > 1$, then the j^{th} criterion is more important than the k^{th} criterion, while if $a_{jk} < 1$, then the j^{th} criterion is less important than the k^{th} criterion. If two criteria have the same importance, then the entry a_{jk} is 1. The entries a_{jk} and a_{kj} satisfy the following constraint:

$$a_{jk} . a_{kj} = 1. \tag{1}$$

Obviously, $a_{jj} = 1$ for all j.

Table 1. Table of relative scores

Value of a_{jk}	Interpretation
1	*j* and *k* are equally important
3	*j* is slightly more important than *k*
5	*j* is more important than *k*
7	*j* is strongly more important than *k*
9	*j* is absolutely more important than *k*

To make comparisons, we need a scale of numbers that indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. Table 1 exhibits the scale [18].

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column, i.e. each entry a jk of the matrix A_{norm} is computed as:

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{jk}}. \tag{2}$$

Finally, the criteria weight vector w (that is an m-dimensional column vector) is built by averaging he entries on each row of A_{norm},

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m}. \tag{3}$$

Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then, for each element in the level below, add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives at the bottom-most level are obtained [19].

Step 4. AHP also calculates an inconsistency index (or consistency ratio) to reflect the consistency of decision maker's judgments during the evaluation phase. The inconsistency index in both the decision matrix and in pairwise comparison matrices could be calculated with the equation:

$$CI = \frac{\lambda_{max} - N}{N-1}. \tag{4}$$

Evaluating Smart Transportation Strategy Alternatives by COPRAS

COPRAS is a method of evaluating alternatives by making step-by-step sequencing of alternatives in terms of importance and utility ratings. It is one of the notable MCDM methods, which select the best alternative among of plausible choices by determining a solution to the best solution to the ratio with the ideal-worst solution [20]. The procedure of the COPRAS method includes the following steps:

Step 1. Construct the decision matrix.

Step 2. Normalize the decision matrix using the following formula.

$$\boldsymbol{x_{ij}^*} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad \text{for (j= 1,2, …,n)} \tag{5}$$

Step 3. Determine the weighted normalized decision matrix.

$$d_{ij} = x_{ij}^* . w_j \tag{6}$$

Step 4. The sums S_i^- and S_i^+ of weighted standardized values are calculated using the following equations for both beneficial and non-beneficial criteria separately:

$$S_{i+} = \sum_{j=1}^{k} d_{ij} \tag{7}$$

$$S_{i-} = \sum_{j=k+1}^{n} d_{ij} \tag{8}$$

Step 5. The Q_i values are relative importance values for each alternative and are calculated using the equation (8). The result of the calculations is determined as the best alternative with the highest relative importance value.

$$Q_i = S_{i+} + \frac{\sum_{i=1}^{m} S_{i-}}{S_{i-} * \sum_{i=1}^{m} \frac{1}{S_{i-}}} \tag{9}$$

Step 6. The highest relative priority (Q_{max}) value is found.

Step 7. Calculate the performance index (Pi) of each alternative with this equation:

$$P_i = \left[\frac{Q_i}{Q_{max}}\right] \times 100\% \tag{10}$$

APPLICATION OF THE MODEL

There is a logistics company, which wants to select the best strategy for smart transportation. There are five possible alternatives in which to select the strategy: A1 is planning and integrating strategy. A2 is competitive smart transport strategy. A3 is a strategy for increasing security and mobility, A4 is access facilitation strategy and A5 is an environmental strategy. The company must take a decision according to the following seven criteria: C11 is innovative and safe transport systems, C12 is physical infrastructure, C13 is digital infrastructure and traffic management, C14 is environmental friendly transport system, C21 is local accessibility, C22 is key technologies and C23 is information flow efficiency. The five possible alternatives Ai (i = 1, 2, 3, 4, 5) are to be evaluated using the AHP and COPRAS.

AHP-Stage 1. Evaluation criteria, definitions, and hierarchical structures are given in the previous section.

AHP-Stage 2. Experts agree on a binary comparison of the criteria underlying the AHP method. A binary comparison matrix has been established for the implementation of AHP.

The decision matrix, which is based on Saaty's nine-point scale, is constructed. The decision maker uses the fundamental 1–9 scale defined by Saaty to assess the priority score. In this context, the assessment of 1 indicates equally important, 3 slightly more important, 5 more important, 7 strongly more important and 9 indicates absolutely more important (Table 1).

AHP-Stage 3. The AHP method was applied to the mathematical movement, which was the result of the consensus of decision-makers' (expert), and the criteria weights were calculated as in Table 2.

The AHP methodology first necessitates the pairwise comparisons of the criteria and the sub-criteria in order to determine their weights. In this study, the weight of the infrastructure based factors is 0.60 and the weight of the technology-based factors is 0.40.

Table 2. The standardized matrix

	C11	C12	C13	C14	Weight
C11	0.630	0.691	0.450	0.525	0.344
C12	0.210	0.230	0.350	0.375	0.175
C13	0.070	0.033	0.050	0.025	0.027
C14	0.090	0.046	0.150	0.075	0.054

	C21	C22	C23	Weight
C21	0.067	0.034	0.106	0.028
C22	0.467	0.241	0.149	0.114
C23	0.467	0.724	0.745	0.258

AHP-Stage 4. The consistency ratio (CR) for the binary comparison matrices is calculated.

By using the criteria weights found with AHP, smart transportation strategies will be evaluated with the COPRAS method.

COPRAS-Stage 1. The decision matrix is established.

COPRAS-Stage 2-3. The weighted normalized decision matrix of the alternatives calculated by multiplying the normalized decision matrix and the weights is represented in Table 3. The normalized decision matrix is calculated using equations (5) and (6).

Table 3. The weighted normalized matrix

	C11	C12	C13	C14	C21	C22	C23
A1	0.184	0.098	0.017	0.020	0.011	0.063	0.137
A2	0.143	0.070	0.007	0.028	0.011	0.063	0.098
A3	0.184	0.042	0.012	0.020	0.007	0.049	0.098
A4	0.143	0.070	0.012	0.012	0.020	0.049	0.137
A5	0.102	0.098	0.007	0.035	0.007	0.021	0.098

COPRAS-Stage 4-5-6-7. The values of Qi, Si+, Si-, Pi were calculated using equations (7), (8), (9) and (10) by COPRAS method. Table 4 shows the results. In view of the proposed model, every option has the preferable values for the maximizing and minimizing indices. At that point, the relative weight and the optimality criterion are figured as appeared in Table 4. According to the value of the optimality criterion, the priority of the alternatives is acquired. Finally, the utility level of every option is measured as displayed in Table 4.

Table 4. The final results

	Si+	Si-	Qi	Pi	Rank
A1	0.512	0.017	0.519	100	1
A2	0.412	0.007	0.428	82.44	3
A3	0.399	0.012	0.408	78.65	4
A4	0.431	0.012	0.440	84.82	2
A5	0.361	0.007	0.377	72.55	5

Ultimately, planning and integrating strategy (A1) has become the most desirable strategy among five alternatives with the final performance value of 100; while the access facilitation strategy (A4), the competitive smart transport strategy (A2), strategy for increasing security and mobility (A3) and the environmental strategy (A5) have positioned at the second, third and fourth ranks with 84.82, 82.44, 78.65 and 72.55 as the final performance values, respectively.

Planning is always a priority for systems. In order for smart transport systems to be successful for logistics companies, the existing system must be analyzed first. Then, what needs to be done must be systematically planned. The integration of the planned system into the existing system should also be done in accordance with the conditions. Smart transport system architecture should be established at the national level. Along with this strategy, organizational arrangements are carried out in order to ensure the systematic planning, coordination, and implementation of the smart transport system. The implementation of legislative arrangements for the implementation and integration of the intelligent transport system is among the foundations of this strategy.

CONCLUSION

The direction of the world in terms of smart transportation is obvious. Countries with high economic levels will make great strides in this area and use the technology at the highest level. It is understood how much the smart transportation is needed if the material and spiritual losses that are caused by the traffic accidents and congestions in our country are taken into account. It is important to choose the right strategy to implement the required system. In this study, the most suitable strategy selection for logistics companies will be determined with the methods presented.

The purpose of this study is to estimate the strategic factors of smart transportation and to choose the best solution for smart transportation strategy in logistics companies. This study will show how verbal information is effective for MCDM and how COPRAS method which is a rare method in the literature.

Consequently, at first, the basic concepts of the smart transportation are reviewed. The model is estimated of the criteria and the alternatives for smart transportation strategy selection. The approach multi-criteria decision making, the AHP, and COPRAS are applied. There are five alternatives for selection of smart transportation and the best alternative of smart transportation is found. The most desirable alternative is planning and integrating strategy (A1).

The subject of smart transportation strategy selection can be advanced in future studies by increasing the number of criteria and the decision makers or using different decision-making methods. Another perspective can be to consider uncertainty using fuzzy approach [21].

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LOGISTICS PROCESS IMPROVEMENT OF KAPIKULE BORDER CROSSING

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Abstract – *In this study, logistics process improvement of Kapikule Border Crossing, one of the largest customs gates, has been evaluated. It is obvious that, any decrease in trade time is expected to realize positive impact on the logistics competitiveness of a specific country. In order to reduce time across all dimensions of the border process, the improvement of physical infrastructure and the proliferation of procedures are the most important issues that should be focused on. The aim of the study is to improve the Kapikule border crossing by reducing the process time. For this purpose, first, in-depth interviews were conducted with the Kapikule customs gate authorities in order to reveal explicitly the process flows. Subsequently, the current situation at the gate was simulated using the Arena simulation software. Finally, several improvement scenarios were tested to identify the ones that will have the highest impact on reducing the queues and the delays at the border.*

Keywords: Process analysis, simulation, border crossing

1. INTRODUCTION

The Logistics Performance Index (LPI), which is published on the website of the World Bank, is an important index for the evaluation of the logistics performance of 155 countries according to six basic indicators. The indicators used in the calculation of the index are: the customs, the infrastructure, the international shipments, the service quality, the tracking and tracing, and the timeliness [1], [2].

As the backbone of international trade, logistics plays an important role in the development of public policies, which are formulated by the national governments and regional and international organizations. In fact, in the countries with good roads and predictable customs clearance, the delivery times will be both shorter and more certain [1]. The development of the logistics sector is expected to have a positive impact in terms of increasing production, consumption and trade, thus stimulating the economic growth. In addition, better infrastructure will contribute to attracting foreign direct investment [3], [4], [5] and [6].

Logistics is critical to the underlying value of businesses, the growth potential, and the economic competitiveness. Unfortunately, logistics is often disrupted owing to border delays, security concerns, and infrastructure constraints. These issues create an environment of uncertainty in the business community, which deters investment, job creation, and economic prosperity [7].

By closely observing the indicators of the LPI report, the international shipment indicator is defined as "The ease of arranging competitively priced shipments" [1]. The LPI measures this factor based on several indicators; among these, the import and export time are used for the measurement of logistics performance. As there is a considerable amount of shipment time variability in the developing countries, it substantially increases the generalized cost of haulage and, thus, has a negative impact on international trade. Therefore, any decrease in trade time is expected to create a positive impact on the LPI. For this, it is necessary to reduce time across all dimensions of the border process, and to enact reforms that focus on the prevalence of physical inspection and the proliferation of procedures and bureaucracy. In a country with better road infrastructures as well as predictable and quick customs clearance, there will be shorter and more certain delivery times, which will develop the SCM sector and will cause that country to gain competitive advantage. Hence, a country has to focus on improving customs, logistics quality, and timelines of its logistics operations. Logistics performance is inevitably highly dependent on government interventions such as investing in improved road infrastructures, developing regulatory transport service regimes, and implementing efficient customs clearance procedure. Governments play an important role on designing operations, processes, and infrastructures for modern and efficient customs and cross-border transport. Nevertheless, customs is not the only agency involved in border management, collaboration among all border management agencies and related stakeholders is especially important.

In this study, the ways of improving efficiency of a cross border, and, hence the logistics performance of a country, will be analyzed in detail. The Kapikule cross border was selected as our case study with the aim to develop a comprehensive system that facilitates fast, safe, secure, and efficient movement of goods.

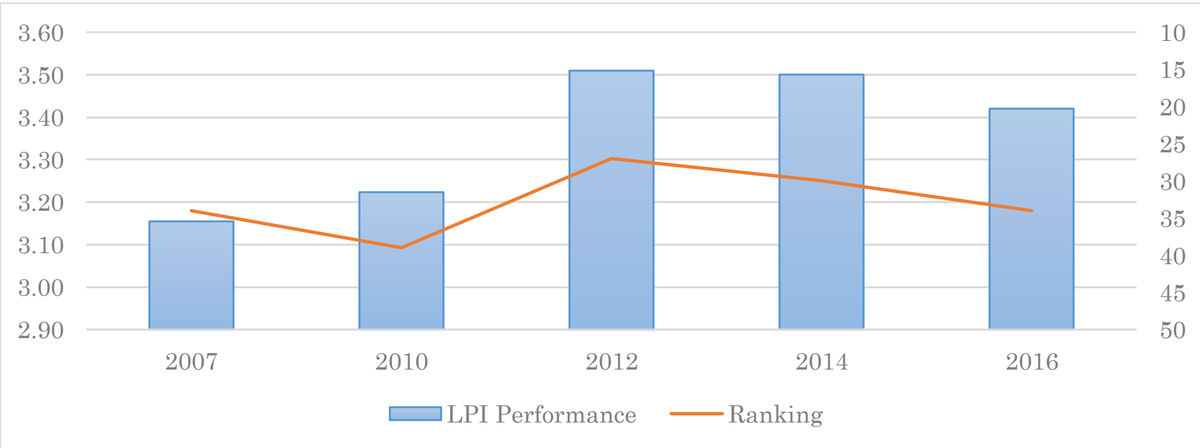

Figure 1 LPI performance score and ranking of Turkey

As can be seen in the literature review, typically, simulation has been used as a tool to model, plan, control, and to analyze the processes and improvement of complex systems, such as cross-border operations. Various discrete event simulation software tools such as Arena, ExtendSim, FlexSim, and Simul8 are used for this purpose [8]. For this reason, in this study, we used simulation analysis to examine the impact of different policies in reducing the waiting times at the Kapikule border crossing, which has become Turkey's gateway to the West with its 12 directorates, such as customs, property administration, food, and Agriculture and animal husbandry. At the Kapikule border crossing, 250 personnel are on duty during the working hours, and there are 100 additional personnel during the night shift.

When logistics competitiveness of Turkey is investigated for the past decade, it may be observed that Turkey should particularly focus on customs, as well as on logistical quality and competence (Kabak et al., 2016).

Therefore, in this study, we aim to focus on the Kapikule border crossing to improve the custom border efficiency of Turkey. The Kapikule border crossing was selected as a case study since it is one of the largest customs gates, with a 333,000 m^2 area that connects Turkey to Europe via road transportation. The present work is organized as in the following: First, the existing situation, process, and problems of the Kapikule border crossing will be investigated, and all the process flows will be derived. Subsequently, the existing situation will be simulated using the Arena simulation software. Finally, the impact of different improvement scenarios will be tested; the scenarios that present the highest impact on reducing the delays will be analyzed in order to provide a road map to the government authorities.

2. RESEARCH METHODOLOGY

The first step of the research methodology is to analyze all the processes that are carried out at Kapikule. The processes are categorized as import and export-related. For this purpose, initially, the stakeholders were identified, the process value maps were created, and document flows and decision nodes were determined. The stakeholders include individuals, such as customs officials (e.g., clerks, veterinarians, and agricultural engineers), truck drivers, and department managers, as well as other actors in the system, who deliver or receive the customs services.

Subsequently, each process was modeled in the Arena simulation software; a number of scenarios were executed to reduce the bottlenecks, hence speeding up the process and, consequently, providing strategic recommendations.

Process Analysis

In the first step, the goal is to lay out the existing situation at the Kapikule border crossing with all the relevant parameters. For this purpose, the sequences of activities that describe how various entities, such as trucks, drivers, cargo, documents, and information in general, move through the system were defined. In order to collect this information a total of five site visits were conducted, which started in March, 2016. Each visit consisted of two five-member teams working separately on the import and export processes. At this step, the team members observed each activity in each department, and conducted in-depth interviews with customs officers and the department managers of all the departments, namely Customs, Immigration Office, Plant Standard and Certification Office, Agriculture, Fisheries, Food and Drug Administration, Animal Quarantine, and Disease Control.

After the observations were completed and the draft process flows were laid out, they were shared with the stakeholders for feedback and confirmation. Based on their responses and feedbacks, further changes were made, and the process flows were finalized. The process value maps were developed such that all activities at the Kapikule border crossing would be inter-connected. Subsequently, time measurements and data collection for each step of each process are conducted to be used as input for our simulation models.

The number of decision nodes and transactions were obtained from the process analysis and data collection steps, and are listed in **Error! Reference source not found.**.

Table 1. Number of decision nodes and transactions

Import				**Export**		
Process Name	DN	TA		Process Name	DN	TA
Passport Control	4	14		Transit Permit	5	22
Scaling Station	1	6		Registration Station	6	11
Pre-inspection	3	11		X-Ray	3	6
Animal inspection	4	14		Inspection	4	7
Agricultural inspection	3	10		Animal inspection	2	7
Registration Station	6	12				
Deadheading	3	8				
Hangar	6	10				
Exit	1	4				

DN: # of Decision Nodes, TA: # of Transactions

A general representation of the import process is illustrated in **Error! Reference source not found.**. As we may observe, after passport control, the truck must enter scaling, which is the first controlling point in the area. Then, the truck must proceed to pre-inspection, where the level of gasoline is controlled. Next, the sub-processes to be followed depend on the type of the load. Freight classified under livestock is diverted to animal inspection, whereas freight classified under agricultural products is diverted to agricultural inspection. The remaining freight proceeds directly to the registration station, where the trucks that have already passed through animal inspection or agricultural inspection must proceed to as well. After the registration process, the truck enters X-ray and/or hangar sub-processes, if necessary; this concludes the import process.

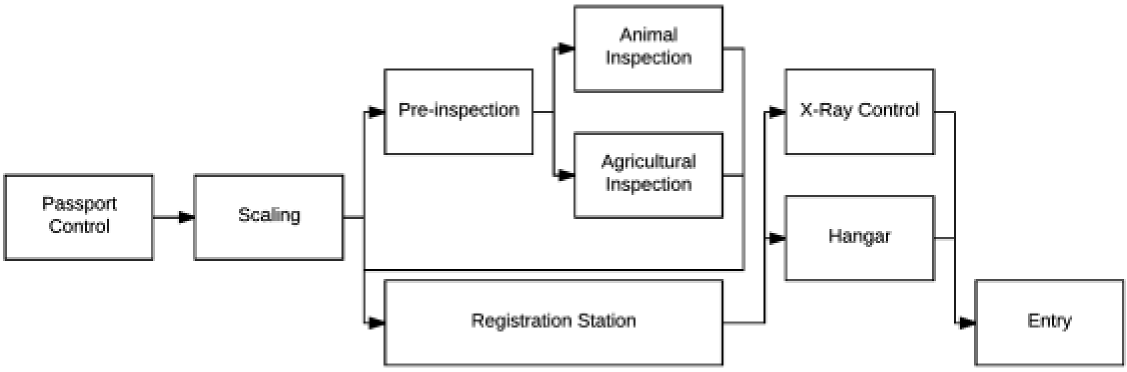

Figure 2 Import process flowchart

A general representation of the export process is presented in **Error! Reference source not found.**. As can be seen, after the truck leaves the park, it has to pass through passport control and scaling before the registration sub-process. According to the freight type of the truck and/or the inspection code that the truck belongs to, the truck must proceed to the animal and agricultural inspection sub-process or to the X-ray control and inspection sub-processes. Before leaving Turkey, the truck enters the gas station to purchase tax-free gas.

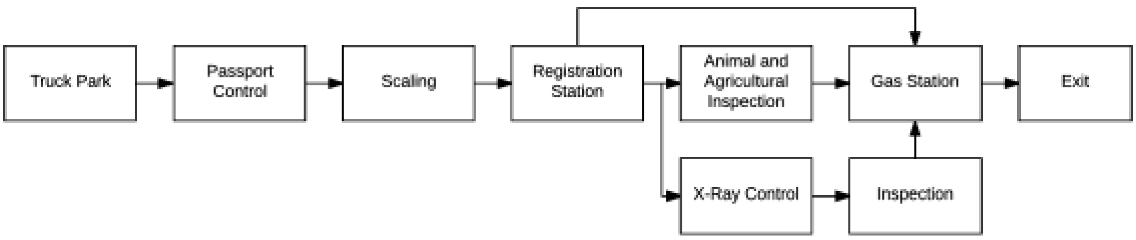

Figure 3. Export process flowchart

Data collection

The data collection approach for the process value maps involves obtaining on-site time measurements and using previously published statistical data. For the latter, the activity times for various customs tasks published by the Ministry of Customs and Trade and other agencies for the period May 1, 2016 to June 17, 2016 were used (Ministry of Customs and Trade, Turkish Union of Chambers and Commodity Exchanges, Customs of Trade and Tourism, International Transporters' Association)

In addition, to collect the activity times, the data on the weekly truck entrance/exit counts and the truck queue lengths for the year 2016 were analyzed. The average annual exiting truck queue length is approximately 5 km (up to 10 km for 20% of the year), and the average annual entering truck queue length is approximately 3 km (up to 11 km). To better understand the problems and bottlenecks regarding the customs processes, the aforementioned traffic information was used; the simulation scenarios were executed using the weekend data, which represent the busiest period.

Simulation Results and Scenario Analysis

The Arena simulation software that was used in this study offers a variety of detailed functionalities for input and output data analysis, scenario analysis, and visual animation, which are the most critical elements of a successful simulation study.

The model that was built as a result of the simulation analysis was then used to determine potential improvements according to various scenarios. To achieve this, first we validated the model to ensure that the simulation model reflected the current status, which will hereafter be referred to as the status quo scenario. The results regarding this scenario were investigated in two sections, namely the import and export sections.

Import–Related Scenario Results

For the status quo scenario set for import activities that take place within the Kapitan Andreevo border crossing, investigation window is specified as 48 hours. Within this period of time It was assumed that the current level of truck activity would remain the same as the daily average of 1245 trucks. However, according to the simulation results only 59% of them (equals to 719) can be served. Since (for import section) the capacity of the servers is not sufficient, an additional 526 trucks waiting to be processed on the side of the Kapitan Andreevo border crossing.

The main reasons for the long waiting times are the registration, the booth operations, and the veterinary and agricultural control operations performed by the Ministry of Food, Agriculture and Livestock. The average number of trucks waiting before the registration booth is 25, whereas before the veterinary operations, the average number of trucks is 29.

A validation has been done for the import processes. For this purpose, the status quo scenario was executed 1000 times for a 48 h window, and the period during which Kapikule was most crowded was investigated. All data within the model had been acquired from the field, with only one exception, namely the time between the arrivals of the trucks at the border. The data acquired were the time between the trucks entering the parking area; however, the required data were the time between each truck joining the end of the queue. Unfortunately, these exact data could not be obtained; instead, the time difference between arrivals at the parking area was modified to reflect the increasing number of trucks arriving. In this manner, the truck arrivals could be modelled as being more crowded.

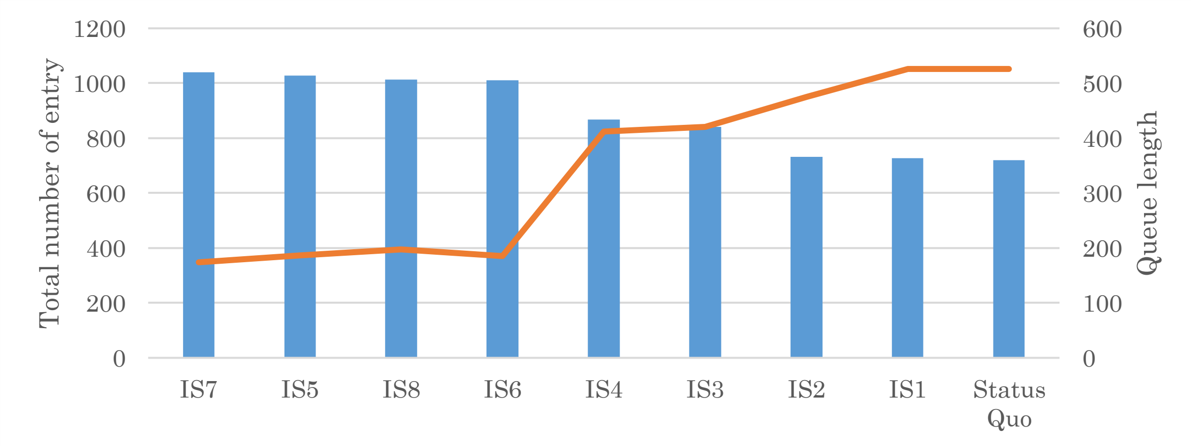

Figure 4 Scenario Analysis results (Import Section)

To resolve these bottlenecks in the most efficient manner, several scenarios were tested. In the first scenario (IS1) the number of lanes is increased by one. The second scenario (IS2) assumed that the passport control and scaling processes were integrated to the registration station. In the third scenario (IS3) the improvement that could be achieved by increasing the number of registration stations from four to seven is investigated. IS4, analyzed the impact of reducing the ratio of the average number of trucks passing from the inspection and X-ray after registration to the total number of entering trucks to 5%. The improvement that could be achieved by placing an officer of the Ministry of Food, Agriculture and Livestock on a 24/7 duty is investigated by scenario 5 (IS5). Scenario 6 (IS6) assumed that the personnel of the Ministry of Food, Agriculture and Livestock actively worked for 21 h a day. The last two import scenarios (IS7 and IS8) are aggregated improvement scenarios in which a combination of IS1, IS2, IS3 and IS5 is investigated by IS7 and a combination of IS1, IS2, IS3 and IS6 is analyzed by IS8.

Export-Related Scenario Results

The results of the status quo scenario can be summarized as follows. During the 48 h investigation window, an average of 3188 trucks arrived at the border. Only an average of 1609 trucks were able to exit, and a queue with an average of 520 trucks was formed. During the same period, the average time between arrival and exit was 13.7 h, out of which an average of 83% (11.4 h) was allocated to waiting in the line, and 15% corresponded to when the drivers are waiting in the parking area or finalizing the required documents. The official operations accounted for less than 2% (15 min)

The corresponding waiting times for each station are as follows. A truck that enters the queue outside the parking area waits for an average of 6.7 h. A truck waits an average of 2 h in the parking area. When a truck is cleared to exit the parking area, it waits for an average of 2 min. The average waiting time from the truck park to the passport control is 20 min, from the passport control to the scale is 3.8 min, and from the scale to the registration booth is 1.22 h. From this point, if the truck is not due for X-ray, inspection, or refueling, it crosses to the Bulgarian side in 1.2 h. This time increases to 3.2 h, if the truck needs refueling. If a truck is directed to X-ray, then the average waiting time increases to 4.4 h, and if it is directed to inspection, the waiting time increases to 3.8 h.

In the first export scenario (ES1) the number of active registration platforms in Bulgaria increased from five to eight. The second scenario ES2 examined the situation in which the second exit lane would be available. In the third scenario (ES3), the situation in which mutual vehicle passing is provided through four exit lanes. The effects of increasing the parking area capacity to 500 is investigated in ES4. In scenario 5 (ES5), all the operations were assumed to be performed at a single station. ES6 assumed that the gas station processing time was zero, and all trucks were assumed to join a single exit lane after the registration station. The situation Doubling the Number of Registration Stations is tested in ES7. In the 8th scenario (ES8), the ratio of trucks directed to the X-Ray or inspection stations after the registration station was decreased to 5%. ES9 scenario assumed that all officers work 24 h per day. The last 4 scenarios were aggregated scenarios. In ES10 scenario, ES2, ES5, ES6 and ES7 were simultaneously applied. ES11 scenario aggregated ES2, ES4, ES5, ES6, ES7, and ES9. In ES12, a combination of ES1, ES2, ES5, ES6, and ES7 were applied and in ES13, ES1, ES2, ES4, ES5, ES6, ES7, and ES9 were simultaneously applied.

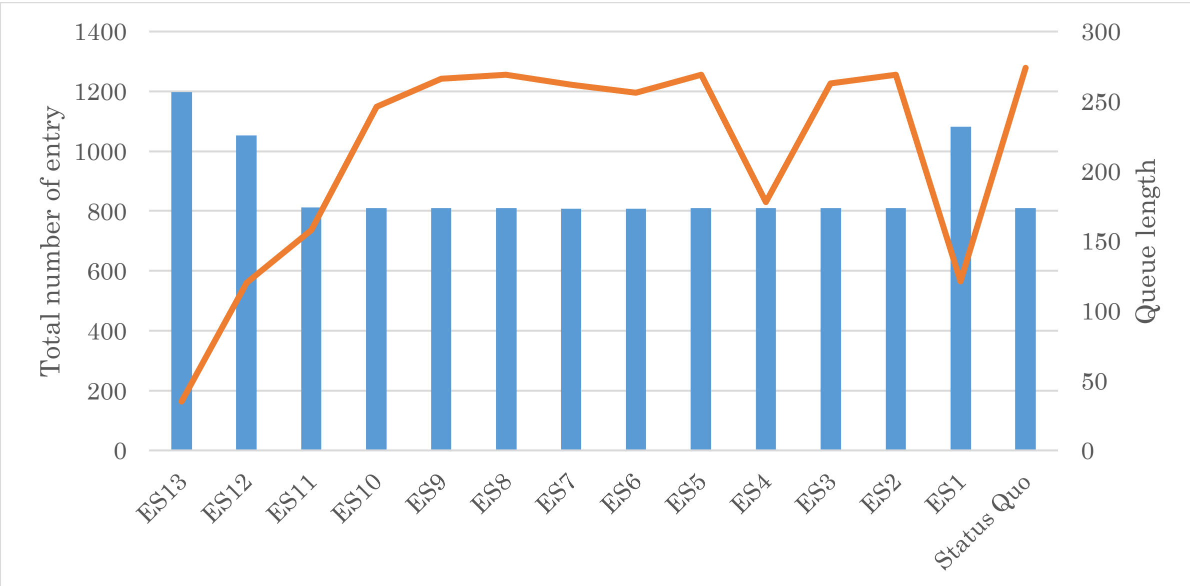

Figure 5 Scenario results (Export Section)

3. Conclusions and Further Suggestions

In this study, we made efforts to increase the efficiency of the Kapikule border crossing through process improvement techniques. For this purpose, the current process flows at Kapikule were specified through in-depth interviews, and were simulated via the Arena simulation software. The model was verified and validated to examine whether the constructed simulation would perform exactly as the actual system performs. Subsequently, several scenario analyses were conducted to reveal the strategies that should be implemented in order to achieve the highest possible increase in the efficiency at the border.

In order to analyze the efficiency of the aforementioned scenarios, three indicators, namely the length of the queue outside the truck park, the number of exiting trucks, and the average time spent in the system, were investigated. The measurement of the average time spent in the system started when the truck joined the queue outside the truck park.

According to the results, the most effective scenario for import is found to be IS7, which is the combination of scenario options IS1, IS2, IS3, and IS5. According to this scenario, it was observed that the average number of trucks entering Turkey increased from 719 to 1039. Under IS7, the total number of trucks waiting to enter to the border gate minimized to 174 trucks. Scaling and passport control did not appear to be bottleneck stations. For this reason, the level of recovery was limited. Within the scenarios that provided the highest positive impact, it was observed that the most crucial action was to change the shift time for the personnel of the Ministry of Food, Agriculture and Livestock. For import processes—rather than infrastructural improvements—the homogenization of the personnel working periods is expected to provide the highest impact on the decrease in the waiting times.

On the other hand, for the export case, there are five scenarios that can make a significant difference in the number of exiting trucks, as well as in the time spent in the system. Their common feature is the inclusion of ES1, which means that the system of the Bulgarian side accelerates its processes. As long as the system of the Bulgarian side does not accelerate, no scenario can make a difference.

The relation among ES11, ES12, and ES13 is interesting. This relationship suggested that the acceleration of the system of the Bulgarian side is essential, and that other policies start to take effect once this condition is met.

The best scenarios with respect to the average time spent in the system are ES1, ES12, ES13, ES14, and ES15. These scenarios present a difference of 6–7 h when compared with the first three scenarios, where the possible projects were implemented. An additional 3 h could be saved in ES14 and E15, which can be considered utopian; in ES14, almost all randomness was removed from the system and in ES15, the resting periods in the truck park were eliminated.

There are eight scenarios that are effective in terms of the length of the queue outside the truck park. These are ES1, ES4, ES10, ES11, ES12, ES13, ES14, and ES15. The slight improvement caused by scenario ES10 can be seen as the total effect of several development policies. However, this effect is rather limited. As ES4 and ES11 scenarios are effective, increasing the capacity of the truck park to 500 was found to be important in reducing this queue length. Nevertheless, the acceleration of the system of the Bulgarian side alone has proved to be more effective. It is clear that ES1 and ES12 caused a further shortening of the queue length compared to ES4 and ES11.

When the collective improvement scenarios ES11, ES12 and ES13 were investigated, it was found that ES13 was the best performing scenarios with respect to the number of exiting trucks and the truck queue outside the truck park. In ES13, in which the gas station was removed, the truck park capacity is increased from 250 to 500, the number of registration booths is increased from four to eight while integrating all operations to one booth, and a 24/7 working-hour schedule is implemented.

The contribution of this research is the simulation results, as well as the proposed practical framework for the analysis of the design of the border crossings, with similar traffic and cross border patterns.

As a further suggestion; a group decision support model can be developed in order to rank the strategies to focus on according to their order of importance in a way to increase the efficiency at the border.

For this purpose the above-given scenarios will be taken as alternatives and a Group Decision Support System will be used to evaluate each alternative from the perspective of different shareholders according to different criteria such as waiting time at the border, sustainability, border security, Investment Cost, Operations Cost, Satisfaction of beneficiaries

In order to achieve the best performance at the border crossing, another further suggestion would be to conduct similar analyses at the Kapitan Andreevo border crossing in Bulgaria and to investigate the possibility of collaborative improvements.

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AIRLINE SERVICE QUALITY ANALYSIS BY USING FUZZY COGNITIVE MAP APPROACH

Orhan Feyzioğlu[1], Celal Alpay Havle[2,3], Gülçin Büyüközkan[4]

Abstract – *Transportation is vital for growing relationships, such as world-wide trade relations, overseas training, and international conferences. On account of these reasons, people who do not wish to lose time expect higher speed and quality in transportation. Air transportation has increased its market share among transportation types to satisfy customer expectations in terms of accessibility, saving time and quality. With this increasing share, the expectations of potential customers of airline companies are shifting towards higher service quality. This trend forces airline companies to focus on their service quality in order to meet sustainable competition and customer demands. This study is conducted to analyze the service quality factors in the airline industry with the help of literature and expert opinions within the scope of SERVQUAL measurement scale. Rather than the main dimensions, the relationship between sub-criteria of these dimensions is used to create a system based on airline service concept. The Fuzzy Cognitive Map (FCM) technique is used with this scale, considering the variability and fuzziness of service quality perception. FCMs are very useful in determining the role of complex system components in a system and analyzing uncertain and fuzzy systems where perceptual interpretation changes from person to person. With the perspective of SERVQUAL, the factors affecting the quality of airline service are determined with FCMs. Then, the direction and power of the interrelationships between these factors are assigned by the experts. This FCM tool shows us the most important factors in the whole system to make a decision for future situations.*

Keywords – Airline industry, airline service quality, SERVQUAL, fuzzy cognitive map (FCM)

INTRODUCTION

In recent years, the effects of globalization are being observed in all industrial sectors. One of these areas is the airline industry. We can say that the need to travel between cities and countries within a short period of time is a result of today's competitive market. Time and speed are important at this point. Activities such as increased commercial relations, educational journeys and international conferences, especially around the world, are bringing transportation-based demand. In today's conditions when the time is seen as a value measure, airline companies try to enhance their activities in the competitive market by meeting customer expectations and demands [1]. According to IATA, the number of airline passengers will continue to rise. This increase should be translated into a competitive advantage [2] for the airline industry in order to meet the increasing demand and the needs [1] related to the passenger numbers. This situation has revealed what is called quality of service [3]. Airline companies need to focus on service quality in order to capture this advantage. Competition between firms depends on the level of service quality. However, service quality is a changing nature from firm to firm and there is a non-linear relationship between customer satisfaction and service quality level [4]. In this case, high quality of service does not necessarily mean high customer satisfaction [5]. It is necessary to correctly understand the requirements for service quality and to determine the right strategies. Failure to correctly perceive or misinterpret anticipations based on service quality may cause the firm to make erroneous decisions during the determination of future-oriented strategies [6]. Therefore, in assessing service quality with an airline management point of view, it is important to determine what customers want, or not [7]. Customer expectations are among the factors affecting airline service decisions [6]. From this reality, it is aimed to analyze the quality of the airline service by creating a dynamic structure considering customer requirements or world requirements that may change in future situations. Factors affecting service quality are gathered under the main dimensions according to SERVQUAL, a method developed by Parasuraman, for measuring service quality.

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After this step, fuzzy cognitive map (FCM) approach is used. The generated map is based on the existence of the interrelationships between the factors and the strength of the relationships obtained from the literature and supported by expert opinions. This way, it is aimed to find out the most important criteria and shed light on the strategic decisions required for airline companies to reach the level of service quality that will meet the customer satisfaction.

The structure of this paper is constructed as follows: Literature survey is given in next section. The proposed model and methodology are detailed in the following section. In latter, application of the proposed methodology is given and the last section concludes the study.

LITERATURE SURVEY

Service represents satisfaction of customer demands and it has no concrete characteristics. At the same time, it is possible to define service as an economic activity which provides time, place, shape and psychological benefits [2]. Service quality is subjective expressions of customers towards provided service by service provider [7]. Even if there are many studies about service quality studies in literature it is still an area where many further discussions can be performed [8]. Therefore, it is hard to find a way to measure service quality in perspective of airline industry researches [9]. Studies based on experimentation or experiences show that service quality is a key component to create market share, competitive advantage and improve operational performance [10] The most vital factor in the improvement of service quality which is needed for keeping up an airline's operations are passengers [11]. To be a step forward, organizations adopted high service quality policy [12]. To reach high service quality in a multidimensional area such as airline industry, all components of service and quality must be considered. For this purpose, entire airline service chain was divided into eight stages which are seat reservation, ground service, flight operation, cabin facility, meal service, cabin service, baggage delivery, and complaint response [7]. In addition to this, competitive advantage providers were determined for an airline in service quality perspective [13]. Also, key competitiveness indicators of full-service airlines were researched [14]. In this study to analyze airline service quality, we used SERVQUAL. In the literature, there are a number of studies based on SERVQUAL to analyze service quality in different areas such as communication [15], education [16], tourism industry [17], marine services [18], web portals [19], airline industry [4] healthcare [2] and finance [20]. SERVQUAL instrument has a great usage rate by many researchers in literature to measure airline service quality [21] In addition to this, if we look at some studies in literature, we can say that some studies [13] used statistical analysis to analyze service quality based on SERVQUAL. Also, fuzzy AHP (analytic hierarchy process) and fuzzy TOPSIS (technique for order preference by similarity to ideal solution) [22], VIKOR (vise kriterijumska optimizacija I kompromisno resenje) [23], DEMATEL (the decision making trial and evaluation laboratory) and ANP (analytic network process) [24] multi-criteria decision making techniques were used with SERVQUAL scale in literature.

PROPOSED METHODOLOGY

The proposed methodology consists of four main steps:

Step 1. Determine the service quality factors for an airline based on SERVQUAL dimensions.

Step 2. Develop a conceptual model for airline service quality in terms of causal relations between dimensions.

Step 3. Construct an FCM for airline service quality and perform the analysis.

Step 4. Determine the most important factors in airline service quality structure.

Airline Service Quality Evaluation Factors and SERVQUAL Relation

To evaluate customer perceptions about service quality for any organizations, SERVQUAL which is a multiple item scale for measuring customer perceptions of service quality was developed [25]. The SERVQUAL scale involves perceived quality [25]. In the literature, airline service quality is based on SERVQUAL scale with its dimensions, which are tangibles, reliability, responsiveness, assurance, empathy [6]. These dimensions are explained briefly in Table 1.

Table 1. SERVQUAL dimensions

Dimensions	Brief Explanations [24, 25]
Tangibles	Equipment, the appearance of personnel and physical facilities.
Reliability	Ability to perform the promised service dependably and accurately.
Responsiveness	Willingness to help customers and provide prompt service.
Assurance	Knowledge and courtesy of employees and their ability to inspire trust and confidence.
Empathy	Caring, individualized attention the firm provides its customers.

The airline service quality framework and the relations that we have proposed was accepted with expert consensus. By following this stage, the factors affecting airline service quality obtained from literature and expert opinions. Gathered criteria were collected under dimensions of SERVQUAL with Delphi method [26]. These factors are given in Table 2:

Table 2. Airline service quality evaluation criteria [6, 22, 27, 28]

No	SERVQUAL Dimension	No	SERVQUAL Dimension
	Tangibles		
C1	Modernized aircraft and equipment	C14	Willingness to help for unexpected situations
C2	Comfort and cleanliness of the cabin	C15	Handling of in-flight operations
C3	Quality of food and beverage service	C16	Responsiveness of crew
C4	Appearance of crew		**Assurance**
C5	Number of aircraft	C17	Flight safety
C6	In-flight entertainment	C18	Confident actions with passenger tangibles
C7	Companies' airport facilities	C19	Behavior of airline employees
	Reliability	C20	Knowledge to answer customers' questions.
C8	Operational Safety	C21	Language skill of crew
C9	On time departure and arrival	C22	Convenient departure and arrival time
C10	Operational quality		**Empathy**
C11	Experience of staff	C23	Individual attention to the passenger
	Responsiveness	C24	Alternative flight schedules are available
C12	Handling of ground operations	C25	Advertising of the airline company
C13	Communication ability of customer service	C26	Convenient ticketing process

Conceptual Framework for Airline Service Quality based on SERVQUAL

To develop a framework for airline service quality, the dimensions of SERVQUAL were used by considering their scope in terms of airline service. The model given in Figure 1 was developed to construct an FCM. This model is originated to a model which is in a study based on service quality in the literature [29]. The arcs between dimensions show the impact and relations in terms of sub-criteria of them.

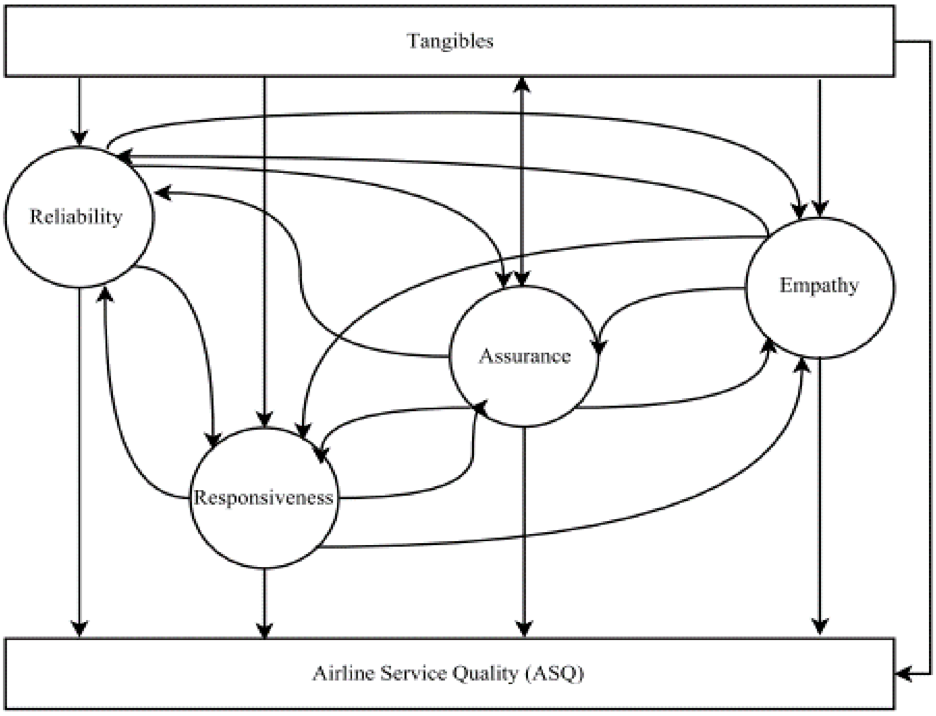

Figure 1. Conceptual framework for airline service quality based on SERVQUAL dimensions

This conceptual model given above is constructed by considering the evaluation criteria relations and checked by an industrial expert from the airline industry. According to this model, tangibles directly affect airline service quality and reliability, responsiveness, assurance and finally, empathy. Also, the four main dimensions except the tangibles directly influence airline service quality. There is a two-way relation between reliability and responsiveness, responsiveness and assurance, assurance and empathy. In addition to this, reliability-empathy, reliability-assurance, responsiveness-empathy duals have two-way relations between each other.

Fuzzy Set Theory and Construction of FCM for Propose Framework

Based on human reasoning and evaluation, the first fuzzy set theory based on a classical cluster definition was published by Zadeh and Goguen [30, 31, 32]. The fuzzy set theory provides a rigid mathematical framework in which fuzzy conceptual phenomena can be studied thoroughly and meticulously [32]. The fuzzy set theory is based on the fuzzy logic that deals with problems involving uncertainty and vagueness [33, 34]. Zadeh, also set forward that the key factor in deciding when faced with uncertain events is set membership [35]. Set membership is central to represent the objects within a universe by sets defined on the universe [35]. A fuzzy set is a class of objects, and such clusters are represented by membership functions in which each object is assigned a value between zero and one and in addition to this, this is not the case in classical clusters. In classical clusters, zero or one assignment is made as follows in (1), whereas in fuzzy sets this assignment occurs in an interval (2). [30]. In real life, fuzzy sets can be used instead of normal sets in uncertain situations where it is not possible to reach precise criteria of a member [30].

$$\chi_A(x) = \begin{cases} 1, & x \in A \\ 0, & otherwise \end{cases} \tag{1}$$

$\mu_A(x) \in [0,1]$ (2)

$\mu_A(x)$ is the degree of the membership of element x in fuzzy set A. Hence, $\mu_A(x)$ is a value on the unit interval which measures the degree of element x belongs to fuzzy set A [35]. To show the difference between crisp and fuzzy numbers following membership functions are given with Figure 2.

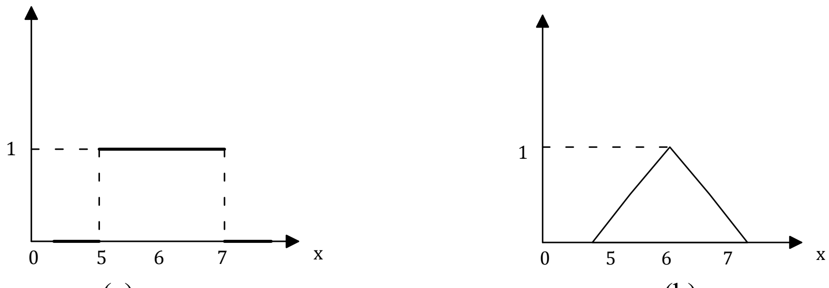

Figure 2. Membership functions of a crisp set (a) and a fuzzy set (b)

There are different fuzzy numbers such as trapezoidal fuzzy numbers and triangular fuzzy numbers and because of easiness of application [34], triangular fuzzy numbers based on linguistic variables are used for the study to construct evaluation matrix for FCM. Used triangular fuzzy numbers can be shown as $X = (x_1, x_2, x_3)$

The FCM method is an artificial intelligence like a system based on neural networks and fuzzy logic [36]. It is developed from cognitive maps (CM) [37]. FCM technique constructs causal relations based system for complex and uncertain structures. This method, which is proposed by Kosko, is based on the evaluation of the factors that constitute or affect a system, such as the opinions of experts in the field or interviews [38]. An FCM is a graphical representation of a system. There are concepts C_i as nodes in terms of factors or criteria and also arcs which are links between these nodes. Each link has its own weight according to the strength of relations between concepts. To show the structure of a FCM Figure 3 is given.

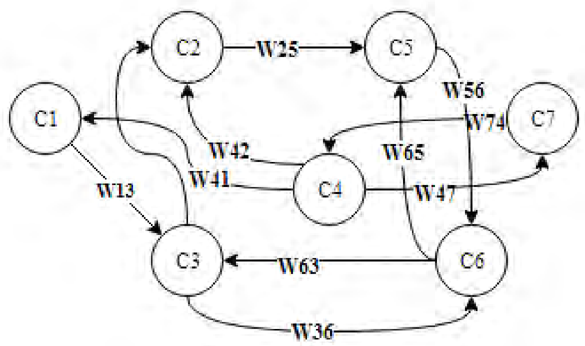

Figure 3. Example of an FCM

There three different options to evaluate the relationship between factors in terms of the strength of the relation. If the effect of a factors to another one is positive, then the weight between these factors will be greater than zero, if there is no relation between any two factors, then the weight will be zero and finally, if the strength of a relation between any two factors is negative, then the weight of this relation will be lower than zero. Construction of an FCM has its own steps:

Step 1. Construction of evaluation matrix:

An evaluation matrix is developed based on factors. This matrix form will help to analyze the relations between factors. It gives an opportunity to control that whether there is a relation between factors or not. This matrix is filled with linguistic variables according to the existence of relations between factors and strength of it. The process starts with C1-C2, C1-C3 and finally ends with Cn-Cn-1. Obtained matrix should be $C_{n \times n}$.

Step 2. Fuzzification:

In fuzzification step, evaluation matrices are filled with linguistic variables which are assigned by experts from industry.

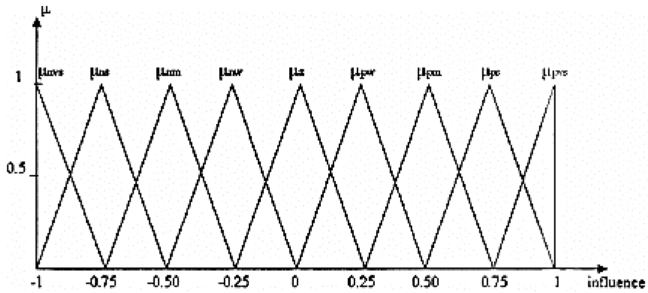

Figure 4. Membership functions for the linguistic variable influence [39]

Each expert evaluates the relationship between factors in evaluation matrix individually by using "Positively Very Strong (PVS)", "Positively Strong (PS)", "Positively Medium (PM)", "Positively Weak (PW)", "Zero (Z)", "Negatively Weak (NW)", "Negatively Medium (NM)", "Negatively Strong (NS)" and finally "Negatively Very Strong (NVS)" linguistic variables according to the way of relation and strength of relation. These variables have influences shown in Figure 4. The number of experts equals to the number of evaluation matrices.

Step 3. Aggregation:

The aggregation process is used to see the relations between the factors, based on the opinions of all experts. Due to different evaluations in different evaluation matrices with fuzzification, the value of linguistic variables has to be integrated to normalize them. This step is actually the beginning of the defuzzification step. To perform the aggregation step, the Fuzzy Tool Box of the MATLAB software can be used. Three different linguistic variables are aggregated to illustrate the process as an example. This process is illustrated in Figure 5.

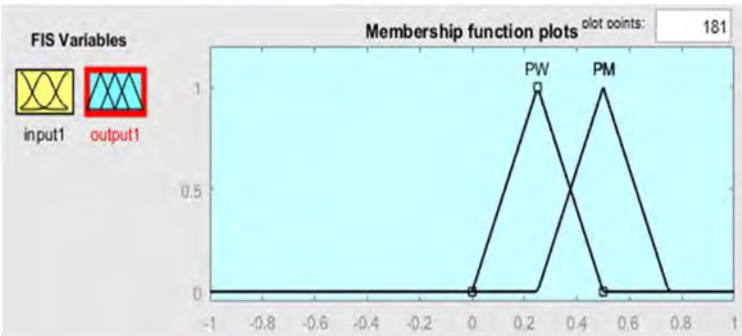

Figure 5. Aggregation process of three different linguistic variables (PM-PW-PM)

Step 4. Defuzzification:

There are various defuzzification methods in literature but we used Center of Gravity (COG) [35] defuzzification method to perform this step.

Center of Gravity (COG):

$$z^* = \frac{\int \mu_{\tilde{A}}(z) z dz}{\int \mu_{\tilde{A}}(z) dz} \tag{3}$$

where z^* is the defuzzified value. With this method, triangular fuzzy numbers with two way-influence used to evaluate relations between factors belong to different expert integrated and returned to crisp values.

Determination of Critical Factors in terms of Airline Service Quality

Defuzzified aggregated matrix gives us a final weight matrix to perform analysis to determine critical factors based on a map which is a network-like graph. In this step, we can use graph theory indices [40]. Graph Theory Indices are in-degree $[id(v_i)]$ out-degree $[od(v_i)]$ and centrality (c). The row sum of absolute values of a variable in the adjacency matrix is called as out-degree and shows the cumulative strengths of connections $\left(a_{ij}\right)$ exiting the variable [40] and calculated with (4):

$$od(v_i) = \sum_{k-1}^{N} \overline{a_{\iota k}} \tag{4}$$

The column sum of absolute values of a variable is called as in-degree and shows the cumulative strength of variables entering the unit and calculated with (5) [40]:

$$id(v_i) = \sum_{k-1}^{N} \overline{a_{k\iota}} \tag{5}$$

The contribution of a variable in a cognitive map can be understood by calculating its centrality (c), whether it is a transmitter, receiver or ordinary variable [40]. The centrality of a variable is the summation of it's in-degree and out-degree and shows the most important players of a system [41]. It is finally calculated with (6):

$$c_i = td(v_i) = od(v_i) + id(v_i) \tag{6}$$

APPLICATION OF THE PROPOSED METHODOLOGY

In the process of application of the method, an evaluation matrix is constructed to enable their evaluation by the experts, who confirmed that the researched factors and the developed model are appropriate for the evaluation of airline service quality. Each expert filled his/her own evaluation matrix individually with linguistic variables. To show the evaluation process as an example, the following matrix is given in Table 3 from one expert's matrix based on the criteria of tangibles.

Table 3. Evaluation matrix for tangibles' factors as an example from one expert

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	Z	PVS	Z	Z	Z	PS	Z
C2	Z	Z	Z	Z	Z	Z	PS
C3	Z	Z	Z	Z	Z	Z	Z
C4	Z	Z	Z	Z	Z	Z	Z
C5	Z	NS	NM	Z	Z	Z	PS
C6	Z	PVS	Z	Z	Z	Z	Z
C7	Z	Z	Z	Z	Z	Z	Z

Completing the evaluation steps leads us to the aggregate of these evaluation matrices. To show the aggregation process over linguistic variables, the following Table 4 is given, which is based on tangibles' criteria.

Table 4. Aggregated matrix for tangibles' factors as an example over linguistic variables

Criteria	C1	C2	C3	C4	C5	C6	C7
C1	(Z, Z, Z)	(PVS, PS, PS)	(Z,Z,Z)	(Z,PS,PS)	(Z, Z, Z)	(PS, PVS, PS)	(Z, Z, Z)
C2	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(PS, PW, Z)
C3	(Z, Z, Z)	(Z, Z, Z	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)
C4	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)
C5	(Z, Z, Z)	(NS, PW, Z)	(NM, PW, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(PS, PS, PS)
C6	(Z, Z, Z)	(PVS, PS, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)
C7	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)	(Z, Z, Z)

To calculate the results of triple combinations in each cell of aggregation matrix, MATLAB fuzzy tool box was used. Triple evaluations are combined into one single crisp number at the end of this process. This result gives us aggregated weight matrix and leads us to construct FCM and perform the analysis. In Table 5, the aggregated weight matrix is given over tangibles' criteria.

Table 5. Aggregated weight matrix for tangibles' factors

	C1	C2	C3	C4	C5	C6	C7
C1	0	0.80	0	0.37	0	0.80	0
C2	0	0	0	0	0	0	0.35
C3	0	0	0	0	0	0	0
C4	0	0	0	0	0	0	0
C5	0	-0.19	-0.10	0	0	0	0.75
C6	0	0.45	0	0	0	0	0
C7	0	0	0	0	0	0	0

Obtaining aggregated weight matrix provides us to analyze the whole system and the results are shown in Table 6.

Table 6. Results from graph theory indices of the FCM of airline service quality

Concepts	Out-degree	Order	In-degree	Order	Centrality	Order
C1 (Modernized aircraft and equipment)	6.80	8	1.25	25	8.04	16
C2 (Comfort and cleannes of cabin)	2.67	20	5.05	12	7.71	18
C3 (Quality of food and beverage service)	1.40	25	3.73	18	5.12	24
C4 (Appearance of crew)	1.85	23	4.57	15	6.43	20
C5 (Number of aircraft)	4.11	16	2.02	23	6.13	21
C6 (In-flight entertainment)	0.84	26	2.01	24	2.85	26
C7 (Companies' airport facilities)	4.42	12	3.52	20	7.93	17
C8 (Operational Safety)	9.65	**4***	9.65	**3***	19.30	**2***
C9 (On time departure and arrival)	4.22	13	5.00	13	9.22	13
C10 (Operational quality)	11.28	**2***	10.60	**2***	21.88	**1***
C11 (Experience of staff)	12.88	**1***	5.36	10	18.24	**3***
C12 (Handling of ground operations)	7.63	6	8.13	**5***	15.77	6
C13 (Communication ability of customer service)	3.58	18	4.91	14	8.49	15
C14 (Willingness to help for unexpected situations)	4.14	14	6.09	8	10.23	11
C15 (Handling of in-flight operations)	4.48	11	5.47	9	9.95	12
C16 (Responsiveness of crew)	7.01	7	4.54	16	11.54	9
C17 (Flight safety)	8.27	**5***	9.53	**4***	17.80	**4***
C18 (Confident actions with passenger tangibles)	4.01	17	6.93	6	10.94	10
C19 (Behavior of airline employees)	10.04	**3***	6,57	7	16.60	**5***
C20 (Knowledge to answer customers' questions.)	6.66	10	5.18	11	11.84	8
C21 (Language skill of crew)	6.70	9	2.30	22	8.99	14
C22 (Convenient departure and arrival time)	2.54	21	3.52	19	6.06	22
C23 (Individual attention to the passenger)	4.13	15	3.31	21	7.44	19
C24 (Alternative flight schedules availability)	2.33	22	0.67	26	3.01	25
C25 (Advertising of the airline company)	3.04	19	12.59	**1***	15.62	7
C26 (Convenient ticketing process)	1.82	24	4.02	17	5.84	23

According to the results of the analysis, Table 6 is obtained. Table 6 shows us ranked airline service quality factors from three different perspectives which are in-degree, out-degree and centrality values. For the sake of easier commenting, the first five factors are considered for each case. Out-degree values show which factors have more impact on other ones. It means that if one concept has more out-degree value, it has more leaving arcs towards to others. According to this; the experience of staff, operational quality, the behavior of airline employees, operational quality and flight safety have the greatest impact on the airline service quality system. On the other hand; advertising of the airline company, operational quality, operational safety, flight safety and handling of ground operations have the highest in-degree values which means that these factors have the highest response in the system. These factors are the most influenced ones in the airline service quality system. Finally, the centrality values of the concept which are in airline service quality system show the most important factors. Because this value is the sum of in-degree and out-degree values. Factors with the highest centrality values represent nodes that have both the highest number of arrows which leave and the most arrows which enter to these concepts. So these nodes are the ones that trigger all the changes in the system and at the same time are most affected by any changes in the system. According to centrality values; operational quality, operational safety, the experience of staff, flight safety and behavior of airline employees' factors are the most important factors in the airline service quality model. It means that if we increase the level of these factors in terms of service, an increase will be observed in airline service quality and vice versa.

CONCLUSION

In order to fulfill the requirements of the conditions we live in, we are starting to take place on a platform where speed, safety, and quality are important. From this point of view, transportation is gaining momentum in the aspect of commercial concerns, education and so on. When all these are considered, it is an indisputable fact to say that the first type of transportation that comes to mind is the airline transportation. It is also possible to say that it is the question of increasing demand for air transportation from this reality. At this point, airline companies have to think about the demands they shall meet to successfully function in a competitive market. For this reason, airline companies have to raise the level of service quality they offer to customers. From this point of view, the focus was on decisions that would enable firms to increase their service quality and compete in the marketplace to ensure their continuity. The aim was to shed light on the strategic decisions that firms should take and to analyze the factors that affect the quality of airline service. In order to achieve this, with the help of experts from the airline industry and the support of the literature, the factors affecting the quality of the airline service have been determined. Then, a conceptual model was developed to form the basis for the FCM method used in the analysis stage in a similar process. The SERVQUAL method, which is widely used in the measurement of service quality, has been utilized at the stage of determining the factors and establishing the conceptual model. The system formed by the factors grouped under the main dimensions of SERVQUAL was analyzed by constructing an FCM and the most important factors were determined for the steps that airline companies will take to increase their service qualifications. However, if such a system is taken into consideration, it is revealed which factors are most influenced by changes, or which are more influential on service quality.

Also, the proposed methodology showed us using group-based approval for constructed model and evaluation of criteria with different experts by using FCM steps instead of single expert's opinion, more meaningful and consistent. In addition to this, the study proved that the proposed methodology, which is a SERVQUAL-based FCM application for airline service quality, can be used for structures which include differences in the perception of service quality with FCM on account of fuzziness of service quality logic in the airline industry.

Hesitant fuzzy sets [42], which are the extensions of fuzzy sets, enable better expressing the experts' evaluations. One of the perspectives for future work can be to use hesitant FCM approach for modeling and analyzing the airline service quality.

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FOOD WASTE MANAGEMENT IN HOTELS

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Abstract *− In this paper we present a multiple case study on current food waste management practices in four large-scale hotels of Antalya, Turkey, one of the top ten most visited cities in the world. We examined the main causes of food waste and how it is processed afterwards. Data collection included both quantitative and qualitative methods: outside observation, semi-structured interviews and questionnaire survey of managers and staff within the hotels. The hotels in this study tend to separate their waste inside the facilities; and three main government offices are responsible for handling food waste management in Antalya; furthermore, we have not observed any practitioners or firms handling waste management entirely as subcontractors. We recommend structured hotel staff training programs to increase awareness, an increase in the number of waste bins with proper labeling, composting for sustainable waste management methods to produce fertilizer and energy, and awareness programs for general consumers.*

Keywords *− Closed-Loop Supply Chain Management, Food Waste Management, Hotels, Sustainability*

INTRODUCTION

Food waste is "any food that is not consumed by humans and can be generated at any level within the food chain" (Okazaki et al., 2008). Food waste has tremendous impacts on the environment; it has been found that 1 kg of food waste causes roughly 1.9 kg lifecycle emissions of CO_2e [7], and 20% of global greenhouse gas emissions are caused by food [8]. Moreover, food waste is expensive to dispose of, and landfilling of it produces methane, a powerful greenhouse gas [19].

Due to its nature, the hospitality industry uses vast amounts of energy, water, and perishable products with food being a substantial item of consumption [6]. Despite occasional stagnant periods due to economic crises and other exogenous factors, the hospitality industry continues to grow and so do the resources it consumes. This also means food waste produced by the hospitality industry will keep increasing. Moreover, food waste also causes wastage of other resources used in the preparation of the food, such as water and energy. In this study we concentrate on food waste generated in the for-profit sector of the hospitality industry, particularly at hotels. A substantial amount of the total waste produced in hotels is food waste; for instance, Iowa Waste Reduction Center (IWRC) reports that 28% of the garbage comes from hotels, whereas Alexander and Kennedy report that food waste constitutes 46% of the hotel waste [9]. These high amounts of food waste calls for studies assessing the current status, opportunities, and challenges regarding the food waste management practices in hotels in all parts of the world.

The international emphasis given to environmental programs and the awareness regarding the role of the hospitality sector in sustainability has been steadily increasing in the last few decades. The Fifth Environmental Action Program of the European Union covered the tourism sector [11] and following Agenda 21 adopted by the United Nations, principles for sustainability in the tourism sector have been recommended [16], [17]. There have been national initiatives battling against food waste, specifically [2], [4]. Food waste reduction and management have also been investigated in different sectors: healthcare [10], [19], education [12], and hospitality [1], [5], [14], [15].

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There are two main types of waste produced in hotels: dry waste and wet (organic/biodegradable) waste. The wet waste is primarily food waste and can constitute more than 50% of the hospitality waste [4], [18]. This high amount of food waste caught the attention of sustainability initiatives, and food waste management practices were applied. However, practical ways to deal with food waste vary across the world due to different sets of regulations and levels of societal awareness; thus, analyses should be done to uncover the challenges associated with food waste management and to search for opportunities for improvement opportunities in different regions. To answer this need, our study aims to report on the current food waste management practices applied in hotels of Antalya, Turkey.

For the purposes of our study, food waste produced in hotels may include any waste resulting from discarding the food due to the operations in the hotel. Thus, food waste included here includes food discarded from storage due to expiration, waste occurred during preparation, and waste from dishes and guests' plates. The management of the food waste involves benefits as well as costs. Benefits include reductions in carbon emissions, risks and liabilities, improvements on health and safety benefits, business image and stakeholder relations. Costs come from disposal and transport of waste and any other waste management operations. Thus, analysis of food waste management practices and determination of improvement opportunities could help decision makers, including hotel management, environmental and government organizations [14]. Here we hope to provide insights and state potential improvements on food waste management for hotels of Antalya to help hotel managers, joint ventures of tourism investors, and government organizations in Antalya.

The distinguishing feature of hotels of Antalya regarding food waste management is that most of them offer all-inclusive accommodation that results in excessive amounts of food waste. When compared to half-board hotels, all-inclusive hotel guests are served more meals (which are included in the hotel rate). With most hotels being all-inclusive and having large numbers of guests, in Antalya, Turkey the amount of food waste can be vast. This extensive amount of food waste calls for effective waste management practices and assessment of the current processes and methods used in food waste management in hotels of Antalya.

In this paper we assess the current food waste management practices used by hotels in Antalya, Turkey (one of the top ten most visited cities in the world) via a multiple case study. The case studies are conducted at four large-scale hotels: three are all-inclusive and one is half-board. It has been reported that each hotel guest can produce at least 1 kg of total waste per day [3], and we have observed during this study that the total monthly organic waste in all-inclusive hotels can be as high as five times the waste collected at the half-board hotels. Food waste constitutes a large percentage of the organic waste in all-inclusive hotels; thus, in touristic destinations with mostly all-inclusive hotels, such as Antalya, the food waste management practices require constant assessment and improvements.

The tourism sector is a big producer of food waste and the search for better food waste management practices in tourism sector requires assessment of the current situation, searching for potential improvements, and reporting these ideas and insights to enhance the literature. Regarding these objectives, in our study we aimed to find answers to the research questions below:

- What are the main types of food waste occuring in hotels of Antalya?
- What methods of food waste processing are used in hotels of Antalya?
- What are potential food waste processing alternatives that can be used in hotels of Antalya?
- What are the advantages and disadvantages of the food waste processing methods currently used in hotels of Antalya?
- What are the advantages and disadvantages of the potential food waste processing methods that can be used in hotels of Antalya?

By reporting on the current resources of food waste, food waste management practices currently used, and potential methods to manage food waste we plan to provide insights and improvement opportunities on an environmentally-critical topic.

To highlight some contributing results, we found that the main type of food waste occurring in Antalya hotels is plate waste (food left uneaten on the plate). This result matches the results in [4], where it was found that plate waste has the highest percentage among the food waste categories generating from basic dining in which the servings come from pre-prepared food. Most hotels in Antalya serve the meals in open buffet format, serving pre-prepared food; thus, similarly we have found that plate waste is the food waste type with the highest percentage in hotels of Antalya.

As the next step after food waste is gathered from plates and other resources at the hotel, a waste collection company transports the waste to the facilities run by tourism investors' joint venture in the respective region. The joint ventures at each touristic region contract with waste collection and also environmental training companies; and they process the waste, thus, the only waste management practice conducted at the hotel is separation of organic waste from other types of waste and keeping it in a cold room until collection time. Only one hotel reported that the food waste from the hot meal buffet is sent to dog shelters. Indeed, at this stage, any recycling and composting methods could help the waste management practices to go forward. After the food waste is composted, it can be used in the gardens. Composting is a much better food waste management method than landfilling. While the food engineers we interviewed report that the current process is easy to manage, they also claim that they wish for improved procedures to segregate food waste from other organic waste (e. g. paper towels, toothpicks, etc.) and have it recycled for sustainability purposes. Segregation and recycling are laborious especially in large-scale hotels, so it currently forms both a challenge and improvement opportunity for food waste management in hotels of Antalya.

In the rest of the paper we will describe our methodology, state the results of our analysis, and finally present our conclusions and future research ideas.

METHODOLOGY

To conduct our multiple case studies we visited four hotels located in the city of Antalya, one of the most visited cities in the world with lots of hotels and touristic facilities mostly offering all-inclusive accommodation. For triangulation purposes and to develop explanations for some of the findings on a more comprehensive basis, we used a combination of data collection methods to obtain answers to our research questions; thus, we conducted our multiple case studies in conjunction with other data collection methods.

Data collection methods included structured interviews, outside observation and surveys. One of the interviews was conducted with three managers: Purchasing Manager, Food Engineer/Quality Control Manager and Executive Chef of the open buffet (Hotel A). Another interview was conducted with a Quality Supervisor (Hotel B). The last interview was with a Food Engineer (Hotel C1 and Hotel C2).

The interview questions started with directly asking the research questions stated in the previous section and continued with questions demanding to: rank the effectiveness of current food waste management practice, describe any food waste management plans, and state the total amount of food waste produced and the number of collection bins. The interview data was recorded via note taking by two researchers and the notes were compared to complete the report.

The observations were conducted at different parts of the facilities (kitchen, wet waste storage, restaurants). Finally, we conducted a survey to measure awareness and contribution of personnel to food waste management. The survey was administered to 80 staff of the three of the hotels. Food waste management can only be done with effective participation from employees; thus, we preferred to collect data from the personnel of the hotels as a homogeneous group.

ANALYSIS

In this part, the information and answers that we collected from outside observations, semi-structured interviews, and survey of managers and other staff within the four hotels we visited will be given.

HOTEL A: is a 7-star all-inclusive hotel that covers an area of 405 thousand square meters with 760 rooms and suits and 1700 bed capacity. It has been open to business since 2005 in Belek, Antalya. The hotel has one open-buffet restaurant and seven other restaurants with different cuisines and some of them being a'la Carte restaurants. Hotel A has a White Flag Award for food safety and hygiene.

Interview: was done with the Purchasing Manager, the Food Engineer/ Quality Control Manager and one of the Executive Chefs of the open buffet. They rank the food waste issue in their hotel as of the least important, ranked 1 out of 5 (1 is the lowest rank on our scale). To achieve this result they have changed their open-buffet style; now they prepare the food during the meal time at the restaurant, rather than bringing already prepared food to the buffet. This way, cooks prepare enough food to feed only the customers actually waiting for it, so this decreases the amount of food served and left unused at the buffets. They also gather information on the guests' nationalities and culture to prepare their national cuisines for the open buffet. They believe this method decreases the amount of plate waste, which, as they state, has the highest percentage within the total food waste occurring at their hotel. Hotel A reported that they produce roughly 100 tons of monthly food waste during the peak season months.

They point out that they have over 100 organic waste bins distributed in different areas of the restaurants and kitchens. However, they cannot manage the separation of the inorganic materials from the plates properly due to the lack of awareness of their staff and any mechanic device to automatically do it for them. They state that the wasted food is thrown into the bins and then brought to and kept in the wet waste collection room inside the facility. The wet food waste is kept at 10 degrees Celsius, ready to be taken by a waste collection company, which is a subcontractor of the tourism investors' joint venture at Belek, Antalya. They revealed that they cannot send the food waste to any other site, (e.g. dog shelters) because it is difficult to segregate food after it is thrown into the bin and, for example, some foods poisonous for dogs.

In their opinions, a potential food waste processing alternative is reusing surplus food from the buffets. Also from our recommendations they strongly agree that composting would be a very efficient way to take care of the food waste issue. However, they would not consider composting food waste on-site as a result of possible threat from pests. They also were concerned about the smell that could be caused by the resulting fertilizer.

As mentioned before, the waste collection company deals with the processing of every type of waste (organic, inorganic, plastic, paper etc.) that is collected with a fee taken monthly from the hotel. For Hotel A, it is an advantage because they would not want to be occupied with it themselves.

Hotel A is legally obligated to work with an environment consultancy company (also mentioning that every hotel in Belek is obligated to work with them) that comes to give educational seminars twice per tourism season and writes a report according to the feedback from these seminars. Hotel A finds educational training is an advantage. However, interviewees do not believe that the education given is enough to ensure staff awareness on food waste and recycling.

Observation: There were two bins (one for organic waste and one for inorganic waste) in each section (for example, red meat section, vegetable section, fruit section) inside of the main kitchen for the open-buffet. One bin is for organic waste and the other is for inorganic waste, including plastic, paper and glass. They were very well labeled and color coded. However, inside the restaurants the bins were hidden in cabinets and were not labeled clearly. Although, we were told that the tissues, toothpicks and wet tissues they use in the restaurant are organic and okay to be thrown into organic bins, we were concerned about the wrappings.

HOTEL B: is the first hotel to be designed specifically for children's comfort in Turkey. Hotel B is built in an area of 639,000 and 110 square meters with a theme park/ aqua world (the largest in Europe) and a large shopping mall, located in Belek, Antalya. The 5-star hotel has 401 rooms and suites and 1100 bed capacity. The hotel has a capacity for 4000 thousand people. Hotel B is half-board with no open-buffet. There are 11 restaurants spread across the facility.

Interview: was done with the Quality Supervisor. We were told that on a scale of 1-5 (1 being the lowest and 5 being the highest importance level) they would rank the food waste issue in Hotel B, with 1, as a result of not having an open buffet. We were told that when people pay for what they consume, they waste less. However, because it is a big hotel they estimate 800 kgs. of organic waste is produced daily.

They have a general environmental waste management plan where they test the amount of pollution the hotel's waste causes to land, air, and water. Then, they calculate the risk ratios to make plans and take steps to decrease these ratios. They separate, collect and keep their organic, plastic, metal, and water waste in different rooms in their facility. Organic wet waste is kept in +10 degrees Celsius. The same waste collection company that works for the tourism investors' joint venture at Belek comes twice a day to take the waste from the facility. They estimate there are more than 100 recycling bins inside kitchens, offices, and outside.

They mentioned that they are obligated to work with the same environmental consultancy company in Belek. The company comes every month to give educational seminars for staff awareness and to report back for metrics. Hotel B thinks composting is a good potential food waste processing method; however, they would not agree to set up on-site composting since they do not have available space in the facility.

HOTEL C: includes two conjoined hotels (Hotel C1 and Hotel C2) next to each other under the same management but with different themes of real life palaces. They are both 5-star hotels located in an area of 75 thousand square meters in Kundu, Antalya. Hotel C1 has 874 rooms and suites with 1771 bed capacity. They provide all-inclusive accommodation. Hotel C2 has 818 rooms and suites with 1500 bed capacity. It is located next door to Hotel C1 and covers an area of 85 thousand square meters. We interviewed the Food Engineer for both hotels and observed the operations of kitchens and the open buffets.

Interview: They rate the food waste issue in Hotel C with 3 (1 represents the lowest importance level and 5 the highest) describing plate waste as the biggest cause of food waste. The second biggest cause of food waste is spoilage during storage due to expiration and lack of proper storage conditions.

All kinds of waste, including organic waste, are kept separately in garbage rooms inside the facilities. Organic waste is kept in +4 degrees Celsius. Waste is collected daily by the waste collection company that works with the tourism investor's joint venture at Kundu. They mentioned that they are obligated to separate and give their oil waste, too. It is calculated with respect to the amount of oil purchases they make and they would get fines if they do not deliver enough oil waste to the collection company. If they provide enough oil waste, they get complimentary services (such as equipment and personnel to do cleaning) in return. They also mentioned that they pay a certain amount of fee to the waste collection company. They separate hot buffet food waste (such as cooked meat) and give it to dog shelters. If they fulfill their environmental social responsibilities they get points for the Green Star Project. Hotel C produces roughly 130 tons of organic waste monthly during the peak tourism season.

To reduce the amount of plate waste they believe any method or technology that can facilitate segregation of food waste would improve food waste processing. They would also agree to composting as long as it is done outside their premises.

Observation: Hotel C has labeled bins in different parts of the kitchen. The bins are not color-coded although bags inside the bins are color-coded (green means organic waste, blue means inorganic waste). Open buffet restaurants have bins kept in cabinets that do not have labels.

Questionnaire/ Survey: were done to cleaners, chefs, and kitchen staff in hotels A, C, and D (another hotel in Lara, Antalya). We didn't get a chance to interview the food engineer in Hotel D (5-star city hotel) since the hotel chain's main campus is in İstanbul and they only have the food engineer visit the facility with regular intervals. The survey was given a total of 80 staff. Analyses were done via PSPP software. According to our regression analysis about the awareness of the staff:

- The responses to the question "*To what extent are you aware of the negative consequences of food waste in the environment, economy and society*?" were dependent on the responses made to two other questions: "*Do you know what happens to the food waste afterwards in this hotel*?" (p value = 0.000;

linear regression standardized coefficient = 0.44); and "*Does this hotel have any food wastage prevention strategy*?" ($p = 0.073$; linear regression standardized coefficient = 0.21)

On measurement of the recycling efforts of the staff, the analysis showed:

- The answers to the 6th question (*How often do you recycle food waste*?) had a statistically significant relation with the responses to the 2nd question (*Do you segregate food waste*?) and the 4th question (*Do you have a food waste bin in your workplace*?) (p value = 0.012 and $p = 0.004$; linear regression standardized coefficients = 0.28 and 0.31, respectively).

From these results, we can say that staff should be educated on what happens to food waste afterwards and if the hotel has any prevention strategies or not. Staff awareness and practices are very important for food waste segregation and processing.

CONCLUSIONS

In this section, we further discuss our findings and results. At the end, we conclude our studies with future research suggestions.

The main types of food waste occurring in hotels of Antalya: is mainly plate waste followed by waste from the dishes in the buffets and food spoilage at the storage. The plate waste is commonly observed at the hotels with all-inclusive open buffets. This system affects guests' psychology and pushes them into taking more food on their plates than they can physically consume. Pre-preparing food without the actual demand leaves waste at the buffets, and this kind of waste will lessen if the food is cooked on demand. Also excessive ordering of the ingredients and lack of adequate food storage results in food spoilage.

Methods of food waste processing used in hotels of Antalya: The hotels give their waste to the waste collection company that works for the region's tourism investors' join venture. If the hotel wants to be occupied with it itself, they do social responsibility projects to get rewards for being environmentally conscious.

Potential food waste processing alternatives that can be used in hotels of Antalya: are any methods or equipment that would simplify or improve the segregation practices for plate waste. When the wasted food is properly segregated it could be useful for different types of places (e.g. dog shelters). Also, off-site composting would be an efficient and useful opportunity for the hotels and the environment.

Advantages and disadvantages of the food waste processing methods currently used in hotels of Antalya:

- Advantages are that they do not want to be occupied with the waste themselves. Paying a fee and having others be occupied with it is easier for them. They also get free services in return from the waste collection companies and environment consultancy companies.
- Disadvantages are that they are not fully aware of what happens to the waste afterwards since they trust in the companies with which they work. This results in the staff in these hotels to not be aware and cautious of their practices. Also, they do not get to measure the amount of wastage they produce.

Advantages and disadvantages of the potential food waste processing methods that can be used in hotels of Antalya:

- Any training or equipment to improve segregation can help process the food waste more effectively and it would help the hotels use less space in their cold rooms for the same plate waste.
- On-site composting is not something hotels want due to the effects of the resulting fertilizer to the hotel (e.g. attracting mice and insects, and bad odor).

- Advantages of composting are (if it is done off-site) that it can produce fertilizer and be sold to hotels and different places. Also, if turned into energy it would be beneficial for the hotels.

From our discussion, analysis, and the fact that every food waste management process is executed by joint ventures of tourism investors, we believe that a well-planned and organized waste management start up would help Antalya process food waste more effectively and efficiently. The hotels need to improve food segregation practices and the region could benefit a great deal from an organization that would process the food waste to produce by-products such as fertilizers and energy. We believe such an initiative could work since there are vast amounts of organic waste produced by many hotels and a great percentage of this waste comes from food.

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Order Picking Problem in a Warehouse with Bi-objective Genetic Algorithm Approach: Case Study

Safak Kiris[1], Derya Deliktas[2], Ozden Ustun[3]

Abstract − *In this paper, an order picking problem with the capacitated forklift in a warehouse is studied by considering the total distance and the penalized earliness and tardiness. These objectives are important to reduce transportation costs and to satisfy customer expectations. Transportation costs are related to the total distance. In addition, earliness causes forklift waiting while tardiness results in temporary inventory. Since this problem has been known as NP-hard, a genetic algorithm (GA) approach is proposed to solve bi-objective order picking problem. The proposed GA approach is applied to auto components industry that produces wire harnesses responsible for all electrical functions in the vehicle. Experimental design is used for tuning the influential parameters of the proposed GA to obtain efficient solutions. The bi-objective GA approach is solved by weighted sum scalarization.*

Key words: *Experimental design, Genetic algorithm, Order picking, Weighted sum scalarization,*

1. Introduction

The firms have policies to gain a success in the market share competition. One of the goals to compete in the market is to minimize the total cost in the production system. Therefore the firms try to minimize their costs such as minimizing work in process, finished goods inventory and their transportations in the shop floor. Holding inventory is often one of the most important problems in the success of a firm. Inventory cost is consist of financing equipment, labor, protective issues and insurance requirements, handling, transporting, obsolescence, losses and the opportunity cost of choosing to deal with inventory. On the other hand, meeting the demand is the other important problem for the firms in the great competition. In this case, the firms have been studying on the strategy to meet the demand on time with sufficient inventory and their transportations in the shop floors to minimize the total costs. In this situation, various problems to be optimized can be faced in shop floors by the firms.

In this study, an order picking problem to determine the order list for a good route in a shop floor is analyzed. The problem is actually similar to a vehicle routing problems (VRP) with one warehouse and twelve workstations. In some researches this problem type is considered as a Travelling Salesman Problem (TSP) [1; 2]. The VRP is also a generalization of the TSP. The goal in VRP is to find the optimal set of routes for a fleet of vehicles delivering goods various locations. Vehicle routing problems also have constraints as the following:

- Capacity constraints
- Maximum number of locations that each vehicle can visit.
- Time or distance constraints
- Time windows
- Precedence relations between pairs of locations

The objective of VRP is generally to design a set of minimum cost routes that serves a number of places. Since its first formulation in 1959, there have been many studies in the literature [3]. Lenstra and Rinnooy Kan in [4] have analyzed the complexity of the vehicle routing problem and have concluded that practically all the vehicle routing problems are NP-hard because they are not solved in polynomial time. The VRP with time windows (VRPTW) is also NP-hard because of its extension structure of the VRP based on Solomon and Desrosiers [5]. The detailed information can be found in [6].
The problem in this study is similar to VRP with one forklift, one warehouse and twelve workstations. One forklift is visiting each workstation and picking up the orders based on its capacity. Each workstation has one

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pallet to store the product and the forklift has a capacity of three pallets. In the exist system, the forklift is visiting the workstations randomly and does not consider any distance or repetition and so the cost.

In the study, the order picking problem with the capacitated forklift in a warehouse is studied by considering two objectives such as the total distance and the penalized earliness and tardiness. A genetic algorithm (GA) approach is proposed to solve bi-objective order picking problem and the proposed approach is applied to auto components industry that produces wire harnesses responsible for all electrical functions in the vehicle.

2. The proposed algorithm

The proposed algorithm is developed according to the concept of the genetic algorithm (GA). The detailed procedure of the proposed algorithm is as follows:

Step 1. Initial Population: As shown in Figure 1, the structure of the chromosome is designed by sequencing the workstations (k=1,2,…,12) in shop floor. An initial population of each chromosome is randomly created as shown in Figure 1. Each chromosome contains 14 genes. The component of the chromosome represents the sequence of workstations with warehouse. The first and the last genes show the warehouse. The beginning and ending node of the forklift should be the warehouse.

0	2	10	7	8	12	3	1	4	11	5	9	6	0

Figure1. Schematic representation of the chromosome structure

Step 2. Fitness Evaluation: After obtaining the chromosome structure, the route is formed based on capacity of forklift. In this study, the current capacity of forklift is three pallets. Each workstation has a pallet for storing the finished product. The route in Figure 2 is created according to these capacity values. Total distance objective value is computed by taking into account both of the route in given Figure 2 and the distance matrix between the workstations. In addition, earliness/tardiness cost objective value is also calculated by considering costs which arise because of the waiting of forklift's operator and holding inventory. Bi-objective fitness value is obtained the sum of weighted total distance objective value and weighted earliness/tardiness cost objective value. Each weight for objectives is determined by decision-makers in the firm.

0	2	10	7	0	8	12	3	0	1	4	11	0	5	9	6	0

Figure 2. The route belonging to the defined chromosome structure

According to the chromosome structure in Figure 1, gen 0 is the beginning node for the operator of forklift. First, the forklift operator visits the second workstation and picks up a pallet for the forklift. The capacity of forklift is reduced to 2 pallets from 3 pallets. The forklift operator visits the tenth and seventh workstations, respectively, until the forklift is full. And then, he visits the warehouse for unloading the forklift. Similarly, by following the rank in Figure 1 from left to right, the route is obtained as shown Figure 2.

The fitness value of each chromosome is determined by evaluating objective functions. The objectives are defined as:

Total Distance: The capacitated forklift must start from the warehouse and goes to workstations for taking the ready pallet or pallets if the loading capacity is available. The forklift comes back to the warehouse when its capacity is full. Then this order picking process is repeated until all workstations are visited. The total travelling distance of the forklift should be minimized according to the distance matrix calculated by using the facility layout.

Penalized Earliness and Tardiness: Every workstation has minimum and maximum order picking times due to the production rate. Managers want to pick the ready pallets between the minimum and maximum times. If the forklift arrive a workstation before the minimum order picking times then the forklift operator waits for the minimum time to load the ready pallet. On the other hand, if the forklift arrive a workstation after the maximum time then it causes the inventory cost. We penalized both of them. The earliness cost is calculated by using the operator's hourly wage. Additionally, the tardiness cost is based on the cost of inventory area. The total earliness and tardiness cost should be minimized.

The fitness function = w_1×(Total Distance) + w_2×(Penalized Earliness and Tardiness)

Step 3. Selection: In the genetic algorithm, parent chromosomes are selected with a probability related to their fitness. Highly fit chromosomes have a higher probability of being selected for mating than less fit chromosomes [7]. Tournament selection method is proposed in this paper. In tournament selection, one tournament is performed for every non-elitist individual. The tournament size is a given parameter and tournament candidates are randomly chosen from the current population [8].

Step 4. Crossover: Crossover is the process that two parents chromosomes recombine to form a new offspring chromosomes. Two chromosomes are randomly chosen to behave as parents. In this study, it is used random keys representation for solving sequencing problems [9]. Random-keys representation is an effective way to guarantee feasibility of all offspring for sequencing problems. For each gene, a real random number in the interval [0,1) is generated. If the random number obtained is smaller than the given crossover probability, then the allele of the first parent is used. Otherwise, the allele used is that of the second parent.

Step 5. Mutation: Mutation operation is applied over the population after performing crossover operation. Mutation operators provide the ability to overcome a local optimum point solution [10]. Swap position mutation (SPM) is used in this paper. The SPM operator randomly selects two elements and swaps their positions if the probability is greater than the given mutation probability to produce new offspring with a randomly generated probability.

Step 6. Termination: In this study, termination criterion is the number of maximum iteration. This procedure continues until the number of maximum iteration is reached. The system is run 1000 times in the problem.

The pseudo code of the proposed genetic algorithm is presented as:

```
Randomly initialize a population of chromosomes()
While x← x_max do
    x←x+1
    Fitness evaluation for each individual using an objective function()
    Elitism()
    Crossover()
    Mutation()
End While
Return the best objective function
```

3. Experimental Results

The parameters required to run the algorithm are population size, number of generations, number of iterations, crossover and mutation probabilities. These parameters have important roles in the performance of genetic algorithm. Full factorial design approach is used for tuning the influential parameters of the proposed GA to obtain efficient solutions. Full factorial experiments are the only means to completely and systematically study interactions between factors in addition to identifying significant factors. After GA parameters are determined, in order to find the effectiveness of these parameters, 81 (3^4) different experiments are needed for each weight to solve bi-objective problem. In addition, the number of experiments would be repeated five times to verify the accuracy of the solutions. Therefore, the number of the experiments required for each weighted problem is 405 (81x5). The number of experiment is 4455 (405x11) for eleven different weights. GA parameters and their levels in Table 1 belong to eleven different weights that is shown in Table 2. Factor levels of population size factor are different from the values in given Table 1 for the weights of w_1=1.0 and w_2=0.0. These levels are 10, 30, and 50, respectively because these values is enough to reach the optimal bi-objective value for the weights of w_1=1.0 and w_2=0.0.

Table 1. GA parameters and their levels

Factors	Levels		
	Level 1	Level 2	Level 3
Population size	100	150	200
Crossover rate	0,1	0,5	0,9
Mutation rate	0,05	0,10	0,15
Tournament size	3	5	7

The ANOVA is calculated by using Minitab 17.0 software. The main effect plot and the interaction plot for the weights of w_1=0.5 and w_2=0.5 are given Figures 3 and 4, respectively as an example.

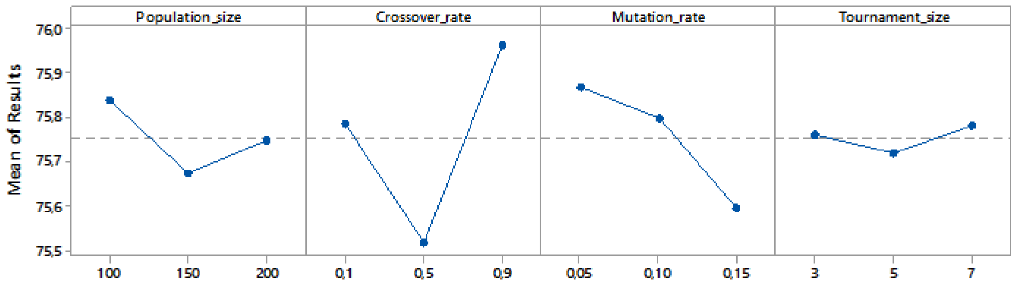

Figure 3. The main effects plot for bi-objective fitness value

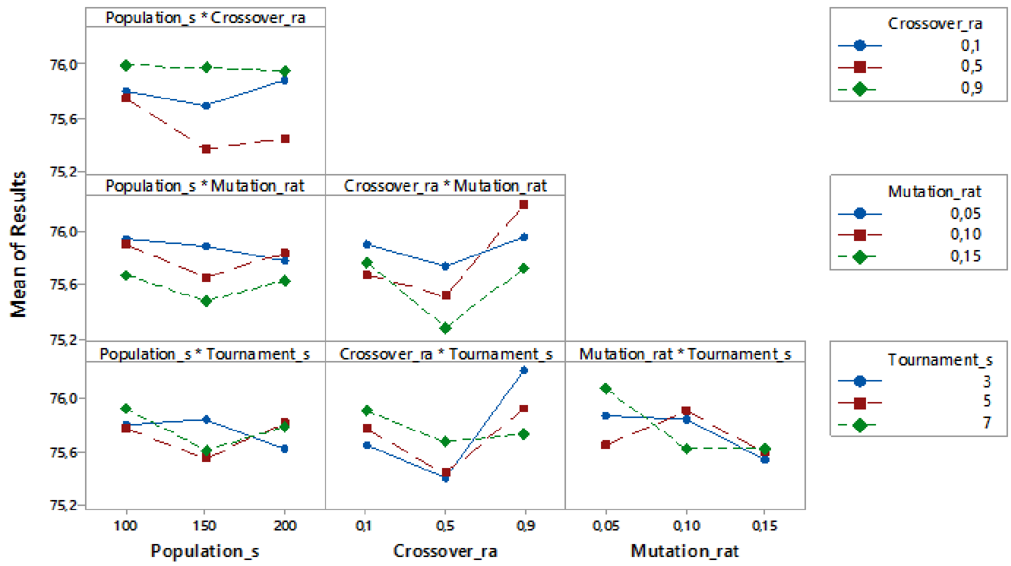

Figure 4. The interaction plot for bi-objective fitness value

GA parameters' levels of the weights of w_1=0.5 and w_2=0.5 were obtained from Figure 3 and 4. Therefore, these levels were defined as 150 for population size, 0.5 for crossover rate, 0.15 for mutation rate and 3 for tournament size as shown in Table 2.

Table 2. The most effective combination of factor levels

	Total distance objective weight (w_1)	Earliness/tardiness objective weight (w_2)	Population size	Crossover rate	Mutation rate	Tournament size
1	1.0	0.0	10	0.1	0.05	3
2	0.9	0.1	200	0.5	0.05	5
3	0.8	0.2	150	0.5	0.15	3
4	0.7	0.3	200	0.5	0.10	3
5	0.6	0.4	200	0.5	0.15	5
6	0.5	0.5	150	0.5	0.15	3
7	0.4	0.6	200	0.5	0.15	3
8	0.3	0.7	150	0.5	0.15	3
9	0.2	0.8	100	0.5	0.15	3
10	0.1	0.9	200	0.5	0.15	3
11	0.0	1.0	200	0.5	0.15	3

* Alltimesaregiven in CPU secondsandthecasestudy is solvedbyusing Intel® Core™ i5-4460 CPU @ 3.20 GHz and 8.00 GB Ram.

After using the proposed GA approach for the analyses based on the experimental design parameters, the results were obtained as seen in Table 3. Three different situations for the capacity of forklift were evaluated to see the more accurate solutions. Sensitivity analysis based on the capacity of forklift is also given in Figure 5.

Table 3. The results of the proposed approach

	w1	w2	Capacity of forklift: 3 (Current)			Capacity of forklift: 4			Capacity of forklift: 2		
			Bi-objective value	Medium	Standard Deviation	Bi-objective value	Medium	Standard Deviation	Bi-objective value	Medium	Standard Deviation
1	1,0	0,0	110,4400	110,443000	0,009487	108,4400	109,440000	1,054093	113,4400	113,440000	0,000000
2	0,9	0,1	105,6838	107,075666	1,833748	105,6907	106,300852	1,222562	109,1283	109,546180	1,216176
3	0,8	0,2	100,5976	101,182811	1,233819	100,5814	101,761569	1,264242	102,4566	102,848457	0,572175
4	0,7	0,3	94,0657	94,159196	0,120689	94,0657	94,081526	0,049964	94,0792	94,117997	0,122806
5	0,6	0,4	84,6076	84,680014	0,120512	84,6068	84,700994	0,157542	84,6155	84,615549	0,000000
6	0,5	0,5	75,1495	75,225051	0,101617	75,1495	75,198717	0,079178	75,1519	75,151936	0,000000
7	0,4	0,6	65,6610	65,724220	0,110475	65,6610	65,711150	0,149180	65,6610	65,692620	0,066619
8	0,3	0,7	56,1379	56,285323	0,190379	56,1379	56,385342	0,467066	56,1379	56,183409	0,077997
9	0,2	0,8	46,6147	46,804293	0,209493	46,6147	46,728241	0,141508	46,6147	46,715389	0,090125
10	0,1	0,9	37,0915	37,233730	0,165712	37,0619	37,132863	0,095673	37,0915	37,162630	0,159963
11	0,0	1,0	27,5355	27,647367	0,190803	27,5355	27,588117	0,166547	27,5355	27,676992	0,194459

It can be seen from Table 3 and Figure 5 that the capacity affects the bi-objective fitness function for all weights of the objective functions. Managers can select the capacity of forklift due to the importance of the objectives.

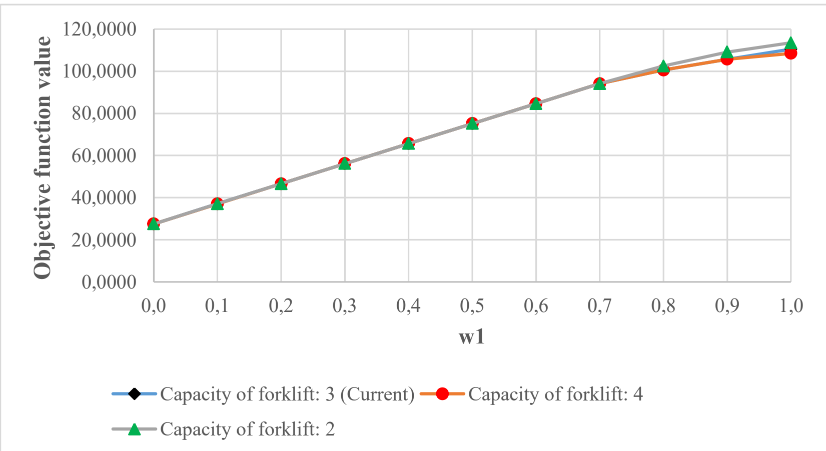

Figure 5. Sensitivity analysis based on the capacity of forklift

4. Conclusion

An order picking problem with the capacitated of three pallets of a forklift in a warehouse is studied by considering two objectives. The first objective is the total distance and the other is the penalized earliness and tardiness. A GA approach is proposed to solve this bi-objective order picking problem for a firm in auto components industry that produces wire harnesses responsible for all electrical functions in the vehicle. The problem is analyzed as a VRP problem and different situations were also evaluated such as different weights and capacity of the forklift. The order picking problem is main part of the production. Therefore, managers need efficient methods to evaluate order picking systems. The proposed approach can support to decide the capacity of the forklift and try to find the more accurate routes based on the objectives.

The proposed GA can be compared with the other meta-heuristics such as simulated annealing, tabu search, ant colony optimization, particle swarm optimization, etc. The bi-objective GA approach is solved by the weighted sum scalarization. It can be compared with the ε-constraint method, the Tchebycheff scalarization method, the conic scalarization method for the bi-objective problem in the future.

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LOGISTIC CENTER DESIGN METHODOLOGY: MALATYA APPLICATION

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Abstract – *Logistics is a concept beyond purely transportation. It also includes uni-modal and multi-modal transport, as well as warehousing, packaging, customs and value-added services. The reduction of logistics costs is critical for the competition since the share of logistics costs in product prices are between 10% and 20%. Beside the logistical cost reduction struggle, decreasing the product delivery time and increasing on-time delivery rate are other important competitive advantages. This situation can vary entirely depending on the effectiveness and efficiency of logistics management. Hence, logistics infrastructure and logistics activities need to be managed effectively for the development and growth of companies in a country, region, province and micro-era. One of the important components of the logistics infrastructure for a particular region is the logistics center. Logistics centers are dedicated areas that are composed of logistics and transportation companies (distribution centers, transportation companies, logistics service providers-3PL etc.), the relevant official institutions (customs, etc.) and social areas (hotels, mosques, restaurants, etc.). This area includes not only active links to all kinds of transport networks but also fast and reliable cargo transshipment equipment among the different modes of transport. In this study, a methodology for establishing a logistics center is proposed. Methodology; it is made up stages such as data gathering, data analysis, demand analysis, location and size determination, planning of in-center facilities, risk and financial analysis. The proposed methodology has been implemented for a potential logistic center design in Malatya Province, which has attractive features in the TRB1 region.*

Keywords – *Logistics Center, Feasibility, Investment Analysis*

1. Introduction

One of the important factors of industrial and commercial development is logistics. Logistics is a concept beyond pure transport and includes road, railway, sea, air and combined transport as well as storage, packaging, customs and value-added service activities. Logistics costs can range from 10% to 20% of the sales price of the product. For that reason, reducing logistics costs is important for competition. Increasing logistics cost as well as decreasing product delivery time and raising on-time delivery rate are other important competitive advantages, which can vary entirely depending on the effectiveness and efficiency of logistics management. Therefore, effective management of logistics infrastructure and logistics activities is required for the development and growth of companies in a country, region, province and micro-base.

The logistics sector has shown a rapid growth parallel with the recent developments in the production and service sectors. From this point of view, it has obviously great importance not only for its own growth potential but also for playin a main role in reaching many economic targets that Turkey has associated with 2023. Turkey's strategic position is accelerating its infrastructure investments and increasing the critical importance of its major transport projects in its region, and is on its way to becoming a preferible country in terms of logistics.

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The logistics centers decrease above mentioned deficiencies, since they helps to increase the use of railway and sea modes by facilitating the transition among transportation modes and also create a economy of scale by consolidating the loads. Logistics center studies in Turkey continue in different dimensions such as logistic specialized organized industrial zones, logistics free zones, the logistics centers of the Ministry of Customs and Trade, TCDD logistics centers, road based logistics centers and Public private partnership logistics centers.

Choosing the convenient locations, determining right the capacities and planning the layout of facilities for logistics centers depend on the success of the carried feasibility studies. Working of the all logistics centers coordinated and supporting each other rather than competing is an important requirement and it can be achieved by a national level logistics master plan. Since this on-going master plan study has not been completed, different regions continue to work locally considering their own objectives. When we consider country policies and regional dynamics, Malatya Province has a strategic importance according to the logistic vision of Turkey and have significant potential as a logistics center. For this purpose, the methodology proposed in this study is applied to the establishment of the Malatya Logistics Center.

The location of the logistics center is a key element in enhancing the efficiency of urban freight transport systems and initializing relative supply chain activities sufficiently; thus, the location of an intermodal freight logistics center should be selected carefully; otherwise it may cause irreversible consequences in the city planning and also it may create bottlenecks that lead to rapid increase in cost in providing transport solutions (Kayikci, 2010).

To better apprehend the issue of freight village location, we carried out a research using Proquest; EBSCO; Science Direct academic databases with the key words “Selection of freight village location” and “Selection of dry ports location.” The findings are summarized in Table 1.

Table.1 Literature Review

Authors	Contents	Case study	Non-case study	Coastal Area	Landlocked Area
(Okan & Özyörük, 2015)	Emphasized the importance of freight services of Turkish State Railways (TCDD); the concept of freight village and the planning of establishment of TCDD freight villages in 12 distinct locations in Turkey and possible contributions of these villages to the railway transport and the freight services of TCDD are considered.	*		*	
(Dimitrios & Seraphim, 2003)	Presented a method and models for assessing the financial viability of a new Freight village financed by private and public investments. The financial evaluation model constitutes an integrated part of a wider planning methodology, with four distinct phases, namely (a) site selection and traffic forecasts, (b) definition of services offered and corresponding dimensions, (c) estimation of investment and operation costs and (d) evaluation of investments.A case study was carried on the of district of Kilkis/Greece	*		*	
(Shahryar & Reza, 2008)	Studied the feasibility of creating a freight village in patronage grounds of the special economic zone of Shahid Rajaie port in Hormozgan Province/Iran.	*		*	

(Ozceylan, Erbas, Tolon, Kabak, & Durgut, 2015)	Proposed a geographic information system (GIS)-based MCDM model to evaluate potential locations for freight villages in Turkey.	*		*	
(Yildirim & Onder, 2014)	Proposed a freight village analysis model for the city of Istanbul/Turkey	*		*	
(Yavas, Volkan, Sakar, & Denktas, 2017)	Investigated the existing situation of freight villages in terms of their operations, potential markets and provided an evaluation of a potential freight village in the Aliağa region. /Turkey	*		*	
(Nguyen & Notteboom, 2016)	Presents a conceptual framework for the inclusion of multiple criteria in the evaluation of dry port location in developing countries from multiple stakeholder perspective with an application on Vietnam.	*		*	
(Jeevan & Eon-seong, 2015)	Examines the functions and challenges of dry ports development in Malaysia through 11 face-to-face interviews with dry port stakeholders.		**	**	
(Violeta & Kenth, 2009)	Extends the theory behind the dry port concept and defines three dry port categories; distant, midrange and close.		**		
(Zheng, Jing, & Zhuang, 2011)	Deals with the problem of optimally locating dry ports for seaport. Evaluation system for dry port location decision is established and FCM is applied to solve the problem. The model is used to select optimal location for inland terminals of port Tianjin in China.	*		*	
(Li, Dong, & Sun, 2015)	Summarizes the status of dry port development in China. Based on this, the study proposes a New dry port development strategic layout.		*	*	
(Garnwa, Beresford, & Pettit, 2009)	Reviews the development of dry ports in the United Kingdom of Great Britain and Northern Ireland and in Nigeria.		**	**	

Data Gathering

In this study, firstly we reviewed the literature and examine the best practice applications of the logistics center. Then, we explained the proposed methodology. And then, we described the methods used in the fourth chapter. In the fifth section we applied the methods for the Malatya Logistics Center. And finally, we discussed the results of our work.

2. Methodology

Flow chart of proposed methodology of Logistics Center Design is given in Figure 1.

DATA GATHERING
- Literature Survey
- Best Practices
- On-site visits
- Statistics (demography, trade, infrastructure, etc.)
- National and International Transportation Corridors
- Competitors
- Survey research SWOT and/or PEST Analysis
- In-depth interviews

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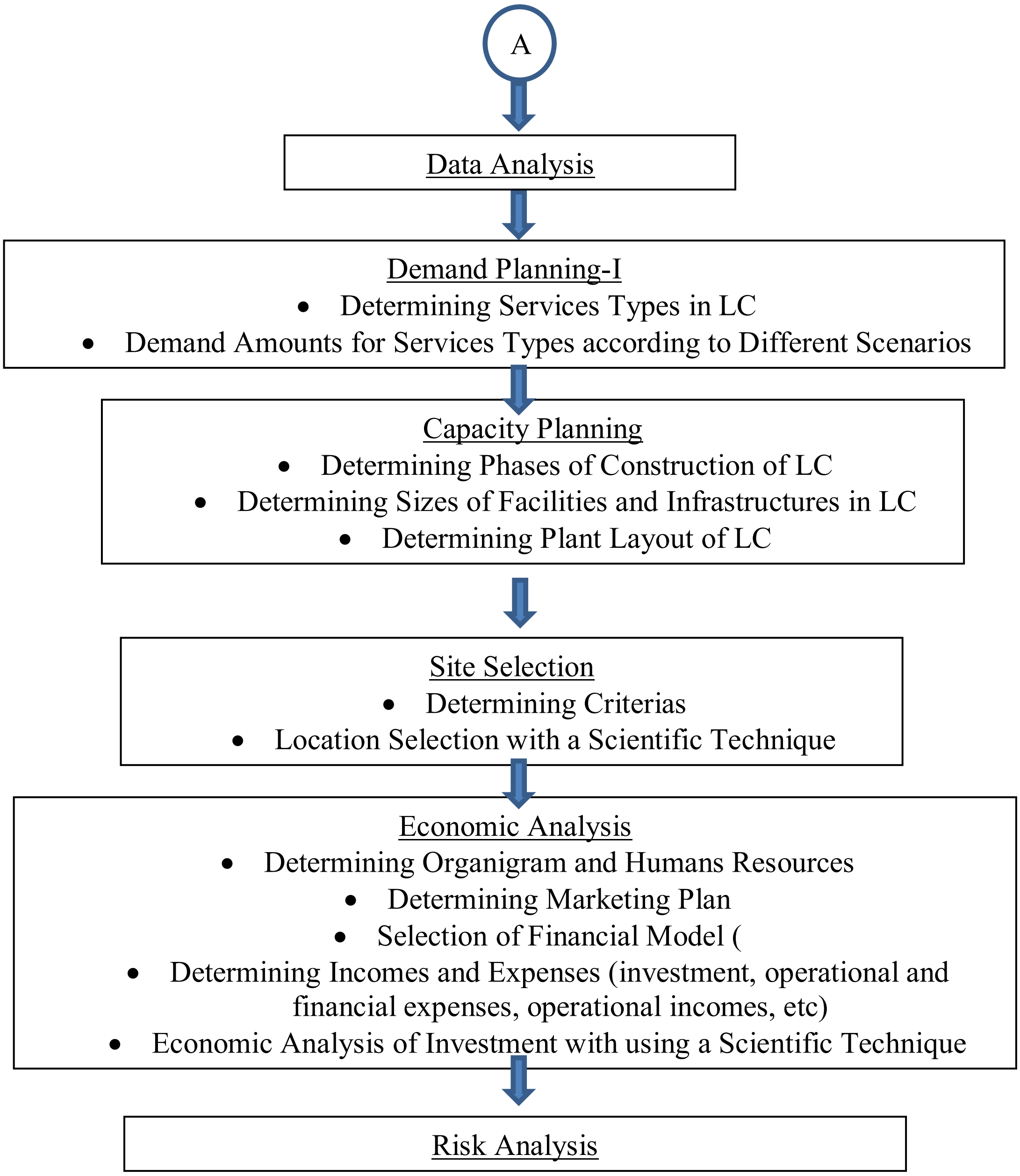

Figure 1. Flow Chart of Logistics Center Design Methodology

3. Methods Used

3.1. Demand Planning

Demand planning may be defined as a multi-step operational process used to create reliable forecasts for various products or materials at various points in a supply chain. Effective demand plans may be helpful for decisions about product life cycles, demand patterns, market variability/seasonality, inventory level alignments and accurate revenue forecasts. Since, various logistics operations are carried out and variety of the customer types is very high in a logistics center, planning the long term demand is a complicated issue. The mostly used approach is beginning with a statistical forecast. Data sources for that forecast should include planned service orders, standing customer contracts and anticipated trade scale in the reagion. In general, main steps in a demand planning include importing historical logistics service sales data, creating statistical forecasts, collaborating with customers, building a consensus forecasts, conforming with the current and possibile customers of the logistics center and reexamining the data and adjusting the plans. These used data are expected to be very comprehensive and convenient softwares facilitating from traditional techniques or artificial neural networks would be used. The obtained demand plans will be an important input for the capacity plans of the logistics center.

3.2. Capacity Planning

All kind of facility designs consider input requirements, some conversion process and output. After making the forecast and long-term planning, organization should undertake capacity planning. The capacity of a facility is generally related with resources that will be in place to handle an increasing number of requests as the number of customers. The aim of the capacity planners is to decide so well that planned capacity is added to meet the anticipated reqirements but not so early that resources go unused for a long period. The successful capacity planning is focused on the trade-offs between the present and the future that overall prove to be the most cost-efficient.

Logistics center capacity may be measured by various metrics like size of the warehouses, number of the gates, parking lots, social facilities, custom areas or nuber of vehicles visit the center in unit time etc. Capacity plans are made for long terms considering the anticipated demand volumes. Analytical modeling tools can help the capacity planner get answers to what-if scenarios so that a range of possibilities can be explored. According to the time horizon, capacity planning can be classified as long, medium and short term plans. At the construction phase, the feasibility of the logistics center should consider the long term capacity plans. Also the affecting factors of the capacity planning depends on layout design, location decisions, service proceses, used technology, human sources, operational structureand external structure (policy, safety regulations) etc. While designing a logistics center all this capacity planning factors should be taken into account.

3.3. Location Selection of Logistics Center

One of the most important decision for all facilities and also for logistics centers is location selection. Location selection generally starts by determining the convenient country, then the region in the country and finally a specific site in the region. While selecting a right location for a facility there are many criteria that should be taken into account. Generally, cost related factors come at the first level but also other qualitative and quantitative criteria should not be overlooked. Because, location of a company has a great impact on many risks and profitability issues. The most common criteria are proximity to the suppliers, demand points, highways, seaports, railway terminals, talented labor, political risks, cultural and economic issues, beside variable and fixed (land and construction) costs. Location selection problem may be considered as evaluating the alternative locations and choosing one of them. The major methods for this problem are the factor-rating method, locational cost–volume analysis, the center-of-gravity method, and the transportation model (Heizer and Render, 2014).

3.4. Economic Analysis

A common definition of the economic analysis is determining the optimum usage of the scare resources, involving comparison of more than one alternatives for achieving one or more objectives under the given constraints. In that study, a logistics center design problem handled and economic analysis turns to feasibility analysis. It allows companies to determine all the necessary details to make a business work. Not only the current and future market potential, competition and forecast but also transportation, business location, technology needed, materials and labor factors are considered. In a feasibility analysis, financial and organizational issues are also handled. A projection of the amount of startup capital needed, what sources of capital will be used, and what kind of return can be expected on the investment is the financial side. Also the organizational analysis tries to determine the number of required human resources and their professional background or the skills they possess necessary to get the company off the ground.

3.5. Risk Analysis

A logistics center is probably a big investment and includes many risk elements. In the design phase something can go wrong and some negative consequneces can be seen. Risk can be hard to spot but it can be managed. Risk analysis is defined as a process that helps to identify and manage potential problems could undermine key business initiatives. In a risk analysis, firstly threats related with human, operations, finance and structure should be identified. After that, likelihood of these threats being realized and propable impact should be calculated. The result of this calculation can named as risk value and it may be obtained by multiplying the probability of event with cost of event. According to the risk values various actions can be planned to manage them. In some cases, risk may be avoided, shared, accepted or controlled.

4. Malatya Logistics Center Application

Malatya is located in the TRB1 Region, which is far from the borders and sea sides of Turkey. Food products production is the biggest industry and also textile products manufacturing and other mining quarries are the other major sectors in Malatya. The economy of the city is based on agriculture and agriculture based industries. 35% of the city surface is used as agricultural land and the basis of the Malatya economy depends on large scale production of apricots. The province of Malatya is an important city in terms of both industry and underground resources of the Eastern Anatolia Region and iron, chrome, copper, amyant and lead mines are operated. Malatya mainly exports agriculture, food and textile products. When the distribution of exports and imports according to sectors in Malatya is examined in 2015, the ratio of manufacturing industry exports and imports are 83,5% and 61,71% respectively. While Gross Domestic Sales in the province took Istanbul in the first rank with 26,20%, İzmir ranked second with 4,81% and Ankara ranked third with 4,71%.

The loads coming to the region mainly cover the raw material needs of the manufacturing industry. Cotton and coal are in the first place among imported goods. In addition, seasonal sugar beet comes from the neighbourhood to meet the needs of the sugar factory. The TRB1 Region is an important junction of Turkey's main highway axles between north-south and east-west, especially the D-300. The region is one of the important railway junctions since the beginning of the republican history and also in good condition in terms of accessibility with airway and ferry transportation on the inner waters. Malatya has a total of 1.102 km road network, including 497 km of state highways and 605 km of provincial road. Between 2003 and 2016, 326 km of divided roads were made and 362 km (33%) of this road network reached the divided road network.

TRB1 Regional railway which is covered by TCDD Zone 5 has approximately 15% of the ton-km transportation capacity throughout Turkey. The TRB1 Region is also important in the transportation of passengers and goods by railway on the lines coming from Southeast and East Anatolia. Economically, transporting the mining ores extracted in the region and neighboring regions to the ports of Iskenderun and Mersin is a big part of the regional railway network. There is a 238 km railway network within the borders of Malatya.

Iskenderun Port is 318 km away from Malatya, Mersin Port is 454 km away and the ports are also accessible by railway. Malatya Airport, which entered service in 1941, is 34 km away from the city center.

Within the scope of the proposed logistics center design methodology, resources were scanned, statistics were analyzed, in-depth interviews and site visits were conducted. On February 4, 2017, the "Malatya Logistics Center" Joint Mind Conference (SWOT analysis) was held as an organization consisting of two sessions. Approximately 200 participants attended from various stakeholders such as public administrators, private sector representatives from various sectors, various non-governmental organizations, representatives of associations and foundations and academicians from universities. As a result of this study, mission, vision, long and medium / short term strategies and projects and action plans for the logistics sector were determined.

Surveys have been conducted on some of the companies using and providing logistical services by making samples to obtain information about the size and course of the logistical activities in Malatya. According to the sample and other data, the types of logistic service providers for the logistics center were determined based on the sector and mode of transportation. Within the framework of the vision, scenarios and strategies, the facilities and areas that should be located at the Malatya Logistics Center are determined as follows: **Railway Station, Construction and Terminal Area, Road Connection, Administrative and Social Facilities Building** (the logistics center's management unit, certification, quality control, laboratory service units, TIR carnets, certificate of authority, non governmental organizations and others, its own warehouse, logistics companies without transport vehicles, transport operations organizers, customs brokerage, agents, shipping agents, Bank, Insurance, Foreign Trade, Consultancy, Human Resources, Information Technologies, Mail, Tire, Battery, Spare Parts, etc. units, Place of worship, accommodation, Food and Beverage Facilities, Recreation-Entertainment Facilities, Market, Shopping, Health, Conference Hall, etc.). C**ustoms Building, Storage Facilities** (Storage and Packaging Facilities, Tanks, Licensed Warehouses, Warehouses, Temporary Warehouses, Heat and Humidity Controlled Warehouses, Distribution Centers and Cargo Transfer Centers), Open Storage Areas (Container Storage, Loading-Unloading, Washing Areas, Open Field Warehouses, Open Customs Areas), Weighting Area, Repair Maintenance Workshop, TIR and Truck Park, Entrance and Exit Doors and Passenger Car Park Area, Public Transportation System Stops, Technical Facilities (Electricity, Water, Gas, Communication, Waste etc.), Fuel Station, Green Area, Accommodation Facilities.

For each type of service, the regression analysis method was used in the realization of the forecasts, and three different scenarios were used, namely "slow pace" (pessimistic), "medium pace improvement (normal)" and "rapid pace (optimistic)". It is assumed that approximately 1 million tonnes of 4,5 million tonnes transported by road will be converted to railway carriage and 30% of the remaining 3,5 million tonnes (approximately 1 million tonnes) will be handled at the logistics center. In this case, the total amount of cargo handled in the logistics center will be 2,9 million tons. Estimates are used to determine the size of the area on a logistics service type basis. The installation was made in such a way as to facilitate the flow of products and information. The center of gravity method was used and it was decided that it would be appropriate to build it in the old wagon factory area of 765 acres.

The assumptions regarding the freight and traffic estimates of the Malatya logistics center are as follows:

- The working day was handled over 300 working days.
- It is assumed that the construction of the logistics center will commence in 2018 and commence at the beginning of 2020.
- The initial figures for the scenarios are based on the year 2016 figures.
- The 3% growth rate is the "slow-speed development scenario" indicating only a local logistic center serving neighbor of the city; the 4,5% growth rate is the medium-speed rapid development scenario indicating a regional logistic center; and the 6% growth rate is the "rapid development scenario" indicating a international logistic center zone.
- It is assumed that the containerization rate will increase in Malatya Logistics Center with the increase of railway freight and this increase in conteinarization will be 50%, 55% and 70% respectively according to the above-mentioned development scenarios.

Considering the above scenarios it is assumed that 40% (slow-speed development), 50% (medium-speed development) and 60% (rapid development) of road freight vehicles will be pulled by the logistics center.

It is aimed to increase the railway usage rate by the establishment of the logistics center. The most important criterion for passing from the highway to the railway is the cost advantage. In this context, the comparison of road and rail transport costs is made below considering various assumptions. Different scenarios have been taken into account when making comparisons. For railway altenative, empty container can be sent to relevant plant and it can be filled as full container load (FCL) in that place. Then FCL can be brought to the logistics center as ready for loading to the train. Or the freight in the factory can be transported as LTL by truck to the logistics center. And then, the freight can be containerized at the logstics center. As another alternative, freight can be transported to the logistics center by FTL or LTL trucks. The the freight can be transferred from truck to traditional railway car. The last alternative is using road transportation for the entire journey as in the present situation. Port of Mersin, which has an important trade rate with Malatya, is assumed as the destination point in cost calculations.

According to the all load volume calculations, demand analysis and other projections, year 2030 is obtained as the break even point and it is accepted as the target year in the financial analysis. The net present value calculation is based on the beginning of 2017. The total fixed investment amount including the land, total number of parcels, number of facilities and sizes and infrastructure planning is calculated as 10.380.150 Euros net present value. The net present value of operating expenses up to 2030 is 3.910.040 Euros.

Income of operations and open and closed area (social facilities, etc.) allocations are estimated as 16.435.360 Euros. Payments of the allocation expenses is assumed that to be paid in years as instalment. An annual rental income payment will also give the same calculation results. With the assumption of not paying any money for the land, the break-even point will be reached 12 years later (in 2030). In other words, the cost of investment is met at the end of 2030. It is envisaged that the infrastructure, public and railway terminals and lines will be realized and operated by TCDD, the land for rent will be settled, and warehouse investments will be made by the operators. This approach will reduce the initial investment cost. Finally, the risk analysis of the investment has been carried out.

5. Conclusions

In this study, a methodology for the design of the logistic centers was proposed and the methodology was applied to the province of Malatya. The establishment of Malatya Logistic Center will be a regional-local hub that can be used by Malatya and regional industry, as well as the size and infrastructure that can provide international and national logistics services with its regional position, railway and road connection and cargo potential.

It has been determined that the potential of highway freight transport is very high compared to the existing road transport data and projections and that it is possible to access the existing foreign trade potential to the ports by the railway even though it is far away from the ports. With the completion of the railway project planned by the TCDD, the using rate of railway transport will increase rapidly. It is therefore appropriate that the Logistics Center to be established is designed to provide the infrastructure for the combined transportation that all these modes of transportation can be used actively, and to be a global competitive advantage.

The national investment and public-sector strategy and action plans for investment are based on 2023 as the year of investment target based on the basic reference. It is foreseen that investments in the proposed logistics center will be made up of 2 stages.

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PRODUCER SELECTION MODEL FOR AGRI-FOOD PRODUCTS WEB PORTAL: AHP APPLICATION

Atiye TÜMENBATUR[1], Mehmet TANYAŞ[2]

Abstract – *The raw materials of food products are generally agricultural products and are also called unprocessed food products. Seeds, seedlings, fertilizers, pesticides, water, agricultural machinery and equipment are required İn the creation of agricultural products. Ratio of logistics expenses to sales revenue are 18% in the agriculture sector and 13% in the food sector. These ratios are above the general average of 10%. In the agricultural sector, production is very fragmented and there are small Producers and trade rules are not clear, There is a trade structure predominant in traders and brokers. The master plan of agricultural production is not clear. Logistics processes are not suitable for consolidation and planning.*

Inflation in prices of agricultural products directly affects the prices of food products. The importance of the agricultural food chain is increasing due to the fact that food prices are so effective at the annual inflation rate. The increase in the prices of agricultural products is very influential on producer prices. There is a chain that prices increase several times from farm to fork. This chain needs to be restructured. There must be a way for the producer to deliver the product directly to the consumer. From this point of view, constructing all supplier communications through a secure and web-based portal are important. Also, all of the process need to logistics management.

In this study, a model for the selection of producer to be included in the supplier portal will be proposed.

Keywords – *Agricultural Logistics, ATP Convention, Cold Chain Logistics, Supply Chain Management,*

1. Introduction

The agriculture sector has an important place in the country's economy because of it has a significant share both in employment creation and in foreign trade transaction. Our country is an agriculture country due to its diversity of products and favorable prices and it is the 9th largest economy of the World Agriculture Sector. According to 2011 data, annual total vegetable fruit production is around 42 million tons. The monetary value of this production is TL 57 billion. However, about 10 million tons of products are lost until they reach final consumption. Due to the mistakes in packaging, storage, transportation and final consumption habits, there is a national income loss of 14.2 billion ₺ per year.

Inflation in prices of agricultural products directly affects the prices of food products. This is also affecting the Consumer Price Index (CPI). According to CBRT data, the share of food and non-alcoholic products in the inflation basket was reduced to 21.77% in 2017 from 23.68% in 2016 (Table 1). The fact that food prices are so effective at the annual inflation rate reveals the importance of the agricultural food chain. The increase in consumer prices in agricultural products is well above the producer prices. There is a chain where prices are increased several times from farm to fork.

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Table 1. The Main Expenditure Group Weights (URL-1, 2017)

The Main Expenditure Groups	2016	2017
Food and Non-alcoholic Drinks	23,68	21,77
Transportation	14,31	16,31
Housing, Water, Electricity, Gas and Other Fuels	15,93	14,85
Restaurants and Hotels	7,47	8,05
Furniture, Home Appliances and Home Maintenance Services	8,02	7,72
Clothing & Shoes	7,43	7,33
Alcoholic Beverages and Tobacco	4,98	5,87
Miscellaneous Goods and Services	4,73	5,04
Communication	4,42	4,12
Entertainment and Culture	3,81	3,62
Education	2,56	2,69
Health	2,66	2,63

If we consider the fresh fruits and vegetable products in the supply chain of agricultural products in Turkey; Products taken from the field / greenhouse will be received by the manufacturer / retailer, retail chain operators, industrialists or exporters. The products reach the market markers, grocery stores, nutrition and consumers in wholesale market. Figure 1 shows the supply chain organizational scheme of agricultural products. As seen in the diagram, the producer either harvests the product, takes it to wholesalers with its own means and sells it through brokers there, or sells it directly to retailers such as supermarkets. Agricultural products go through many stages until reaching final consumption. The time spent in each transaction within this network affects the quality and price of the product in the negative direction.

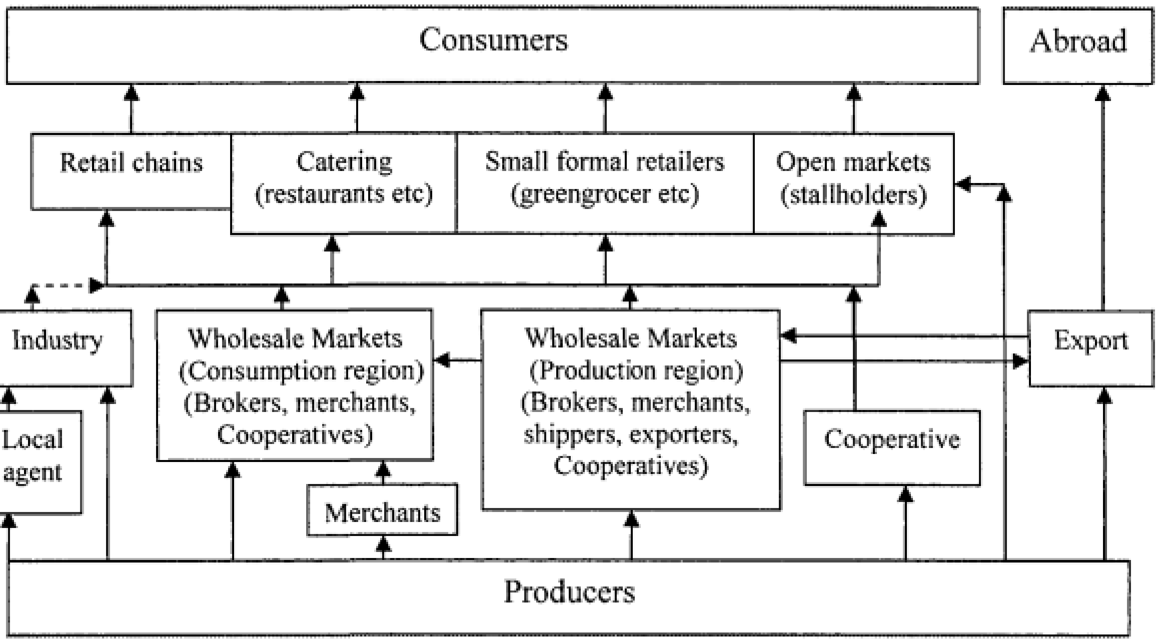

FIGURE 1. Turkish Fresh Fruits and Vegetables Supply Chains
Yilmaz & Yilmaz—Evaluation of the Wholesale Market System, 2008

Agriculture and food value chain are given in Figure 2. Basic suppliers providing input to the agricultural sector; seed, fertilizer, medicine, insurance, machinery and equipment. The effective identification of consumption claims at the end of the supply chain is the main determinant of the calculation of input requirements (KPMG, 2013).

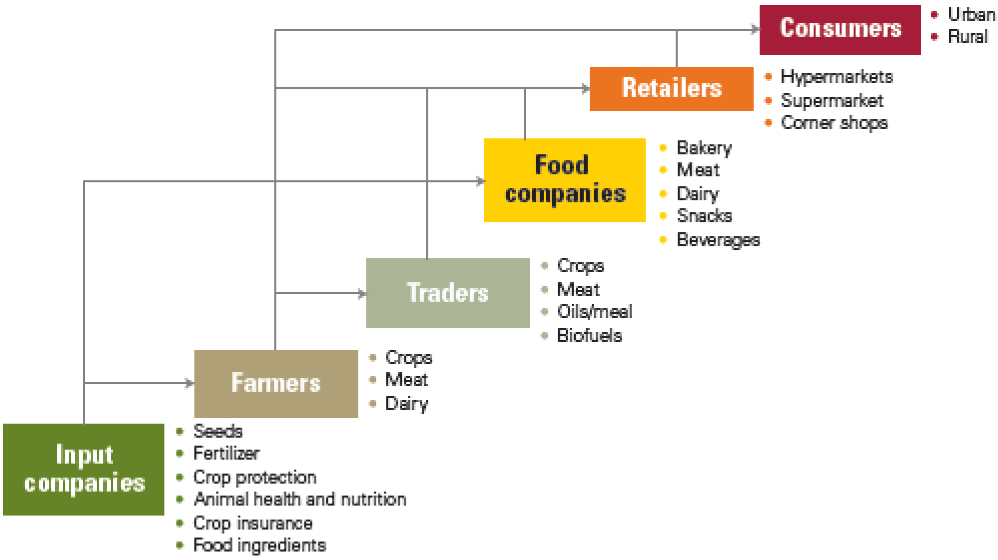

FIGURE 2. The Agriculture and Food Value Chain (KPMG,2013)

One of the product groups covered by herbal products is fresh fruits and vegetables. As shown in Figure 1, there are many stages in the fresh fruit and vegetable supply chain. This situation both increases the cost and delivery time of the product presented to the consumer and increases the loss of the product. In our country, 46 million tons of fresh vegetables and fruits are produced annually, worth 75 billion liras. Furthermore, fresh vegetables and fruits are going through important losses until reaching the table. Surveys reveal that losses average 15 to 50 percent. If we consider that on average 25% of our total fresh vegetables and fruit production is wasted each year, this loss is about 20 billion TL (TZOB, 16.05.2015).

Losses are between 4-12% during harvest, 2-8% during the transportation of the products to the market, 5-15% during the market preparation phase, 3-10% during the storage period and 15-50% during the consumer stage. The main causes of losses are: decay, due to diseases that occur in the period after harvest, not precooled, failure to provide protection in a controlled atmosphere, not appropriate packaging, handling and transportation.

Losses at harvest line; collection of the product before and after its time, insufficient and inappropriate collection containers, unsuitable collection methods (mechanical damage etc.), non-qualified personnel, the protection of the product from the climatic conditions (cover etc.), delay of cooling, no cold storage in producer areas and are the delays in product delivery.

Agricultural product producers are one of the important steps of the chain. The production of the producer at the desired standards, the proper harvesting of the product and the necessary importance to the logistics will increase the efficiency and efficiency of the chain. Therefore, it is necessary to choose appropriate producers.

In the second part of the study, the related literature is given, the problem discussed in the third part is defined and the solution method used is explained. In the fourth part, the application is included. In the fifth chapter, the results and suggestions are presented.

2. Literature Review

In order to better understand the importance of the supply chain of agricultural products in academic literature, the articles were collected under three headings as "agricultural supply chain", "agricultural logistics" and "cold chain logistics". For this research, Web of Sciences and Science of Direct academic databases were scanned in the with keywords "agricultural supply chain", "agriculture logistics" and "cold chain logistics". Summary and title analysis of the articles published between the years 2000-2017 were aimed at 30 studies, but 10 were considered in terms of direct consideration of this study. The researches conducted in Table 2 are classified according to methods and key words.

Table.2: Dispertion of Researches Food Supply Chain

RESEARCHER	Case Study	Conceptual Study	Literature Review	Operation Research	Operation Management	CONTENTS
O.Ahumada,J.Rene Villabos, 2009	*	*				Meet the cold chain management system requirements and to manage provide a tools which allows to choose the cheapest configuraiton.
Soysal, Ruwaard, Meuwissen, Vorst, 2012				*		It is reviewed quantitative studies in food logistics management in a structured way.
Tsolakis, Keramydas, Toka, Aidonis and Iakovou, 2012					*	Development and management of sustainable agrifood supply chain management provide a guiding systemic framework for researchers and practioners.
Bosona, Gebresenbent, 2013		*				The definition, driving forces, barriers in developing food traceabilitys's and identified benefits, Technologies and preformences.
Soysal, Ruwaard, Vorst, 2013	*					A MOLP model for the generic beef Logistics network problem in this study. It has two competing goals. Minimizing total logistic cost and minimizing total CO2 emmissions from transportation operations.
Dabbene, Gay, Tortia, 2013					*	To analyse how traceability concepts, requirements and Technologies influence modern supply chain management and are handled by the ensuing optimisation principles.

Validi, Bhattacharya, Byrne, 2014	*						Sustainable distribution process and dairy market Logistics problems. With a model presented which adresses the multi objectives of carbon reduction and cost minmisation in the design stage of the milk distribution system.
Mohan, Gunjan, Jain, 2015		*					To provide a lietrature Review of perishable food supply chain qulaity and includes all the products/process(milk,meat,vegetable,grains and butter)
Defraaye, Nicolai, Kirkman, Moore, Niekerk, Verboven and Cronje, 2016	*						Interection of the cargo load with the container for the cold Logistics management. This Research shows that the way of convectively cooling container has a clear impact on.
Ali, Shukran, 2016		*					Literature of organizational behavior and strategic management into multi-level supply chain.

Developing effective strategies to meet consumers' demand for agricultural products is a complex and challenging issue while responding to changes in lifestyle and nutritional preferences on a constant basis.

3. Definition of Problem and Solution Method

As it is known, the price of agricultural products, which is low in the production place, increases significantly as to the consumption of food, and this situation increases the inflation rate. One way to reduce inflation is to increase productivity. Efficiency is the ratio of output to input. The output in the logistics of agricultural products is to deliver the products undamaged, complete and on time. Agricultural products will be delivered to the customers in the fastest manner and at the lowest cost with a system based on the standards and the provision of these standards and working on a pull-based basis.

E-commerce is the latest information technology (IT) methodology in agriculture, which has gained widespread development along the Internet. We can say that e-commerce in agricultural product management is the theoretical benefits such as speeding up price determination, efficient data sharing, information flow, market transparency, and cutting or lowering the transaction costs (Leroux, 2001). Therefore, the use of appropriate information technologies in the supply chain management of agricultural products creates competitive advantage, depending on the amount of information shared. With e-commerce, manufacturers can have their products sold directly to retailers or end-users via the internet. Furthermore, with this system, which allows the vehicles in the distribution chain to be deactivated, the transaction costs are reduced significantly.

One of the major problems in the Agri-Food supply chain is that the chain is very gradual and the product flow to the consumer is long. It increases process length, losses and costs. It is the creation of a short supply chain through the removal of activities that do not create added value in the process. The creation of a short supply chain naturally requires the use of information technology to increase the producer and consumer communication. For this purpose, a suitable web portal creation is proposed. Ordering on the web is dependent on the increase of the confidence environment of the manufacturer. Therefore, the choice of appropriate producers is required. This study deals with the problem of choosing the farmers to be included in the web portal to form a short supply chain. The method we use to solve the problem is the Analytic Hierachacy Process (AHP) method.

The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision making, and may aid the decision maker to set priorities and make the best decision. By reducing complex decisions to a series of pairwise comparisons, and then synthesizing the results, the AHP helps to capture both subjective and objective aspects of a decision. In addition, the AHP incorporates a useful technique for checking the consistency of the decision maker's evaluations, thus reducing the bias in the decision-making process.

The AHP considers a set of evaluation criteria, and a set of alternative options among which the best decision is to be made. It is important to note that, since some of the criteria could be contrasting, it is not true in general that the best option is the one which optimizes each single criterion, rather the one which achieves the most suitable trade-off among the different criteria.
The AHP generates a weight for each evaluation criterion according to the decision maker's pairwise comparisons of the criteria. The higher the weight, the more important the corresponding criterion. Next, for a fixed criterion, the AHP assigns a score to each option according to the decision maker's pairwise comparisons of the options based on that criterion. The higher the score, the better the performance of the option with respect to the considered criterion. Finally, the AHP combines the criteria weights and the options scores, thus determining a global score for each option, and a consequent ranking. The global score for a given option is a weighted sum of the scores it obtained with respect to all the criteria.

The AHP can be implemented in three simple consecutive steps; Computing the vector of criteria weights, computing the matrix of option scores and ranking the options.

4. Application

Production cost have a low proportion of the whole cost, however, each links in the produce process can bring extra cost in the agricultural product trade. For this reason, the primary producers only gain very tiny profit. Moreover, unit-weight of agricultural product's lower worth result in higher transportation and market cost. The natural attributes especially the seasonal and the regional of fresh agricultural products require a more stringent process flow, a faster speed of transport and a stricter requirement of storage transport relative to the ordinary goods to make sure the safety of entire distribution process of agricultural products supply chain (Li S., Hu L., 2015). The criteria we have chosen in the selection of farmers in the short supply chain that we have created under all information are as follows.

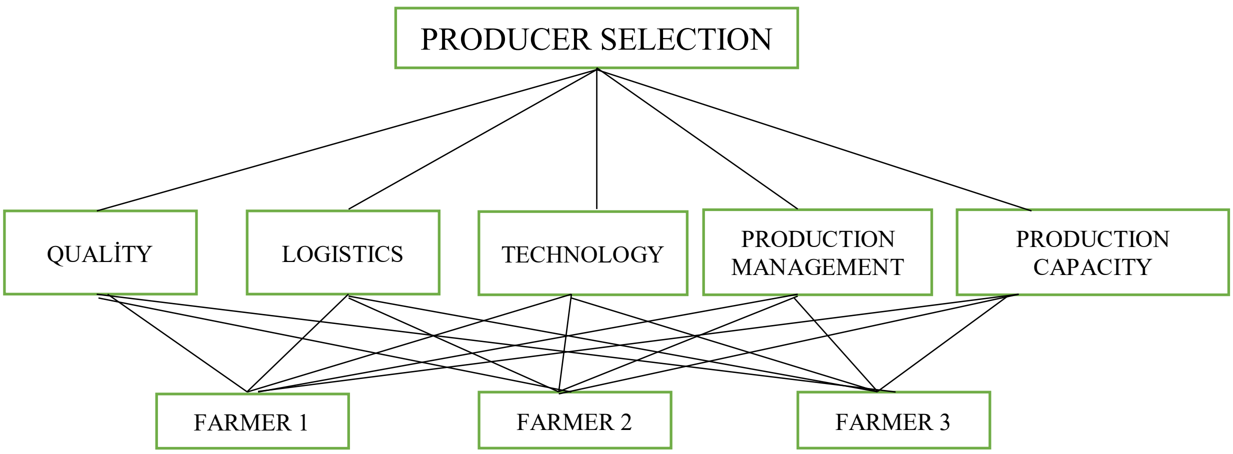

Figure 3. Hierarchical Structure for Selection of Producer

The main criteria determined in figure 3 were evaluated by three academicians and the geometric mean was taken. And then, these criteria were normalized and weighed. As seen in table 3, quality is in the first place and production management is in the second place.

Table 3. Weights of Main Criteria

NORMALİZED	QUALITY	LOGISTICS	TECHNOLOGY	P. MANAGEMENT	P. CAPACITY	WEIGHTS
QUALITY	0,32	0,25	0,38	0,30	0,35	**32%**
LOGISTICS	0,16	0,13	0,13	0,15	0,06	**12%**
TECHNOLOGY	0,11	0,13	0,13	0,15	0,12	**12%**
P. MANAGEMENT	0,32	0,25	0,25	0,30	0,35	**29%**
P. CAPACITY	0,11	0,25	0,13	0,10	0,12	**14%**

Later in the application, weights of each criterion were calculated for the three types of producers selected. As shown in the application result table, farmer 1 is in the first place with 54%. Although all three farmers are on equal footing in terms of technology criterion, farmer first is superior to others in terms of logistics, quality and production management.

Table 4. Application Result

OPTIONS	QUALITY	LOGISTICS	TECHNOLOGY	P. MANAGEMENT	P. CAPACITY	**TOTAL**
FARMER 1	0,5243	0,6965	0,3333	0,7187	0,3022	**54,803221**
FARMER 2	0,1410	0,2320	0,3333	0,8100	0,6080	**43,83952**
FARMER3	0,3350	0,7200	0,3333	0,2710	0,9000	**44,2661**

5. Conclusions and Suggestions

Farming represents the largest employment sector in the world. Development of these small farms in emerging economies is fundamental to the overall progress of economic development in a process known as ‘agricultural transformation’. The sector is extremely diverse and can be segmented by farm size, crops grown and level of sophistication. Farming is the riskiest activity in the value chain, subject as it is to the vagaries of the weather (amplified by global warming) and market volatility. However, in good years it is also potentially the most profitable.

The technique used when we look at the supplier relationship management dimension is not only limited to a one-time selection of the manufacturer but also depends on the process management principles and should enable continuous repetition of evaluation and be flexible in terms of criteria. In our AHP study, five main criteria were used as quality, logistics, technology, production management and production capacity. The fact that the specified criteria are below 10% of the consistency rates indicates the feasibility of this study. In this regard, the AHP is also able to respond to these needs.

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SUPPLY CHAIN OPTIMIZATION STUDIES: A LITERATURE REVIEW AND CLASSIFICATION

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Abstract *– Supply chain planning has been considered as one of the most integrated process in which a group of several organizations, such as suppliers, producers, distributors and retailers, work together. It comprises procurement, production, distribution and demand planning activities. These activities require taking strategical, tactical and operational decisions. The literature in some of these activities is vast, but the literature in others is not sufficient. This research revealed which supply chain topics and, also which decision/planning levels are popular and which optimization methods are mostly studied in supply chain planning. Hence, this paper is aimed to be a guiding research for researchers. This paper presents a review of optimization studies about supply chain planning. A total of 77 reviewed works published between 1993 and 2016 are used as references. The reviewed works are categorized according to following elements: decision levels, supply chain optimization topics, optimization models.*

Keywords - *Decision level, literature review, optimization model, supply chain, supply chain optimization topic.*

INTRODUCTION

Nowadays, customer demand and supplier business principles are changing according to technological changes. Therefore supply chain optimization is a complex issue for enterprises. There have been challenges for managing suppliers, customers and other members in the supply chain. Classical optimization models are not sufficient to manage this complexity. And so heuristic algorithms are being developed for optimizing supply chains.

A supply chain (SC) can be defined as an integrated system synchronizing a series of interrelated business processes in order to: (1) acquire raw materials and parts, (2) transform these raw materials and parts into finished products, and (3) distribute these products to either retailers or customers [1].

Supply chain is the integration and coordination of procurement, production, distribution and demand planning. These planning activities require taking strategical, tactical and operational decisions. And optimization models are being developed to operate these activities in the supply chain.

The objectives of this paper are to (i) review the literature, (ii) analyze and categorize the works based on the decision levels, supply chain topics, optimization models, (iii) identify future research directions.

The remainder of the paper consists of three other sections. The next section introduces the review methodology. Then Section 3 presents the taxonomy of the reviewed papers. Finally, the last section provides the conclusions and directions for future research.

REVIEW METHODOLOGY

The literature search is carried out with scientific-technical bibliographic databases which include publishing portals like Science Direct, Springer & Kluwer, Elsevier, Taylor & Francis, Wiley. Additionally, internet sources are used. The following search criteria are applied: Production and distribution planning in supply chains, production and transport planning in supply chains, production, distribution, and inventory planning in supply chains, supply chain optimization methods, multi-objective programming of production and distribution planning, integrated supply chains.

77 references were collected for the study with the years between 1993 and 2016. References are categorized into 3 groups: According to decision levels, according to their topics, according to optimization models used.

These references were obtained from journals (98.7%) and congresses (1.30%). Table 1 shows distribution of references according to journals and impact factor of journals.

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Table 1. Distribution of References According to Journals

Journal	Impact Factor	References	% Total
International Journal of Production Research	2.325	8	10,39%
European Journal of Operational Research	3.297	6	7,79%
Transportation Science	3.275	2	2,60%
Computers & Operations Research	2.600	9	11,69%
Computers & Industrial Engineering	2.623	8	10,39%
International Journal of Production Economics	3.493	5	6,49%
Journal of Heuristics	1.807	1	1,30%
Production Planning & Control	2.369	2	2,60%
Journal of the Operational Research Society	1.077	2	2,60%
International Journal of Operations & Production Management	3.339	1	1,30%
IIE Transactions	1.451	2	2,60%
Interfaces	0.579	2	2,60%
Annals of Operations Research	1.709	1	1,30%
Computers & Chemical Engineering	3.024	3	3,90%
Applied Mathematical Modelling	2.35	2	2,60%
Industrial and Engineering Chemistry Research	2.843	1	1,30%
International Journal of Advanced Manufacturing Technology	2.209	2	2,60%
Omega	4.029	4	5,19%
International Journal of Computer Integrated Manufacturing	1.949	1	1,30%
Applied Mathematics and Computation	1.738	1	1,30%
Transportation Research Part E: Logistics and Transportation Review	2.974	1	1,30%
Chinese Journal of Chemical Engineering	1.174	2	2,60%
Advances in Engineering Software	3	1	1,30%
International Transactions In Operational Research	1.745	1	1,30%
International Journal of Physical Distribution & Logistics Management	2.577	1	1,30%
Fuzzy Sets and Systems	2.718	1	1,30%
AICHE Journal	2.836	1	1,30%
International Journal of Systems Science	2.285	1	1,30%
Journal of Scheduling	1.281	1	1,30%
Journal of Purchasing and Supply Management	3.24	1	1,30%
International Journal of Management Science and Engineering Management	1.78	1	1,30%
Expert Systems with Applications	3.928	1	1,30%
Journal of Cleaner Production	5.715	1	1,30%
Total		**77**	**100,00%**

TAXONOMY

In this section 77 reviewed works are categorized according to decision levels, supply chain optimization topics and optimization models.

Huang et al. (2003) proposed four classification criteria as: supply chain structure, decision level, modeling approach and shared information. In this paper, Huang's taxonomy is used as a reference. Decision level and modeling approach are used between of them. And in addition to them, supply chain optimization topic and objective are used. So four classification criteria are proposed: Decision level, supply chain optimization topic and supply chain optimization model and objective. Supply chain structure and shared information criteria will use in future study.

These criteria are briefly described below:

Decision level: Decisions in a supply chain can be divided into three hierarchical levels. These levels are strategical, tactical and operational.

Supply chain optimization topic: These topics are related with supply chain operations, and required in making strategical, tactical and operational decisions. Some of them are: Supply chain network design, facility/depot location, supply planning, production planning/scheduling, inventory planning, capacity planning, lot sizing, and supplier/carrier selection.

Optimization model: Optimization models are used to operate supply chain operations and cost, effectively. They can solve supply chain complex problems. Some of them are: Linear programming, mix integer programming, multi objective linear programming, multi objective mix integer programming, fuzzy mathematical programming, stochastic programming, heuristics and hybrid models.
Objective: Objectives are specific. They serve as the basis for evaluating performance. Some examples of objectives include minimizing costs, maximization benefits, maximization customer satisfaction. They are defined in the optimization model.

Review of The Works According to "Decisions Levels"

Decision levels are mainly classified by the extent or effect of the decision to be made in terms of time [2].
Strategical decisions consist of long term plans about 5 years or longer. These decisions are about determination of supply chain design and strategies. Selecting production, storage and distribution locations can be given as examples.
Tactical decisions consist of medium term plans about annually or monthly. These decisions are about supply chain planning. Purchasing decisions, inventory planning, procurement planning, demand forecasting, production and distribution planning, assigning production and transport capacities can be given as examples.
Tactical planning in a supply chain incorporates the synchronized planning of procurement, production, distribution and sale activities, in order to ensure that the customer demand is satisfied by the right product at the right time [3].
Operational decisions consist of short term plans about daily or hours. Scheduling of production, determination of distribution routing, scheduling of vehicle loading, scheduling of deliveries can be given as examples.
The reviewed works according to decision levels are categorized into 3 levels: Strategical, tactical and operational.
Table 2, classifies the works reviewed in terms of the decision level.

Table 2 "Planning/Decision Level" of Reviewed Works

Article	Strategical	Tactical	Operational
[4]		x	
[5]		x	
[6]		x	
[7]		x	
[8]		x	
[9]			x
[10]			x
[11]	x		x
[12]	x		x
[13]	x	x	
[14]		x	
[15]		x	
[16]	x	x	
[17]		x	
[18]	x	x	
[19]		x	
[20]		x	
[21]		x	
[22]		x	
[23]		x	x
[24]			x
[25]		x	
[26]		x	
[27]		x	x
[28]		x	
[29]		x	
[30]		x	
[31]		x	
[32]		x	
[33]		x	
[34]		x	
[35]		x	
[36]		x	
[37]		x	
[38]		x	

[39]		x	
[40]		x	
[41]		x	
[42]		x	
[43]		x	
[44]		x	
[45]		x	
[46]	x		
[47]		x	
[48]		x	
[49]		x	
[50]		x	
[39]		x	x
[51]		x	
[52]	x	x	
[53]		x	
[54]	x		
[55]		x	
[56]			x
[57]	x		
[58]	x		
[59]		x	x
[60]	x	x	
[61]		x	
[62]		x	x
[61]		x	
[63]		x	
[64]		x	
[65]	x		
[66]		x	x
[67]	x		
[68]		x	
[69]		x	
[70]		x	
[71]		x	
[72]	x	x	
[73]			x
[74]		x	
[75]		x	
[76]		x	
[77]		x	
[78]	x		

In Table 3, the numbers of reviewed works according to decisions levels are shown. Table 3 indicates that Tactical Planning is the most studied planning/decision level.

Table 3 Number of Reviewed Works According to "Planning/Decision Level"

Planning/Decision Level	**Number of Reviewed Works**
Strategical	7
Tactical	52
Operational	4
Strategical-Tactical	6
Strategical-Operational	2
Tactical-Operational	6
Total	**77**

Review of The Works According to "Supply Chain Optimization Topics"

In this section, the categorization of reviewed works is presented according to supply chain optimization topics. Reviewed works show that integrated topics are trend for studying, so most of the work does not only study one topic like production planning, they are working about more than one topic like integration of production and distribution planning. And it is also dedicated from reviewed works that Production Planning/Scheduling and Distribution/Routing Planning are the most studied integrated topic.

Table 4, classifies the works reviewed according to supply chain optimization topics.

Table 4 "Supply Chain Optimization Topics" of Reviewed Works

Article	Supply Chain Network Design	Facility/ Depot Location	Supply Planning	Production Planning/ Scheduling	Distribution / Routing Planning	Inventory Planning	Capacity Planning	Lot Sizing	Supplier/ Carrier Selection
[4]					x	x			
[5]				x	x	x			
[6]				x	x				
[7]				x	x				
[8]				x					
[9]				x	x	x			
[10]					x				
[11]				x	x	x			
[12]	x			x					
[13]	x			x	x				
[14]							x		
[15]				x	x				
[16]	x			x	x				
[17]				x					
[18]		x			x	x			
[19]				x	x				
[20]				x	x				
[21]				x	x	x			
[22]				x	x				
[23]			x	x	x	x			
[24]					x	x			
[25]				x	x				
[26]				x	x				
[27]			x	x	x				
[28]				x	x				
[29]				x	x				
[30]				x	x				
[31]				x	x				
[32]			x						
[33]				x					
[34]				x	x				
[35]				x	x	x			
[36]				x	x				
[37]				x	x				
[38]				x	x				
[39]				x	x				
[40]				x	x				
[41]				x					
[42]				x	x				
[43]				x	x	x			
[44]				x	x	x			
[45]				x	x				
[46]	x								
[47]				x	x				
[48]				x	x	x			
[49]				x	x				
[50]				x	x				
[39]				x	x				
[51]				x					
[52]			x	x					
[53]			x						
[54]	x								
[55]				x	x				
[56]				x	x				
[57]	x								
[58]		x							
[59]				x	x		x		
[60]								x	x
[61]				x					
[62]				x	x				
[79]					x				
[63]				x	x		x		
[64]				x	x				
[65]	x			x	x	x			
[66]	x			x	x				

[67]	x								
[68]			x		x				
[69]			x		x				
[70]			x	x	x				
[71]				x					
[72]	x								
[73]				x					
[74]					x				
[75]			x	x	x				
[76]			x	x	x				
[77]				x				x	
[78]	x								

Table 5 shows that Production Planning/Scheduling- Distribution/Routing Planning is the most studied integrated topic. And following this, the other integrated topic is Production Planning /Scheduling-Distribution/Routing Planning-Inventory Planning.

Table 5 Number of Reviewed Works According to "Supply Chain Optimization Topic"

Supply Chain Optimization Topic	**Number of Reviewed Works**
Supply Chain Network Design	6
Facility/Depot Location	1
Supply Planning	2
Production Planning/Scheduling	8
Distribution/Routing Planning	3
Capacity Planning	1
Lot Sizing-Supplier/Carrier Selection	1
Production Planning/Scheduling- Distribution/Routing Planning-Inventory Planning	9
Production Planning/Scheduling-Lotsizing	1
Supply Planning-Production Planning/Scheduling- Distribution/Routing Planning-Inventory Planning	1
Supply Planning-Production Planning/Scheduling- Distribution/Routing Planning	4
Supply Planning-Production Planning/Scheduling	1
Supply Planning- Distribution/Routing Planning	2
Production Planning/Scheduling- Distribution/Routing Planning	27
Supply Chain Network Design-Production Planning/Scheduling- Distribution/Routing Planning	3
Supply Chain Network Design-Production Planning/Scheduling	1
Supply Chain Network Design-Production Planning/Scheduling- Distribution/Routing Planning-Inventory Planning	1
Production Planning/Scheduling- Distribution/Routing Planning-Capacity Planning	2
Distribution/Routing Planning-Inventory Planning	2
Facility/Depot Location-Distribution/Routing Planning-Inventory Planning	1
Total	**77**

Review of The Works According to "Optimization Models"

Optimization models are used to operate supply chain processes effectively. These models can handle complexity of supply chain. There are many optimization models used in supply chain processes. In this review, the optimization models are limited considering optimization models used in reviewed works. These are linear programming (LP), mixed integer programming (MIP), multi objective linear programming (MOLP), multi objective mixed integer programming (MOMIP), fuzzy mathematical programming (FMP), stochastic programming (SP), and heuristics (HEU).

Table 6, classifies the works reviewed according to optimization models.

Table 6 "Optimization Models" of Reviewed Works.

Article	LP	MIP	MOLP	MOMIP	FMP	SP	HEU	Heuristic name
[4]							x	Decomposition
[5]	x						x	Decomposition
[6]							x	Lagrangian relaxation
[7]	x							
[8]		x						
[9]							x	Lagrange Relaxation
[10]							x	Ant colony system -Tabu search
[11]		x						
[12]				x			x	Multi Objective Mixed-Integer Prog. (MOMIP) based Heuristic
[13]							x	Lagrangian relaxation
[14]							x	Lagrangian relaxation
[15]					x			
[16]							x	Lagrangian relaxation and genetic algorithm
[17]						x		
[18]							x	iterative heuristic approach
[19]	x							
[20]							x	Decomposition approach
[21]		x					x	Mixed-integer Prog. based Decomposition approach
[22]	x							
[23]			x				x	Multi-objective linear prog.(MOLP) based Heuristic algorithm
[24]							x	Lagrangian relaxation
[25]			x					
[26]		x					x	Mixed integer prog. (MIP) based local improvement procedure
[27]			x					
[28]	x							
[29]					x			
[30]							x	A greedy randomized adaptive search procedure (GRASP)
[31]					x			
[32]	x							
[33]				x	x			
[34]							x	Decomposition Approach
[35]		x					x	Tabu Search and Lagrangian Relaxation
[36]							x	Branch-and-price
[37]			x				x	Mixed integer linear prog. (MILP) and genetic algorithm
[38]							x	Memetic algorithm
[39]		x					x	Mixed-integer prog. based heuristic algorithm
[40]		x					x	Mixed-integer prog. based heuristic algorithm
[41]			x					
[42]							x	Hybrid mathematical-simulation model
[43]		x					x	Mixed-integer linear prog. (MIP) based branch and price heuristic algorithm
[44]							x	Tabu search heuristic algorithm
[45]		x					x	Mixed-integer linear prog. (MIP) based iterative heuristic algorithm iterative heuristic algorithm
[46]		x						
[47]							x	Hybrid simulation–analytic heuristic approach
[48]							x	Meta-heuristics Genetic Algorithm Simulated Annealing
[49]		x						
[50]							x	Tabu search algorithm
[39]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[51]		x						
[52]							x	The Savings Algorithm Clarke in combination with a 2-opt improvement heuristic
[53]				x				

[54]							x	Lagrangian based heuristic algorithm
[55]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[56]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[57]							x	Lagrangian relaxation heuristic
[58]							x	Lagrangian relaxation heuristic
[59]			x				x	Multi-objective Linear Prog. (MOLP) based heuristic
[60]				x				
[61]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[62]							x	Lagrangean andGenetic algorithm
[79]				x				
[63]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[64]							x	Adaptive large neighborhood search algorithm
[65]			x					
[66]							x	Lagrangian decomposition
[67]			x					
[68]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[69]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[70]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[71]		x					x	Mixed-integer linear prog. (MIP) based heuristic algorithm
[72]				x				
[73]							x	Lagrangian decomposition
[74]							x	Lagrangean based heuristic
[75]							x	Cluster decomposition algorithm
[76]							x	Lagrangean heuristic
[77]							x	Lagrangian heuristic
[78]							x	Lagrangian relaxation and Surrogate sub-gradient algorithm

Table 7 shows number of reviewed works according to optimization methods. It can be inferred from that heuristics is the most studied optimization method.

Table 7 The Number of Reviewed Works According to "Optimization Methods"

Optimization Method	Number of Reviewed Works
LP	5
MIP	5
MOLP	5
MOMIP	4
FMP	3
SP	1
MOMIP-FMP	1
HEU	53
Total	**77**

Review of The Works According to "Objective/s"

Objective/s are decided before solving optimization models. All the developed models consider minimization or maximization objective or a combination of both. In this review, objective/s are limited considering objective/s used in reviewed works. These are maximization product rate (MPR), maximization revenues (MR), maximization benefits (MB), minimization costs(MC), maximization service level(MSL), maximization customer satisfaction (MCS), minimization environmental impact(MEI).

Table 8, classifies the works reviewed according to objective/s.

Table 8 "Objective/s" of Reviewed Works**.**

Article	Max Production Rate (MPR)	Max Revenues (MR)	Max Benefit(MB)	Min Cost(MC)	Max Service Level (MSL)/ Max Customer Satisfaction	Min Enviromental Impact
[4]	x					
[5]			x			
[6]				x		

[7]			x			
[8]			x			
[9]				x		
[10]				x		
[11]		x	x			
[12]				x		
[13]				x		
[14]					x	
[15]				x		
[16]				x		
[17]				x		
[18]				x		
[19]				x		
[20]				x		
[21]				x		
[22]			x			
[23]				x		
[24]				x		
[25]				x		
[26]		x				
[27]				x		
[28]				x		
[29]				x		
[30]				x		
[31]			x	x	x	
[32]			x			
[33]				x	x	
[34]				x		
[35]				x		
[36]			x			
[37]				x		
[38]				x		
[39]		x				
[40]				x		
[41]		x	x	x		
[42]				x		
[43]				x		
[44]				x		
[45]				x		
[46]				x		
[47]				x		
[48]				x		
[49]				x		
[50]				x		
[51]				x	x	
[52]				x		
[53]		x		x		
[54]				x		
[55]				x		
[56]			x			
[57]				x		
[58]				x		
[59]				x	x	
[60]				x		
[61]				x		
[62]				x		
[79]				x	x	
[63]				x	x	x

[64]				x		
[65]				x		
[66]				x		
[67]				x		
[68]				x		
[69]				x		
[70]				x		
[71]				x		
[72]		x		x		
[73]				x		
[74]				x	x	
[75]						
[76]		x				
[77]				x		
[78]		x				

Table 9 shows number of reviewed works according to objective/s. It can be inferred from that minimization costs is the most studied objective function in optimization models.

Table 9 The Number of Reviewed Works According to "Objective/s"

Objective/s	Number of Reviewed Works
Max Production Rate (MPR)	1
Max Revenues (MR)	8
Max Benefit (MB)	10
Min Cost(MC)	49
Max Service Level (MSL)/Max Customer Satisfaction	8
Min Enviromental Impact	1
Total	**77**

Table 10 shows number of reviewed works according to multiple/single objective/s. It can be inferred from single objective is the most studied.

Table 10 The Number of Reviewed Works According to "Multiple/Single Objective/s"

Multiple/Single	Number of Reviewed Works
Multiple	11
Single	66

CONCLUSIONS AND FURTHER RESEARCH

This paper presents a review of optimization studies about supply chain planning. A total of 77 reviewed works published between 1993 and 2016 are used as references.

Huang et al. (2003) proposed four classification criteria: supply chain structure, decision level, modeling approach and shared information. Huang's taxonomy is used as a reference here, and two classification criteria are selected from classification criteria proposed by Huang et al. (2003). And new classification criteria are added to them. And finally we proposed four classification criteria: decision level, supply chain optimization topic, supply chain optimization model and objective/s.

This paper's purpose is to provide general overview of supply chain optimization works and directions for future research. It can be starting point for researchers. They can see which supply chain topics are popular for working, and which decision/planning level are mostly studied and which optimization method is the most preferred, and which objective/s is/are mostly studied. It would be useful for them to see supply chain topics that weren't studied more.

The conclusions drawn from this work show that:

(1) 7 of 77 works reviewed are about strategical decisions, 53 of them are about tactical decisions, 3 of them are about operational decisions, 6 of them are about both strategical and tactical decisions, 2 of them are both strategical and operational decisions, and six of them are about both tactical and operational. We can infer from that most of the works reviewed are interested in tactical decisions.

(2) Majority of reviewed works are about integrated planning. The most popular topic is integrated production planning and distribution planning or production scheduling and routing planning. 28 of 77 reviewed works are about this topic. Today most of the studies are focused on real supply chain cases. So it can be the reason for why production planning and distribution planning or production scheduling and routing planning is the most popular topic.
(3) The most preferred optimization method is heuristics; 53 of 77 works reviewed use heuristics. In real supply chains, the product types are changing, the number of customers and the number of members like suppliers, distribution centers, and depots are increasing. Developing a supply chain model that considers production, distribution and inventory planning becomes complicated, and this complexity can't be solved by classical optimization methods in a short time. So, heuristics are widely used to overcome this complexity and provide solutions within a reasonable time.
(4) The most studied objective is minimizing costs; 49 of 77 works reviewed use minimization costs in objective function. And 66 of 77 works reviewed use single objective in optimization model. In real business world single objective is not sufficient to firm success, there are conflicting objectives so multiple objectives are considered together.
After this review, following future directions can be proposed:
In further studies, supply chain structure, supply chain cost (holding cost, purchase cost, production cost, etc.), and aspects relating to modeling and solving the problem: production (number of products, production capacity, set up times etc.) , inventory (safety stock available, inventory capacity etc.), routing (fleet and number of vehicles, number of visits, transport parameters like distance, time period etc.), can be added as classification criteria.
Real supply chain case studies can be analyzed and these studies can be categorized according to business branch, and other criteria.
Which heuristic methods are used mostly can be studied according to supply chain topics (production planning/scheduling, distribution/routing planning, inventory planning, procurement planning, etc.). And these heuristic methods can be compared according to their performances.
The most studied single/multiple Objective/s can be categorized according to supply chain topics (production planning/scheduling, distribution/routing planning, inventory planning, procurement planning, etc.).
Future research can focus on supply chain problems by considering multiple real-life limitations like resource constraints, capacity constraints, loading constraints etc.

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EMPLOYEES' TECHNOLOGY USAGE ADAPTATION IMPACT ON COMPANIES' LOGISTICS SERVICE PERFORMANCE

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Abstract *− In global business environment, information technology capabilities of the companies are one of the determinants of their competitive power. While technological infrastructures need high costly investments, if they are used efficiently and effectively, they will create many opportunities (such as cost minimization, reduction of failure, quick response, standardization, etc.) to companies. On the other hand, outputs of these technologies depend on employees' intention to use them. Port automation systems as information technology capabilities are very critical and widely used technological investments in container terminals. That is why the behavioral intention to use of these technologies is one of the important factors that may affect the port's logistics service performance. This study aims to analyze the employees' technology usage adaptation impact on ports' logistics service performance. In this context, behavioral intentions of employees to use port automation systems are tested by Technological Acceptance Model.*

Keywords *− Competitive Power, Logistics Service Performance, Port Automation Systems, Technology Acceptance Model*

INTRODUCTION

In today's global business environment, logistics services become an important part for gaining strategic competitive advantage. One of these logistics services is transportation and over 66% of world trade (value based) is transferring through maritime transportation [1]. According to literature, ports as an important complementary of international trade and global supply chain [2] and they are integral part of maritime transportation due to the services they provide.

Today, like other industries, competition in container port industry is more intense than before [3]. So it is needed to improve port's performance and efficiency [4] to gain competitive advantage. Considered as a competitive weapon, information technology (IT) can contribute to a firm's competitive advantage by providing cost leadership and product differentiation [5]. In global business environment, information technology capabilities of the companies are one of the determinants of their competitive power. While technological infrastructures need high costly investments, they are creating strategic opportunities to companies.

Port automation systems as information technology capabilities are very critical and widely used technological investments in container terminals. On the other hand, most of the time, the efficient and effective outputs of these technologies depend on employees' intention to use them.

This study aims to analyze the employees' technology usage adaptation impact on ports' logistics service performance. In this context, behavioral intentions of employees to use port automation systems tested by Technological Acceptance Model (TAM). A questionnaire designed and all constructs are measured with existed scales from previous literature. The relationships between all variables are tested using factor, reliability, correlation and regression analyses by SPSS 23 statistical package program.

In this context, this study is organized as fallows. After the part literature review about the main concepts of the study is given, after that methodology of the study including questionnaire design and sampling presented, and data analyses and findings are given, finally the results are discussed in conclusion.

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LITERATURE REVIEW

Due to the logistics services shift from low-value basic to high value-added services, IT has the greatest impact on the way of minimizing risks, standardizing processes and reducing uncertainty [6], whereas it depends on employees' intention to use IT.

Information Technology Capabilities (ITC)

Capability is an ability to accomplish organizational goals in a competitive environment [7]. In a research-based view, IT is a capability for companies that can provide competitive advantage [8, 9] and if a company combine IT related resources to a unique IT capability, it can create competitive power [10]. IT investments add value to companies by improving organizational efficiency and effectiveness [11]. According to literature, ITC has three dimensions; IT Infrastructure (ITCI), IT Qualifications (ITQ), and IT Operations (ITO) [12, 13, 14, 15, 16, 17].

Technology Acceptance Model

Information technology plays a critical role in a company performance, but without users, it will not enough for competitiveness. For that reason individual's behavioral intention to use a system measured by many researchers and models developed [18, 19, 20, 21, 22]. One of these models is TAM, which is created by Davis in 1989. According to this model "Perceived Usefulness (PU)", and "Perceived Ease of Use (PEOU)" are two parts of individual behavioral intention to use a technology [20].

PU is the degree to which a person believes that using a particular system would enhance his/her job performance, and PEOU is the degree to which a person believes that using a particular system would be free of effort [20].

METHODOLOGY

Conceptual Framework

The main focus of our empirical study is to evaluate the the effects of port automation systems' capabilities on logistics service performance. In this context, behavioral intentions of employees to use port automation systems are tested by Technological Acceptance Model (TAM). In this connection, the hypotheses which we use in our study are improved by scientific paradigms and we construct a model that explains the relationship between TAM, ITC, and LSP (Figure 1), with support of the modern literature, these hypotheses are expanded:

- H1: There is a positive, significant and direct relationship between TAM and ITC
    - H1aa: There is a positive, significant and direct relationship between PU and ITCI
    - H1ab: There is a positive, significant and direct relationship between PU and ITQ
    - H1ac: There is a positive, significant and direct relationship between PU and ITO
    - H1ba: There is a positive, significant and direct relationship between PEOU and ITCI
    - H1bb: There is a positive, significant and direct relationship between PEOU and ITQ
    - H1bc: There is a positive, significant and direct relationship between PEOU and ITO
- H2: There is a positive, significant and direct relationship between ITI and ITC
    - H2a: There is a positive, significant and direct relationship between ITI and ITCI
    - H2b: There is a positive, significant and direct relationship between ITI and ITQ
    - H2c: There is a positive, significant and direct relationship between ITI and ITO
- H3: There is a positive, significant and direct relationship between TAM and ITI
    - H3a: There is a positive, significant and direct relationship between PU and ITI
    - H3b: There is a positive, significant and direct relationship between PEOU and ITI
- H4: There is a positive, significant and direct relationship between ITC and LSP
    - H4a: There is a positive, significant and direct relationship between ITCI and LSP
    - H4b: There is a positive, significant and direct relationship between ITQ and LSP
    - H4c: There is a positive, significant and direct relationship between ITO and LSP
- H5: There is a positive, significant and direct relationship between TAM and LSP
    - H5a: There is a positive, significant and direct relationship between PU and LSP
    - H5b: There is a positive, significant and direct relationship between PEOU and LSP

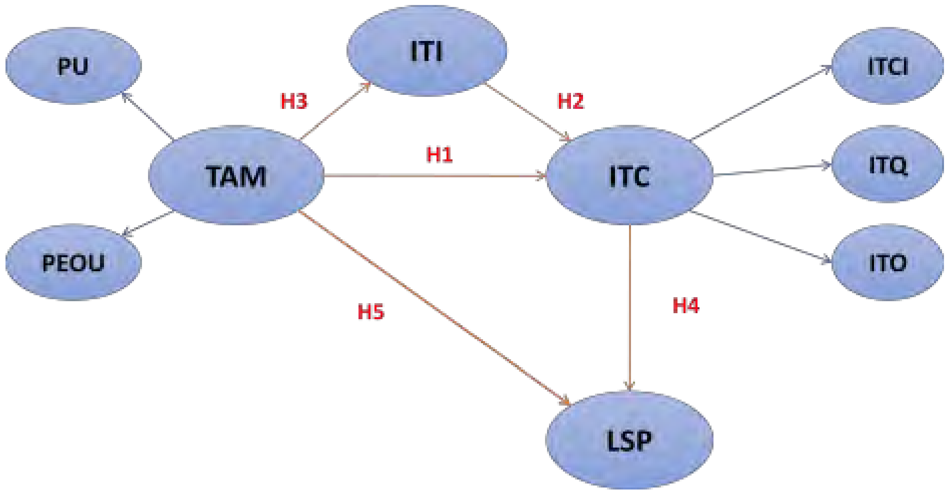

Figure 1. Research Model

Questionnaire Design

All constructs are measured with existed scales from previous literature and adapted for port industry. The first of these scales is Technology Acceptance Model (TAM), and questionnaire is taken from recent studies [20, 23, 24, 25, 26, 27]. Second one is Information Technology Investments (ITI), and questionnaire are taken from recent studies [28, 29]. The other scale is Information Technology Capability (ITC) and questionnaire is taken from recent studies [12, 13, 14, 15, 16, 17]. At last, Logistics Service Performance questionnaire taken from recent studies [30, 31, 32, 33, 34, 35].

Sampling and Data Collecting

To perform the analyses valid data are collected from Turkish Container Terminals' employees. Total 62 questionnaires have returned among over 11 ports. The descriptive statistics of the respondents are shown in Table 1. All items are measured on 5 point Likert type scale (1= strongly disagree and 5= strongly agree). The relationships between all variables are tested using factor, reliability, correlation and regression analyses by SPSS 23 statistical package program.

Table 1. Descriptive Statistics of the Sample

Hierarchical Status	Frequency	Percent
Owner/ Shareholder	1	1.61%
Top Level Man.	2	3.23%
Middle Level Man.	15	24.19%
Bottom Level Man.	9	14.52%
Office Employee	12	19.35%
Fieldworker	23	37.10%
TOTAL	62	100%

Working Year	Current Company		Total	
	Frequency	Percent	Frequency	Percent
1-4	28	45.16%	10	16.13%
5-10	18	29.03%	18	29.03%
11-19	13	20.97%	26	41.94%
20 >	3	4.84%	8	12.90%
TOTAL	62	100%	62	100%

Education	Frequency	Percent
Primary School	3	4.84%
High School	13	20.97%
Vocational School	10	16.13%
Graduate	23	37.10%
Master/ PhD	13	20.97%
TOTAL	62	100%

Department	Frequency	Percent
Operation	29	46.77%
IT	3	4.84%
Sales and Marketing	7	11.29%
Administrative Services	7	11.29%
OTHERS	16	25.81%
TOTAL	62	100%

Data Analyses and Findings

In this study, all items and components are tested by comprehensive reliability analyses. Overall scale reliability test coefficient has been determined α= 0.790; this value is over the recommended 0,70 threshold [35, 36], and in correlation matrix , PEOU has not a strength mutual relationship between each other, so this item removed, and after that reliability test made again and coefficient has been determined α= 0.840; this value is quite over the recommended 0.70 threshold. After removing PEOU, results of correlation analysis reveals that all constructs which differed from each other as a factor are also correlated each other positively and significantly.

Table 2. Correlation Matrix

	PU	ITCI	ITQ	ITO	ITI	LSP
PU	1					
ITCI	,409**	1				
ITQ	,529**	,431**	1			
ITO	.208	,413**	,540**	1		
ITI	,443**	,605**	,672**	,658**	1	
LSP	,280*	,299*	,574**	,528**	,416**	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

After correlation analysis, the linear relationships are tested through regression analysis. According the results that given in Table 3, PU has statistically significant direct positive effects on ITC dimensions of ITCI, and ITQ. On the other hand, there is no significant prove of the affects of PU on ITO.

Table 3. The Effect of TAM on ITC

D. V.: ITCI	Beta	t	Sig.	Hypotheses	Results
PU	0.409***	3.468	.001	H1aa	Support

R^2=0,166 ; F=12,023 ; p<0,001

D.V.: ITQ	Beta	t	Sig.	Hypotheses	Results
PU	0.529***	4.832	.000	H1ab	Support

R^2=0,280 ; F=23,344 ; p<0,001

D. V.: ITO	Beta	t	Sig.	Hypotheses	Results
PU	.208	1.647	.105	H1ac	No Support

R^2=0,043 ; F=2,711 ; p>0,05

According the results that given in Table 4, ITI has statistically significant direct positive effects on all ITC dimensions.

Table 4. The Effect of ITI on ITC

D.V.: ITCI	Beta	t	Sig.	Hypotheses	Results
ITI	0.605***	5.886	.000	H2a	Support

R^2=0,366 ; F=34,643 ; p<0,001

D.V.: ITQ	Beta	t	Sig.	Hypotheses	Results
ITI	0.672***	7.027	.000	H2b	Support

R^2=0,451 ; F=49,375 ; p<0,001

D.V.: ITO	Beta	t	Sig.	Hypotheses	Results
ITI	0.658***	6.776	.000	H2c	Support

R^2=0,433 ; F=45,915 ; p<0,001

According the results that given in Table 5, TAM has statistically significant direct positive effects on ITI.

Table 5. The Effect of TAM on ITI

D.V.: ITI	Beta	t	Sig.	Hypotheses	Results
PU	0.443***	3.824	.000	H3a	Support

R^2=0,195 ; F=14,624 ; p<0,001

According the results that given in Table 6, ITC dimensions of ITQ and ITO has statistically significant direct positive effects on LSP. On the other hand, there is no significant prove of the affects of ITCI on LSP.

Table 6. The Effect of ITC on LSP

D.V.: LSP	Beta	t	Sig.	Hypotheses	Results
ITCI	-.005	-.046	0.963	H4a	No Support
ITQ	0.410**	3.256	0.002	H4b	Support
ITO	0.309*	2.478	0.016	H4c	Support

R^2=0,397 ; F=12,734 ; p<0,001

According the results that given in Table 7, TAM has statistically significant direct positive effects on LSP.

Table 7. The Effect of TAM on LSP

D.V.: LSP	Beta	t	Sig.	Hypotheses	Results
PU	0.280*	2.263	.027	H5a	Support

R^2=0,0786 ; F=5,121 ; p<0,05

The results not only reveal the positive effect of information technology investments and technologic acceptance on the information technology capabilities, but also exposed the mediating role of information technology investments on this relationship.
According the regression analysis ITI has a mediating effect between TAM and ITC.

Table 8. Mediating Role of ITI

D.V.: ITCI	Beta	t	Sig.
PU	,175	1,545	,128
ITI	,528***	4,654	,000

R^2=,391 ; F=18,914 ; p<0,001

D.V.: ITQ	Beta	t	Sig.
PU	,288**	2,861	,006
ITI	,544***	5,401	,000

R^2=,518 ; F=31,737 ; p<0,001

According the regression analysis ITC has a mediating effect between TAM and LSP.

Table 9. Mediating Role of ITC

D.V.: LSP	Beta	t	Sig.
PU	,001	,005	,996
ITQ	,408*	2,903	,005
ITO	,308*	2,525	,014

R^2=,397 ; F=12.733 ; p<0,001

According to analysis final research model shown in Figure 2.

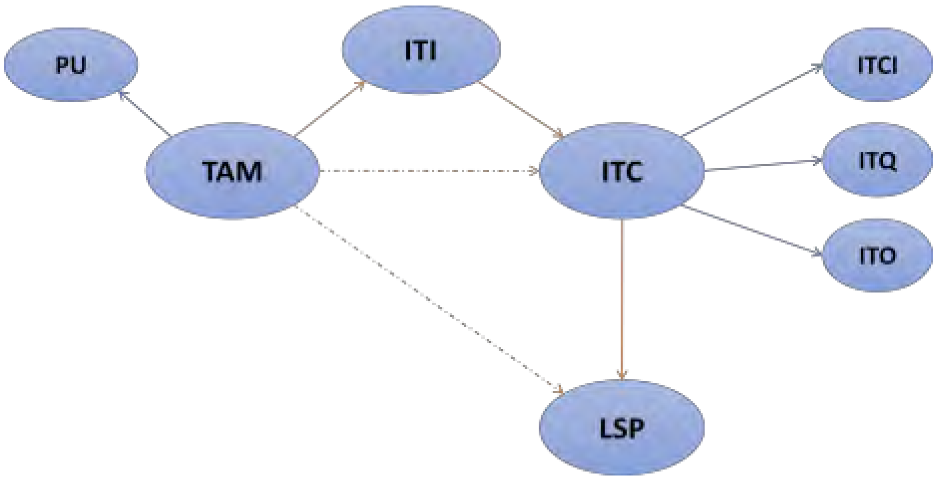

Figure 2. Final Model of the Research

CONCLUSION

This study explore the relationship between technologic acceptance, information technology capabilities and logistics service performance. Information technology capabilities and technological acceptance have a positive effect on logistics service performance. The results not only reveal the positive effect of information technology investments and technologic acceptance on the information technology capabilities, but also exposed the mediating role of information technology investments on this relationship. Information technology capabilities and technological acceptance have positive effect on logistics service performance and information technology capabilities have mediating role on this relationship. 45% of employers are totally worked less than 11 years, and according to literature new generation has more ability to information technology's usage. If information technology investments are supported by employers training, information technology capabilities and logistics service performances will be performed positively.

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COMPARISON IN THE AUTOMOTIVE SECTOR

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Abstract – *Why compare? Because, benchmarking is one of the most effective ways of achieving better. In this study, automotive export companies will be compared with each other by using data envelopment analysis method. As a result, it will be analyzed in order to clarify which companies are technically efficient and which are not. Regarding to the results of method, it will lead to inefficient automotive companies how to become fully efficient.*

Keywords *- DEA; Efficiency; Automotive industry*

INTRODUCTION

In order to determine the performance level of a company, mostly comparisons are taken into account among similar companies. The reason behind is just being aware of a company is not enough; rivals' conditions is much determinative. This is actually similar to measure of any process performance. If there is no standard for a process, its effectiveness could not be exposed. For example, delivering within a day can be perceived as a good process, but what if competitors at the same industry make a similar delivery in an hour. In this scenario, the expectations of the customers vary according to the performance of the industry and they probably will choose the one which is serving in an hour with the assumption all other conditions are same. Comparisons or benchmarking is done for detecting to how much companies reached their aims and objectives. With best practice examples, other companies get an opportunity to improve their selves. On the other hand, the owner of the best performance can keep it as their core competency. Benchmarking can be applied with different perspectives, but commonly used with the following steps [1]:

1. Determining of the best practitioners
2. Determining benchmarking targets
3. Implementation

At the selection step there is no identified criteria, but the priority is being objective. At the second step, it is considered as strategic while analyzing results, all firms could have different objectives like aiming best at operational processes, costs or customer satisfaction. “Best practice” implementation is the las step which leads to a company to improve itself. Data envelopment analysis is one of the most used method for benchmarking. Thus in this research data envelopment analysis is used for comparing automotive companies.

Table 1. List of Average Export by Sector per Company

Sector	#of firms	Total Export	Average Export per Company at the Sector
Automotive Industry	100	20.746.135.385,55	207.461.353,86
Electrical Electronics and Service	56	7.019.991.858,00	125.356.997,46
Hazelnut and Products	14	1.753.002.090,32	125.214.435,02
Defense and Aviation Industry	12	1.306.156.483,26	108.846.373,61
Tobacco	10	966.330.125,53	96.633.012,55
Steel	78	6.594.569.242,54	84.545.759,52
Chemical Materials and Products	106	7.900.030.665,92	74.528.591,19
Gem	21	1.460.981.479,97	69.570.546,67
Mining Products	25	1.521.861.779,42	60.874.471,18
Ship and Yacht	10	581.865.002,86	58.186.500,29

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Iron and Non-Ferrous Metals	41	2.104.139.586,54	51.320.477,72
Machine and Accessories	21	1.049.465.870,22	49.974.565,25
Cement Glass Ceramic and Soil Products	22	1.071.966.604,40	48.725.754,75
Grains, Pulses, Oily Seeds and Products	79	3.745.047.101,01	47.405.659,51
Furniture, Paper and Forest Products	26	1.132.092.703,13	43.542.027,04
Air Conditioning Industry	30	1.239.343.491,96	41.311.449,73
Textiles and Raw Materials	76	2.994.806.629,20	39.405.350,38
Aquaculture and Animal Products	23	897.520.108,31	39.022.613,40
Carpet	20	769.795.061,76	38.489.753,09
Dried Fruits and Products	18	608.601.704,62	33.811.205,81
Fresh Fruits and Vegetables	16	521.208.360,20	32.575.522,51
Other Industrial Products	1	31.601.765,79	31.601.765,79
Fruit and Vegetable Products	13	328.895.310,33	25.299.639,26
Leather and Leather Products	6	122.919.632,79	20.486.605,47
Olive and Olive Oil	1	20.264.909,50	20.264.909,50
Ornamental Plants and Products	1	209.370,00	209.370,00

Data collected from [2]

As seen at Table 1, automotive industry has the highest export rate at the company basis, so this paper focus on the automotive. The companies in this sector are compared with data development analysis to provide an insight. The content of the study begins with the literature review in order to examine the subject more deeply, then the DEA method will be introduced and lastly the application and results will be given.

LITERATURE REVIEW

Determination of export performance and factors that affect performance is one of important aspects of this paper. One of these studies is done by [3] At the study survey method is used and performance indicators which are statistically significant are export marketing strategies, environmental factors, firms attributes, and director characteristics. Another survey findings are firm size, having export department, experience on export, geographical location, and firm's sector [4]. A similar study is done by [5], export performance indicators are given and SWOT analysis proposed as a method for determination of export performance factors.

When the automotive sector related studies are investigated, a number of studies which considered Turkish automotive sector performance are emerge. One of them was done by TOPSIS method, five firms were included to study and compared with each other [6]. Following study is used data envelopment analysis to measure performance of Turkish automotive industry. 17 firms were included to study and Malmquist method was used to evaluate 1990-2004 period [7]. Another study on performance of automotive industry in Turkey was done with DEA, differently capital structure was used as inputs and results are evaluated in SPSS with Anova test [8]The final study on automotive sector analysis in Turkey was done with Malmquist method to the 2003-2007 years period, inputs were determined as number of workers, net assets and outputs are total export, profit before tax, and gross value added [9].

Similar studies are done at automotive sector, however inputs and outputs are determined differently and our study comprise 2016 period.

DATA ENVELOPMENT ANALYSIS

The analysis is based on linear programing, it evaluates relative efficiency or performance of the entities, or in other words decision making units (DMUs), based on their inputs and outputs [10]. Actually, it is a quantitative and analytical tool for evaluating only relative performance. Data envelopment analysis (DEA) enables us to make comparisons with even noncommensurable units [11]. Initial model was named as constant return to scale or CCR (Charnes, Cooper and Rhodes). They defined DEA as, "mathematical programming model applied to observational data provides a new way of obtaining empirical estimates of external relations- such as the production functions and/or efficient production possibility surfaces that are a cornerstone of modern economics" [12]. Later on (1984), Banker et al., developed the model and BCC (Banker, Charnes, and Cooper) or variable return to scale (VRS) model was enhanced. At this model, technical and scale inefficiencies were distinguished [13].

Moreover, DEA models are also classified as input and output oriented models. Input oriented DEA is used when outputs are fixed [14], in other words it is used when the decision maker has no control on outputs, but has control on inputs. At private sector usually input oriented models are preferred, since inputs like number of employee or other assets can be controlled easily. Output oriented models are used when inputs cannot be controlled with the same logic. Since public utilities has limited control on inputs, output oriented model is commonly used at this kind of institutions.

FINDINGS AND DISCUSSIONS

Determination of DMUs is the first step of DEA applications. As seen in Table 1, 100 automotive firms are in the leading companies in export, however 21 of them were hidden their name from the list and most of them are not willing to share their information such as total equity and total assets. Eventually, only ten of leading companies in export at automotive sector included in this research. The selected inputs and outputs are given below:

- Inputs are number of workers, total equity, total assets
- Outputs are automotive export, domestic sales

These inputs and outputs are selected according to literature review and shown in Table 2 with related statistics information.

Table 3. Effectiveness of the automotive companies at 2016

DMU	Constant Return to Scale	Variable Return to Scale	Scale Efficiency	Return to Scale	Summary of Peers
1	0.538	1	0.538	Decrease	2
2	0.462	0.863	0.535	Decrease	0
3	1	1	1	-	**5**
4	0.378	0.397	0.952	Decrease	0
5	1	1	1	-	4
6	0.556	0.622	0.894	Increase	0
7	1	1	1	-	2
8	0.612	.0.670	0.914	Increase	0
9	0.145	0.332	0.437	Increase	0
10	1	1	1	-	1
Mean	0.669	0.788	0.827		

At Table 3. CRS and VRS results are given. According to CRS, 4 companies are found fully affective and according to VRS results 5 companies are operating with fully effective capacity. Scale efficiency is a ratio which shows the relationship between CRS and VRS. Increasing return to scale indicator means that technical efficiency will increase accordingly and when it is a decreasing return to scale then with an increase in scale of the DMU reflects as a decrease in technical efficiency. When the DMUs' situation is considered, DMU 6., 8. And 9. Get more increase in output rather than the input they had used, whereas DMU 1.,2., and 4. Get less output than the input they had used. DMU 3, which is Mercedes-Benz Türk A.Ş., is the most referenced firm in the list. This firm is taken as reference 5 times. Other companies which are fully efficient and taken as reference are DMU 5, DMU 1, DMU7 and DMU10, 4,2,2 and 1 time(s) respectively. At Table 4 detailed reference set is given. This table also shows which DMU is a reference with what rate in detail. Since DMU 1,3,5,7, and 10 are fully effective, their reference is showed as they are.

Table 4. Reference set of Automotive Companies

DMU	DMUs which should be imitated and its peer rate		
1	DMU 1		
2	DMU 5 (0.194)	DMU 3 (0.003)	DMU 1 (0,803)
3	DMU 3		
4	DMU 1 (0.003)	DMU 3(0,070)	DMU 5 (0.927)
5	DMU 5		
6	DMU 3 (0.159)	DMU 7 (0.841)	
7	DMU 7		
8	DMU 3 (0.077)	DMU 5 (0.817)	DMU 10 (0.106)
9	DMU 3 (0.004)	DMU 7 (0.008)	DMU 5 (0.987)
10	DMU 10		

Table 2. Summary of inputs and outputs

		OUTPUTS			INPUTS	
DMU	**Firms**	**Automotive Export**	**Domestic Sales**	**# of Workers**	**Total Equity**	**Total Assets**
1	Ford Otomotiv San. A.Ş.	3.909.433.937,37	6.002.043.021,00	10.261,00	3.163.619.311	9.286.152.113,00
2	Tofaş Türk Otomobil Fab. A.Ş.	3.178.552.540,91	4.845.821.468,00	9.624,00	2.957.451.000	11.829.708.000,00
3	Mercedes-Benz Türk A.Ş.	951.236.355,71	8.140.327.859,95	6.146,00	726.642.000	3.608.871.000,00
4	Goodyear Lastikleri T.A.Ş.	247.480.928,65	597.359.855,00	1.741,00	455.536.076	807.940.670,00
5	Federal Mogul Diş Tic.A.Ş.	183.939.978,05	12.028.356,98	67,00	39.894.193	46.690.325,00
6	Brisa Bridgestone Sab. Las. San. Ve Tic.A.Ş.	169.329.406,82	1.292.178.348,44	2.611,00	213.297.239	2.836.268.145
7	Tirsan Treyler San. Ve Tic. A.Ş.	118.880.554,63	0,00	548,00	20.530.000	82.106.000,00
8	Anadolu Isuzu Otom.San.Ve Tic. A.Ş	55.062.586,66	666.912.808,00	815,00	262.464.571	885.066.797
9	Jantsa Jant Sanayi Ve Tic.A.Ş.	33.556.024,86	47.287.492,00	601,00	128.550.848	187.977.227
10	Karsan Otomotiv San. Ve Tic.Aş	20.361.238,54	281.010.520,30	167,00	320.281.434	2.603.313.027,00
	Average	886.783.355,22	2.188.496.972,97	3.258,10	828.826.667,20	3.217.409.330,40
	Minimum	20.361.238,54	0,00	67,00	20.530.000,00	46.690.325,00
	Maximum	3.909.433.937,37	8.140.327.859,95	10.261,00	3.163.619.311,00	11.829.708.000,00
	Standart Deviation	1436443587	2989406070	3954,423218	1195198298	4109384358

Table 2. Expected Outputs According to VRS Output Oriented Analysis

DMU	Real Output: Total Export (*1000)	Expected Amount to Be Fully Effective (*1000)	Percentage Change	Real Output: Domestic Sales	Expected Amount to Be Fully Effective	Percentage Change
1	3909433	3909433	0	6002043	6002043	0
2	3178552	3178552	0	4845821	4845821	0
3	951236	951236	0	8140327	8140327	0
4	247480	247480	0	597359	597359	0
5	183939	183939	0	12028	12028	0
6	169329	251006	1,482356832	1292178	1292178	0
7	118880	118880	0	0	0	0
8	55062	225668	4,098434492	666912	666912	0
9	33556	186746	5,565204434	47287	47287	0
10	20361	20361	0	281010	281010	0

Table 5. summarizes the situation of outputs of automotive firms. Real outputs are given firstly and the amounts and then in the side column the expected amounts are given which are calculated by VRS model. With the current inputs all automotive firms are found effective at domestic sales. However, DMU 6, 8, and 10 needs to increase their total export amount to become fully efficient.

Table 3. Expected Input Amounts with VRS

DMU	Real Input: number of employees	Expected Amount to Be Fully Effective	Percentage Change	Real Input: Total Equity (*1000)	Expected Amount to Be Fully Effective (*1000)	Percentage Change
1	10261	10261	0	3163619	3163619	0
2	9624	8272	0,140482128	2957451	2550914	0,137461956
3	6146	6145	0,000162707	726642	726642	0
4	1741	520	0,70132108	455536	96212	0,78879386
5	67	67	0	39894	39894	0
6	2611	1437	0,449636155	213297	132616	0,378256609
7	548	548	0	20530	20530	0
8	815	546	0,33006135	262464	122617	0,532823549
9	601	97	0,838602329	128550	42723	0,667654609
10	167	167	0	320281	320281	0

DMU	Real Input: Total Assets	Expected Amount to Be Fully Effective (*1000)	Percentage Change
1	9286152	9286152	0
2	11829708	7478074	0,367856417
3	3608871	3608871	0
4	807940	320553	0,603246528
5	46690	46690	0
6	2836268	641937	0,773668426
7	82106	82106	0
8	885066	592962	0,330036404
9	187977	62474	0,66765083
10	2603313	2603313	0

Table 6. shows the inputs of the related DMUs and their expected amount to be fully technical efficient with their current output amount. DMU 2,3,4,6,8 and 9 need to decrease their number of employees. The 9th DMU has the highest number of employees in percentage. The firm needs to decrease 601 employees to 97. DMU 2,4,6,8 and 9 need to decrease total equity to become fully effective. Again the 4th DMU has the most excessive amount of total equity. They need to decrease it by the amount of 359,324,000. Finally, when the total assets are examined, DMU 2,4,6,8 and 9 needs to decrease their total assets. DMU 6 has the highest excessive amount of total assets with percentage 0.77. When these companies decrease their inputs at these stated rates, they also would become fully effective.

CONCLUSION

Export is an important factor for companies and in fact it's even more important for the economy. Accordingly, the development of export-oriented companies is essential. The automotive sector, one of the sectors where Turkey exports most, has been studied in this study. Comparisons have been made to find out areas where companies are imperfect. In order to achieve this aim, data envelopment analysis has been used. Half of the participating firms were found to be fully effective and for the remaining firms it has been tried to show in which areas they need to develop themselves. By means of the method, inputs and outputs that are not used effectively are identified and administrative decision-making is supported. Thus, companies will be able to take their future decisions according to this information and become one of fully active firms. However, the study has been limited in terms of data sharing due to the sensitivity of firms. For the future studies, if this problem is overcome, the size of the work can be expanded by including companies with similar country economies, in addition to the comparisons to be made between firms themselves.

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DETERMINING THE PERFORMANCE CRITERIA FOR WAREHOUSE AND THEIR IMPORTANCE SEQUENCE

Irmak Daldır[1], Ömür Tosun[2]

Abstract – *Every firm, even nonprofit ones, desire to perform well, but how? Most of the firms allocate a high amount of budget to manage warehouses and evaluating their performance is not easy if the measurement criteria are not properly determined and measured. In this study, warehouse performance criteria are selected from a literature survey and expert opinions. Afterwards, warehouse performance indicators are analyzed with Analytic Hierarchy Process and by the help of it their importance weight and ranking will be specified.*

Keywords – *AHP, Criteria Determination, Performance, Warehouse*

INTRODUCTION

In business logistic is an area which they can differ themselves among rivals. Today, at most of firms all logistic processes are monitored thoroughly. Warehousing is one of these processes and has very important impact on firm's profitability. For SMES (small and medium enterprises), transportation has the highest impact on logistic costs with 50-65%, and then warehousing and handling costs with 20-35%, managerial costs with 10%, and finally forecasting, ordering, and production planning with 5% [1]. Some business types and their cost of sales turnover is shown in Table 1. The table gives clue about the warehouse costs according to business types. For example, when it is an office equipment sector, nearly 10% of its sale price is its warehouse cost, but it is much less when it is a computer supply sectozelr. Of course, dimensions of a product and easier storage conditions are important. However, more importantly, warehouse costs have a place in total costs. In order to reduce the costs of these processes and become more efficient than rivals' businesses firms must measure the performance of their warehousing activities.

Table 1. Warehouse Cost as percentage of Sales Turnover

Cost as Percentage of Sales Turnover Main Company Business	Warehouse/depot Cost %
Office Equipment	10,70
Health Supplies	9,77
Soft Drinks	2,71
Cement	9,10
Automotive Parts	6,35
Gas Supply (non-bulk)	2,45
Computer Supply	0,78
Healthcare	1,08
Fashion	1,31
Food Packaging	3,73

Source: Edited from and done for UK [2]

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WAREHOUSE AND PERFORMANCE LITERATURE REVIEW

Studies on warehouse topic usually focus on 3 main subjects which are warehouse location selection, warehouse designing and analyzing warehouse performance and which are focus on performance assessment. Location selection is out of scope of this paper. Warehouse design and performance measurement are mainly based on pallet placement, storage layout, determination of number of cranes and aisles, and storage rack dimension. Different methods are used for these problems. For pallet placement and picking problem is reviewed with statistical simulations in [3]. For the storage layout study [4] a multiple-level warehouse shelf configuration with the aim of minimizing annual carrying cost is done. For the study swarm optimization method is used. A placement problem is done by [5] focusing on cross-aisles in a picker-to-part warehouse to minimize path length. They used analytical formulae to solve the problem.

Performance measurement can be done with some mathematical expressions, however using a set of ratio for performance assessment can lead to confusion too [6]. For example, time indicators, productivity indicators, cost indicators, and quality indicators are the main classifications [7] [8] [9]. Each class has nearly fifteen expressions and this lead to evaluation challenges as implied before. At [6] study, labor, space, and investment are used as inputs and broken case lines, full case lines, pallet lines are used as outputs and after using some statistical tools they identified key factors, that affecting efficiency of warehouse. Factors are specified from 33 different warehouse practices. The determined factors are temporary labor, inventory turns, seasonality, total replenishments, inventory, cross docking, SKU span, and SKU churn. At Istanbul Logistics Sector Analysis Report (2014) [10], warehouse performance assessment factors are determined as productivity, warehouse fill rate (%), warehouse cycle time (hours), percentage of total cost to total warehouse costs (%), usage percentage of warehouse equipment, warehouse staff capacity usage (%), warehouse transportations accuracy, warehouse registration accuracy (%), warehouse loss rate, loss working days because of employment-industrial accident, overtime working rate, supervision results, location fault/number of location, and extra freight payment origination from warehouse. Another performance assessment is designed or customer requirements according to customer requirements as correct product, correct quantity, good condition, on time delivery [11].

With respect to these performance indicators that are collected from literature AHP method is used for measurement. The decision to evaluate performance indicators is a difficult decision which involves both subjective and objective factors. The first reason of selecting AHP is to overcome this complexity and secondly, the reason of these study is to determine the importance weights of these criteria. The method is selected to determine the importance weight of the all criteria, so that practitioners will be able to measure an overall performance with the help of weights of criteria. There is no study that present the warehouse performance criteria's weight and ranking, so it is aimed to contribute literature to provide weights of the criteria.

ANALYTIC HIERARCHY PROCESS

Although the method was known in 1977 by Saaty, it was originally first introduced by Myers and Alpert in 1968 [12]. Decision-making is a process that we are accustomed to experiencing in many phases of life, but may become difficult when the options are very close together. In order to overcome this difficulty, AHP aims to reduce the number of sub-criteria that can be solved in a single problem, from multiple dimensions to one dimension. Criteria are evaluated by the decision maker by binary comparisons in order to determine the importance levels. If there are n states in this case, $n (n-1) / 2$ comparisons are necessary. In doing so, more than one decision maker can include in the decision making process [13]. According to the scale developed by Saaty, comparisons are made on a scale of 9 [14].

AHP method's steps are given [13]:

1. Definition of the problem and determining the purpose
2. Listing of decision-making factors in order to realize the specified objective
3. Determination of alternative decisions
4. Preparation of the hierarchical structure of the decision making problem
5. Performing binary comparisons of the criteria for each level of the specified hierarchy and determining the significance levels using the eigenvectors
6. Making binary comparisons of the alternatives according to the factors and setting priorities
7. Determination of compliance ratio
8. Listing of alternatives and criteria selection according to the highest priority value

APPLICATION

There are a number of criteria for performance measurement in warehouses, as seen in the literature review. Because of this, the criteria have been reduced based on expert opinion before applying the AHP method. The selected criteria are listed in Table 2.

Table 2. Selected Warehouse Performance Criteria

Criterion	Definition	Source
Warehouse fill rate	(%)	[10]
Warehouse cycle time	(Average receiving, handling, picking, preparation and transporting time)	[10]
Warehouse staff utilization rate	(%)	[10]
Warehouse loss	(%)	[10]
Warehouse utilization	Rate of warehouse capacity used	[9]
Inventory costs	Holding cost and the stock out penalty	[9]
Labor cost	Cost of personnel involved in warehouse operations	[9]
Storage accuracy	Storing products from in proper locations	[9]
Perfect order	Number of orders delivered on time, without damage and with accurate documentation	[9]
Customer satisfaction	Number of customer complaints per number of orders	[9]
Total replenishment	Annual total number of replenishment for all SKUs	[6]
Number of SKUs	Total number of SKUs	[6]
Temporary labor	Number of temporary labor for a year	[6]
Inventory turns	Ratio of a warehouse's annual shipment to its inventory measured in dollars	[6]
SKU span	Total SKUs stored in the warehouse annually	[6]

As indicated before AHP based on binary comparisons. Selected criteria are asked to experts in the form given in Table 3. If they prefer warehouse fill rate to cycle time, then they put a check mark on left side at the appropriate rank for them. Total 105 comparisons were made (n*(n-1)/2). Participating experts are both from academy and sector. The results are evaluated at Excel according to AHP method of calculation. Consistency index of the AHP is 0,0993.

Table 3. Sample of Comparison Table

	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	
Warehouse fill rate																		Warehouse cycle time
Warehouse fill rate																		Warehouse equipment utilization rate
Warehouse fill rate																		Warehouse staff utilization rate
…																		…
…																		…
…																		…

RESULTS AND DISCUSSION

According to results of AHP Table 4. is formed, where the criteria are ranged according to their importance rate. Customer satisfaction has the highest rank with 21.99%. Customer satisfaction involves complaints per year, however when it is considered, it involves other criteria too. Such as if the orders are not delivered on time (storage accuracy), or damaged (perfect order), customer would probably complain. Storage accuracy, prefect order, and warehouse utilization have also high rank according to the AHP results. Storage accuracy is important for making on time delivery, has impact on reducing loss. Perfect order also involves order entry accuracy, picking accuracy, on time delivery, shipping without damage and invoicing correctly. On the contrary, temporary labor, labor cost, and staff utilization rate are found with lowest importance. All three related with warehouse staff. Since, the employee expenses are not high as developed countries, experience is not so important for warehouse staff, so easy recruitment and easy dismissal could the reason behind these results.

Table 4. AHP Weights for Each Criteria

Criteria	Weight
Customer satisfaction	0,2199
Storage accuracy	0,1422
Perfect order	0,1161
Warehouse utilization	0,0805
Inventory costs	0,0726
Warehouse loss	0,0713
Warehouse cycle time	0,0579
Total replenishment	0,0552
Inventory turns	0,0530
Number of SKUs	0,0317
SKU span	0,0280
Warehouse fill rate	0,0211
Warehouse staff utilization rate	0,0200
Labor cost	0,0174
Temporary labor	0,0132
Total	1,000

For further studies, it is recommended that the weighted criteria be used to measure warehouse performance rather than using just ratios. Weights can give overall situation of the warehouse performance, which can be used to make comparisons through different warehouses.

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THE FUTURE OF SUPPLY CHAIN MANAGEMENT IN THE CLOUD COMPUTING

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Abstract - *Supply chain management typically involves supervising the transfer of products and goods, such as from a supplier, then to a manufacturer, a wholesaler, a retailer and finally to the consumer. Disruptive innovations are currently changing the landscape of many industries and their business models. Because of increasingly digitalized processes and an exponential growth of sensible data, supply chains are also impacted by the fourth industrial revolution. In the modern world companies are investigating ways to optimize both cost and operational efficiency of each phase of their supply chain, such as planning and forecasting, sourcing and procurement, logistics and service and spare parts management. Cloud computing emerges as a useful technology that contributes to this optimization by providing infrastructure, platform and software solutions for the whole supply chain via internet.*
This paper adopts basic idea of cloud computing to provide an efficient and scalable solution for supply chain management

Keywords: *Cloud Computing, Supply Chain Management, Third-Party Logistics.*

1. INTRODUCTION

Supply chain management is the management of the flow of goods and services. It includes the movement and storage of raw materials, work-in-process inventory, and finished goods from point of origin to point of [1]. Businesses from manufacturers, wholesalers and retailers, to warehouses, healthcare providers and government agencies use supply chain management principles to plan, assemble, store, ship, and track products from the beginning to the end of the supply chain. Figure 1 represents the model of supply chain management.

Figure 1. Supply Chain Model [2]

Cloud computing is a rapidly evolving technology that more and more companies are adopting in order to improve their efficiency. According to a recent study of IBM, a top multinational IT (Information Technology) consulting corporation, the use of cloud computing will be more than double until 2014 [3]. Motivated by the above research, the objective of this paper is to plainly present how cloud computing can be implemented by companies in supply chain management as well as demonstrate the profits that this application has to offer in this field. Activities like planning and forecasting, sourcing and procurement, logistics and service and spare parts management are the first to move to the cloud [4]. Innovation and time are the main competitive advantages [5]. Time, here, is understood as the frequency of the introduction of new or significantly upgraded versions of the product. Its growth changes and shortens the life cycle of such products in comparison to conventional products. The different phases of the life cycle are short in-time and rapid demand-dimension [6]. Supply chains traditionally are linear in nature, with a discrete progression of design, plan, source, make, and deliver. Today, however, many supply chains are transforming from a staid sequence to a dynamic, interconnected system that can more readily incorporate ecosystem partners and evolve to a more optimal state over time. This shift from linear, sequential supply chain operations to an interconnected, open system of supply operations could lay the foundation for how companies compete in the future.

The connection between the regions, the logistics innovation and the industry 4.0 is the competitiveness [7], because the regional environment shall be attractive to the players in the industrial sector in order to settle plants to the region (wherever on the planet as they are independent from the most of the resources because of the global trade and economy). Those companies, who had settled down, are going to utilize the latest logistics related, developed solutions to manufacture there (actually, to create value there) not on other possible location globally.

According to research conducted in 2014 by Forrester Consulting on behalf of Zebra Technologies [8]:

- nearly 90% of companies from the logistics and transport sector have already implemented or will implement IoT solutions in the coming year
- more than half of respondents expect that the Internet Things will improve the supply chains
- 40% of respondents expect that the IoT will help companies increase their level of safety and cost-effectiveness key technologies in the implementation of the Internet of Things are assumed to be Wi-Fi connectivity, security sensors, NFC communications (Near Field Communications)
- Nearly 40% of respondents expressed their concerns about the privacy and security of information as the biggest obstacle to the implementation of IoT solutions
- 38% indicate a high degree of complexity of these solutions, and as such – a high risk of implementation.

Thereafter, Figure 2 shows how computing resources can be accessed from a variety of customers (from different devices and places) using one of the three different service models of cloud architecture [9].

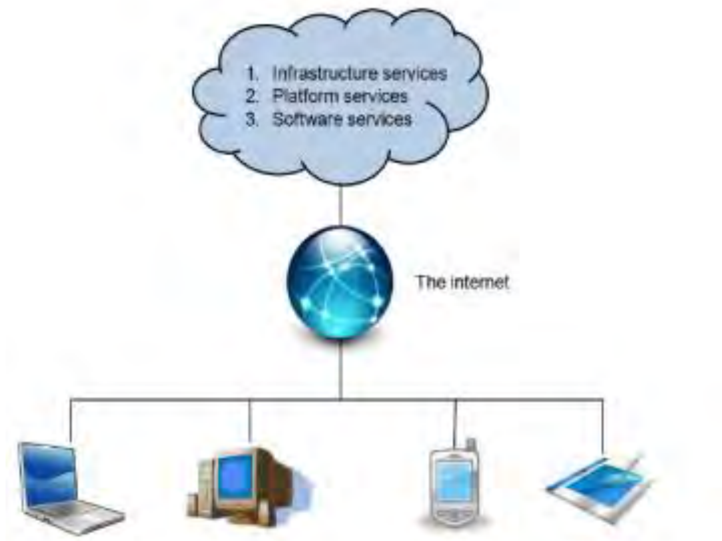

Figure 2. Cloud computing architecture

2. EVOLUTION OF CLOUD COMPUTING

Cloud computing is the development of Distributed Computing, Parallel Computing, Grid Computing, which is a super calculating model based on internet. In a remote data center, thousands of computers and servers connected to a computer cloud. The definition of cloud computing is that cloud computing distributes computing tasks into a large number of resources pools of computer constitute, making different application system according to the requirements to acquire computing power, storage space and all kinds of software service. Special cloud computing refers to the manufacturers through distributes computing and virtualization technique building data center or the super computer, to provide data storage, analysis and scientific computing etc. services by free or on-demand renting methods to technical developers or enterprise customers. The history of the evolution of Cloud Computing has a number of versions which all differ from each other in some small way, they generally are classified into 4 phases [10]. Based on that version of the history, the four phases are: Grid & Utility Computing, Application Service Provision (ASP), Software as a Service (SaaS), and Cloud Computing.

- **Grid & Utility Computing**

This phase starts back in the 1950s during the days when Main Frame computers were the mainstay of the industry. While the computers were getting larger and more and more powerful, not everyone could afford to have their own mainframe computers. Also, while the powerful computers were very fast, their capacities were too extensive to most users of computers. This led to the arrangements where a single mainframe computer was being accessed by a number of users using data phone lines and dedicated data cables.

Application Service Provision (ASP)

This phase is said to have started in the late 1990s. At this time, the industry started providing applications as a service. One of the first firm to provide this service was Salesforce.com in 1999, which pioneered the concept of delivering enterprise via a simple website. This type of a Service Firm paved the way for delivery of applications over the internet. This practice started with specialist firms and then was followed by mainstream software firms also.

Software as a Service (SaaS)

This next phase is identified with the entry into the market by Amazon Web Services in 2002. Amazon provided a number of services through their website including storage and computation. They also provided the service of "Human Intelligence" through their site Amazon Mechanical Turk. In this site, people could bring problems that customers need solved using software as well as human decision making skills. The web site then let "workers" bid for and pick up the tasks that needed to be solved for the customer. Later, in 2006, Amazon launched their Elastic Cloud Compute (EC2), which is a web site that allows small individual companies to rent computers to run their computer applications. It features a complete application offered as a service on demand. A single instance of the software runs on the cloud and services multiple end users or client organizations. The most widely known example of SaaS is salesforce.com, Google Apps.

Cloud Computing

Cloud computing really took off with the onset of web 2.0, when technology giants like Microsoft and Google rolled out "killer apps" which brought all the features of cloud computing in a viable functioning mode. It is widely accepted that one of the true pioneers who initially had a concept of "Cloud Computing" was J.C.R. Licklider, the major force behind the development of ARPANET, with his concept of "Intergalactic Computer Network". This concept was proposed in the 1960s. The concept he proposed was for everyone to be interconnected and accessing programs and data at any site from anywhere. Cloud computing these days has evolved into providing Infrastructure as a Service (IaaS) and Platform as a Service (PaaS), in addition to SaaS. As a result, you can build and access all of your Information Technology needs entirely in a web based environment.

- **PaaS (Platform as a service)**

It encapsulates a layer of software and provides it as a service that can be used to build higher-level services. There are at least two perspectives on PaaS depending on the perspective of the producer or consumer of the services: Someone producing PaaS might produce a platform by integrating an OS, middleware, application software, and even a development environment that is then provided to a customer as a service. Someone using PaaS would see an encapsulated service that is presented to them through an API.

- **IaaS (Infrastructure as a service)**

It provides basic storage and compute capabilities as standardized services over the network. Servers, storage systems, switches, routers, and other systems are pooled and made available to handle workloads that range from application components to high-performance computing applications. Prominent examples of this category are AmazonEC2, GoGrid, and Flexiscale.

3. CLOUD-BASED SUPPLY CHAIN ACTIVITIES

Supply chain management (SCM) involves coordinating and integrating these flows both within and among companies. It is said that the ultimate goal of any effective supply chain management system is to reduce inventory as a solution for successful supply chain management, sophisticated software systems with Web interfaces are available, and who promise to provide part or all of the SCM service for companies who rent their service. Supply chain management flows can be divided into three main flows: The product flow includes the movement of goods from a supplier to customer, as well as any customer returns or service needs. The information flow involves transmitting orders and updating the status of delivery. The financial flow consists of credit terms, payment schedules, and consignment and title ownership arrangements.The application of supply chain concept in the context of cloud computing is innovative and generates a new field of research. A cloud supply chain is two or more parties linked by the provision of cloud services, related information and funds [11]. In the next paragraphs, the paper investigates the manner in which cloud computing can be applied in order to facilitate each supply chain step and create the previously mentioned cloud supply chain. Thomas Schramm, Jonathan wright, Dirk Seng and Derk Jones divide the era of SCM in cloud computing in three parts (Table 1).

Table 1. Implementation process of SCM on cloud platforms [12]

2010-2011	2011-2013	2013-2015
Processes & providers characteristics & examples	Processes & providers characteristics & examples	Processes & providers characteristics & examples
In early pilots SCM using cloud needs innovation and continuous improvement. Testing attitude also needed. Support & administrative processes. These can easily be abstracted and isolated, and do not require complex integration. Examples: • Capability development/training delivery • Simple analytics	This era captures maturing phase, first providers disappears from the market and other invest to grow and improve service offering. Higher focus on core and rather complex processes. Examples: • Pricing optimization • Replenishment planning • Order processing • Transportation load building	Here consolidation phase starts and major player in each category of SCM defined. SCM accept well establish models for usage and payment of cloud based services. Also complex process covered in cloud e.g. requiring collaboration between many entities and tighter integration with other processes and perhaps involving physical capacity constraints. Examples: • Collaborative engineering • Warehousing and distribution of physical product • Reverse logistics/returns processing • Fleet management
User group interests	User group interests	User group interests
Companies with highest pressure for operational excellence and through competition, e.g. Products / Consumer Goods, High-Tech	Broader industry scope, companies with higher integration needs will start using cloud based services as part of their operating model	All industries applied cloud based processes

3.1. Forecasting and Planning

Cloud-based platforms are going to help companies improve their service levels by coordinating the chain's partners (retailers, suppliers and distributors) that are playing a major role in demand forecasting [4]. These clouds based platforms get the data from internet and perform basic operation like analytics and perform more accurate demand forecast for all supply chain partners. This will help to aware the chain partners to if there is volatile of real demand, they can handle it with easily [13].

3.2. Source and Procurement

Sourcing includes acquisition, receipt and inspection of incoming materials as well as procurement process. Cloud based tools also enable companies and suppliers to mutually develop contracts and enhance contract management. Moreover, cloud-based tools enable companies and suppliers to mutually develop contracts, drastically improving contract management [4].

3.3. Inventory Management Using Wireless Devices

Inventory management enhanced by many organization using bar coding technologies and wireless services. RFID system integrates with the cloud based centralized data management sys-tem to deliver the global identification and tracking of any items or goods across the global supply chain management lifecycle [14].

3.4. Inventory Management Using Wireless Devices

Along with the development of information technology, internet network transmission technology is mature gradually, its security, stability, compatibility is constantly improved, and all application range is expanding continually, become a kind of the making universal of transmission [15]. All the developments process shared over secure network between different organizations. These processes include specific information, marketing firm, test result and design changes as well as customer feedback.

3.5. Logistics Management

Logistics information management system keep track on inventory information.by using logistic management under cloud gives fallowing benefits. Cloud computing is also useful for inventory, warehouse and transportation management, as it is able to offer logistics tracking to multiple supply chain partners [4]. Especially in the logistics sector, cloud services appear to be essential for 3PL companies' necessity for itinerary and warehousing management for many different customers in one single system.

4. IMPACT OF CLOUD COMPUTING ON SCM

Cloud computing system uses lot of technology like standardization technology, virtualization technology, data management technology and platform management technology in supply chain information collaboration. Cloud provide on demand services by which a supply chain user use when required. The firm or company which is using supply chain has different branches in different geographical regions like Asia, Europe and North America. If the supply chain of any firm distributed globally then it requires a distinct infrastructure of cloud for each of its branches. Information sharing must be reliable and secure between different supply chain users so there is need of its own private cloud system. In private cloud information sharing has done reliable and secure way. So besides using a centralized Cloud data center, a company or firm should use distributed data center under private cloud circumstances. Using distributed data center under private cloud has fallowing benefits over centralized one.

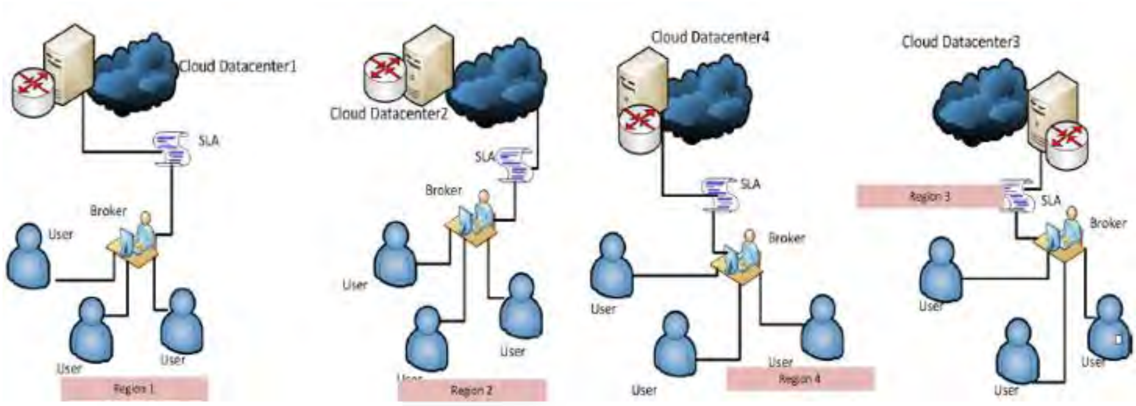

Figure 3. Distributed Cloud datacenter for SCM Users

4.1. Efficiency

Centralized system takes request from users globally which create more loads on servers. So there will be chance of increment in latency. This will create time delay between request and response. On the other hand local datacenter under distributed cloud environment gives more fast response to their users.

4.2. Scalability

A system would scalable if cloud gives least amount of latencies during information sharing and collaboration between two or more users.

4.3. Security

In private cloud the firm creates its security policy according to their own requirement. If it is distributed then policy has great effect due to their regional information sharing policy. A single supply chain company can use different security policy for different users in different regions.

5. WORLDWIDE APPLICATIONS

Intermediaries can be defined as firms that operate between the members in the SC network and involve suppliers as well as customers. In this paper we see the intermediaries' as an information provider which have technological platform which enable information flows between different types of ISs within each firm and between SC members. An information provider aims to transform and distribute information between SC partners and act as a third party information provider (3PIP) where the SC members outsource information related services requiring special know-how to provide the services.

Cloud has recently started to move from its original purpose as a vehicle for sharing computing resources to a platform for collaboration. For example, Cloud as a technology for supply chain management has started to emerge in many industries [16].

Amazon is an E-commerce and cloud computing company. It's the biggest Internet Retailer in the America. It began as an on-line bookstore but its current business scope covers DVD, blue ray, CD, video game, electronic, furniture, food, toys, jewellery and so on. Amazon has independent sales website facing different countries and areas, including America, the U.K. and

Ireland, France, Canada, Germany, Italy, Spain, Netherlands, Australia, Brazil, Japan, China, India and Mexico. Amazon saves a lot of storage costs by integrating the inventories in DC (Distribution Center) and the warehouses of partners. Then there is no need for Amazon to keep a high level of inventory like physical retail stores [17].

The example is the UPS logistics system, which is the Supply Chain system that United Parcel Services use to make sure that all their packages reach their customers at the right place at the right time. To get a view of the enormity of the task, here are some snap shot statistics of the package delivery business from the view point UPS Logistics: In 2012, the company delivered more than 4 billion packages and documents to nearly million daily customers in more than 220 countries and territories. To carry out these tasks, UPS used a fleet of more than 96,000 cars, vans, tractors and motorcycles, as well as 230 jets. To get this enormous an undertaking to flow smoothly through their system, UPS (just like any other Logistics company of the past) constructed a network of customer counters, local warehouses, regional distribution centers, and a variety of modes of transportation and operated them with the help of the latest in communication and processing hardware and software. All this was before the company pioneered the use of Cloud Computing in the Logistics business.

As a global industry, cargo shipping is beginning to utilise cloud computing as a way of boosting communications, operations and collaboration with workers around the world, according to The Wall Street Journal.

Ports have also seen developments in cloud-based solutions. One of PTI's previous articles looked at ARL Shipping's 'Crane Executor' app – a cloud based solution for improving container discharge and load operations at ports and terminals.

Smart-phone manufacturer BlackBerry has recently announced plans to launch an 'Internet of Things' platform to enable shippers to boost business growth through hardware, and software, that will be used for cloud-based communications boxes within shipping containers.

There is also talks of container ships holding the key to forming a global 'quantum network' through the process of data transfer between ships. This could potentially provide a secure network for sending and receiving data across long distances.

6. CONCLUSIONS

Supply chain firms are initially start using cloud computing for their services and using cloud services supply chain efficiently utilized. The various architecture of cloud is available and need to explore fully utilized and scalable cloud infrastructure. In practice, cloud-based models have already been implemented by leading international 3PL companies with great success so far, firstly at private and later on at public cloud structure. These real-world cases, as presented in the paper, indicate that these companies have succeded in adopting the new collaborative thinking in supply chain management and enjoy the benefits of cloud computing, especially real-time visibility throughout their customer network. Thus to overcome this complexity in supply chain and handle the humongous data that has compiled over the years, we need a powerful tool. The use of cloud computing systems in the Supply Chain is a chance to increase the flexibility, as well as the efficiency. Especially the logistics mall and its partners allow successful business services for companies with individual workflows and special needs. Therefore companies who are willing to improve their services of information collaboration and want to scale their services at large level can use distributed cloud datacenter.

As thoroughly discussed in this paper, the concept of cloud computing can be effectively used in the field of supply chain management facilitating mainly the collaboration among the supply chain stakeholders through the integration of supply chain activities.

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CITY LOGISTIC AND LEZS: SITUATION IN TURKEY

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Abstract – *City Logistic is logistic and transportation activities carried out by different companies in urban area. Urban heavy or light duty vehicles are capable of producing significant quantities of emissions including particulate matter (PM), sulfur dioxide (SO2) and nitrogen oxide (NOx). It is also necessary to minimize these emissions because of the population living and working in urban areas is exposed to high levels of harmful emissions. Low emission zone (LEZ) is the area where vehicles that don't meet minimum standards for vehicle emissions are restricted and where vehicles outside these limits are subject to major penalties if they enter the area. In this study, we will conduct general information about emissions and air pollutants generated by road transport vehicles, Examine examples of successful applications in the world and will offer suggestions.*

Keywords – Air Pollution, City Logistic, Low Emission Zone, LEZ,

INTRODUCTION

Urban Logistics (*city logistics*, *urban freight transport),* logistics and transportation activities carried out by different companies in urban areas. When these activities are carried out, the traffic infrastructure, conditions and safety as well as environmental effects and energy saving are taken into account. Urban logistics is based on 4 basic principles.

These are mobility, sustainability, livability and resilience. These 4 principles are the building blocks that fulfill the objectives to be determined in urban logistics. With the principle of mobility, it is aimed to reach all areas of the city, to ensure efficient use of road-rail-sea-air-way and less traffic congestion. With the sustainability principle, it is aimed to minimize environmental impacts such as air pollution and noise, and to minimize energy consumption. The livability principle is to promote public health and well-being, traffic safety and silence. Resilience principle aims to ensure that the urban logistics infrastructure is resistant to natural and man-made disasters and emergencies and that if such events occur, it can be quickly recovered. As a result of these basic principles urban logistics; Targets global competitiveness, productivity, adaptability to environment and to remove the traffic congestion, safe transportation, maximum efficiency with minimum energy consumption and labor productivity (Tanyaş, 2016).

Urban heavy or light duty vehicles are capable of producing significant quantities of emissions including particulate matter (PM), sulfur dioxide (SO2) and nitrogen oxide (NOx). It is also necessary to minimize these emissions because the population living and working in urban areas is exposed to high levels of harmful emissions.

There have been many different ways to improve the quality of air in the world over the last 30 years. A number of policy measures, including urban consolidation centers, regulations of access control to city centers, off-peak hour deliveries, low emission zones (LEZs) have been tested and implemented in urban areas of cities around the world to achieve the goals of city logistics; mobility, sustainability, livability and resilience. Today people want to spend their lives safer, healthier and more comfortable. They also want to improve air quality and energy efficiency while reducing traffic congestion and accidents. All of these situations lead to the emergence and increase of LEZs (Taniguchi, Thompson, & Yamada, 2014).

LEZs are areas where vehicles that do not meet a minimum standard for vehicle emissions are restricted from entering and are subject to large fines if they do enter. The LEZ was introduced with the aim of reducing the emissions of air pollutants including particulate matter (PM) and nitrogen oxides (NOx) from vehicles. These air pollutants are seriously harmful to human health and it is very important to reduce them (Ellison, Greaves, & Hensher, 2013). LEZ is a new and important approach that will contribute to the goals of urban logistics.

In this article, we will give general information about emissions and air pollutants created by road transport vehicles, urban logistics and LEZ, and then examples of successful applications in the world will be examined. In some cities in Turkey, the necessity of creating LEZ will be determined and readers and researchers will be guided for future researchers.

AIR POLLUTANTS

Air pollutants are known as substances contained in the air that can harm humans and the environment. The pollutants may be in the form of solid particles, liquid droplets or gaseous. They may additionally be natural and / or man-made. Pollutants are most commonly classified as primary and secondary pollutants. Generally, primary pollutants are substances that are released directly from a volcanic explosion-causing ash, carbon monoxide from the exhaust of a vehicle, or sulfur dioxide, which is released from factories. The spread of secondary pollutants does not occur directly. Primary pollutants form secondary pollutants in the air when they react or interact. An important example of secondary pollutants is ground-level ozone. This is one of the secondary pollutants that form the photochemical fog (Sonsuz, et al., 2011).

The urban mobility assumes a key role in the promotion of sustainable urban development. In fact, urban areas consume about 70% of energy and produce about 80% of Greenhouse Gas (GHG) emissions Urban mobility accounts for 32% of energy consumption and for 40% of all CO2 emissions of road transport and up to 70% of other pollutants from transport (Russo & Comi, 2012). In major cities, main streets and intersections, roadways are important dimensions emissions of air pollutants (atmospheric gas, dust, etc.). Only one vehicle in a period of 10 minutes a person's daily requirement of 15 m3 of clean air can become dangerous for breathing. If we consider hundreds of thousands of vehicles in the cities; we can foresee the frightening picture of the size of air pollution caused by vehicles. Today, more than 1 million vehicles registered in Istanbul are on the streets of the city. These tools, which can release polluting gases and particles (particles) into the air, are an important source of pollution due to poor maintenance, unconscious use, and some of the very old (Sert, 2017).

EMISSIONS

Emission is the term used to describe gases and particles released into the air or emitted from various sources. Urban transport vehicles can produce significant amounts of emissions, including sulfur oxides, particulate matter and nitrogen oxides. It is necessary to minimize emissions because of people living and workings in urban areas are exposed to harmful emissions at high levels (Taniguchi, Thompson, & Yamada, 2014). The European Union's (EU) emissions standards for road vehicles dictate the minimum emission standards required for all new commercial vehicles being sold in the EU. These emissions standards, commonly described as the "Euro" emissions standards have also been adopted by other countries (Ellison, Greaves, & Hensher, 2013).

Europe first introduced heavy-duty vehicle emission standards in 1988. The "Euro" track was established beginning in 1992 with increasingly stringent standards implemented every few years. Euro I standards were introduced in 1992, followed by the introduction of Euro II regulations in 1996. These standards applied to both truck engines and urban buses. The EU adopted Directive 1999/96/EC in 1999, which introduced Euro III standards (2000), as well as the Euro IV/V standards (2005/2008). The directive set voluntary emission limits that are slightly more stringent than Euro V standards for "enhanced environmentally friendly vehicles" or EEVs. When Euro IV and Euro V standards were adopted, regulators expected the stringent PM emission standards to require the use of DPFs (Diesel Particulate Filters) in commercial heavy-duty vehicles. However, by tuning their engines for high-NOx, high-fuel economy and relatively low PM emissions, manufacturers are able to comply with the Euro IV and V emission standards without the use of DPFs. These manufacturers use selective catalytic reduction to lower tailpipe NOx emissions to meet Euro IV and Euro V standards. However, this compliance strategy does not reduce emissions of the smallest and most hazardous particles to the same degree as DPFs. Euro VI emission standards were introduced by Regulation No 595/2009, which was published on 18 July 2009 (with a Corrigenda of 31 July 2009). The new emission limits, comparable in stringency to the US 2010 standards, became effective in 2013 for new type approvals and for all registrations in 2014.

EU Member States are allowed to use tax incentives in order to stimulate marketing and sales of vehicles meeting new standards ahead of the regulatory deadlines. However, the use of incentives is contingent upon the following:

- They apply to all new vehicles offered for sale on the market of the EU Member States that comply in advance with the mandatory limit values set out in the directive.
- They terminate when the new limit values come into effect.
- They must not exceed the additional cost of the technical solutions introduced to each type of vehicle. This is to ensure compliance with the limit values (transportpolicy.net, 2015).

The EU has also introduced air quality standards that set a limit to the concentration of various pollutants to try to limit their negative impacts on human health. These standards require the concentration of PM_{10} to be below an average of 50µg/m^3 in a 24 hour period or 40µg/m^3 over one year. The equivalent standards for NOx are 200µg/m^3 in a one-hour period or 40µg/m^3 over one year (Ellison, Greaves, & Hensher, 2013).

CITY LOGISTICS

With the progress of urbanization in the world, about half of the population is concentrated in urban areas in 2010 according to the statistics of United Nations and it is predicted that this will increase to 70% by 2050. A number of mega-cities with populations of over 10 million have appeared and there have been various issues due to dense populations in mega-cities, including traffic congestion, air pollution, crashes and large energy consumption (Taniguchi, Thompson, & Yamada, 2014).

Urban logistics is the process of optimizing the logistics and transportation activities carried out by different companies in the cities, the traffic infrastructures, the conditions and the security in the market economy context with the support of the advanced information technologies, considering the environmental effects and energy saving (Tanyaş, 2016). City logistics plays an important role in creating efficient, environment-friendly and safe urban freight transport systems (Taniguchi, Thompson, & Yamada, 2014).

Urban logistics has 4 main actors. These: producers, consumers, carriers or logistics operators and local and national policy makers. These four different units have different interests. Whether the producers want to present their goods to the market in the most profitable way, the carriers want to move the products in the fastest and most profitable way. Consumers that are the city dwellers want to buy the products cheapest. They also demand that the traffic is not congestion and that environmental policies are adopted. City managers are looking for ways to achieve an optimal balance by reconciling all parties (Tanyaş, 2016).

In order to increase the quality of life of the city, the quality of the load movements in the urban areas is important. It is important to effectively implement the principles of urban logistics. It is important to meet the needs in the most optimal way without disregarding the requirements of the market conditions and to be satisfied with all of the urban sides. The importance of highways in urban areas is not to be underestimated. However, damage to society and the environment is also thought-provoking. It is necessary to increase intermodal transport, to use maritime and railway transport in freight transport and to regulate the occupancy rate, fuel types and ages of the vehicles in traffic. The most significant negative impact of road transport on the environment is noise and air pollution.

Urban logistics has four main strategic goals. These: mobility, sustainability, livability and resilience. Mobility; to ensure trouble-free and reliable traffic flow and to deliver loads smoothly wherever possible. In addition, the city is concerned with removing infrastructure problems, parking problems, and the inability to use different modes of transportation. Sustainability aims to create environment friendly cities, to minimize emission of greenhouse gas emissions. Livability is to improve the quality of life of end users in urban life. It aims to increase the social, cultural and economic standards of urban residents. Resilience principle aims to ensure that the urban logistics infrastructure is resistant to natural and man-made disasters and emergencies and that if such events occur, it can be quickly recovered (Tanyaş, 2016). The most important progress in urban logistics has been observed in sustainability and livability. A number of policy measures, including urban consolidation centers, regulations of access control the city centers, off-peak hour deliveries, low emission zones have been tested and implemented in urban areas of cities around the world to achieve the goals of city logistics (Taniguchi, Thompson, & Yamada, 2014).

LOW EMISSION ZONES (LEZ)

Low Emission Zones (LEZ) have been implemented in about 200 different cities in Europe in order to reduce negative environmental impacts arising from old polluting vehicles (Dablanc & Montenon, 2015). These pollutants are seriously harmful to human health and it is very important to reduce (Ellison, Greaves, & Hensher, 2013). Recent studies show that these zones have been successful in minimizing emissions based on CO_2, NOx and other particulates (Awasthi, 2016).

Atmospheric particulate matter (PM) is an extremely complex structure containing many different organic and inorganic components released from different sources. The particles released by the combustion at the end of the combustion activities have a high organic content. Particle matter (PM) is a complex mixture consists of various materials, such as metal, soot, soil, dust or a combination of these materials. The two most regulated classes of particulates are PM10 and PM2.5. PM is created as a direct result of burning fuels such as oil, gasoline or wood. PM10 has been linked to serious cardiopulmonary diseases, acute respiratory infection, and trachea, bronchus and lung cancers. In the EU alone, PM10 is estimated to cause 348,000 premature deaths annually. The European Commission has taken these health impact very seriously, and, in response, enacted the 2005 Clean Air Directive, which marks an unprecedented attempt to mandate low levels of PM10 (Wolff & Perry, 2010).

Logistics operators can move in 4 different scenarios after entering LEZ operation:

1. No change in existing fleet (Logistic operators take on the extra costs: fines etc.)
2. Change in delivery operations (Logistics operators change the delivery timings, routes, delivery zones, use of dedicated hubs/delivery zones)
3. Change in delivery vehicles (Retrofit existing vehicles, Buy-Newer Used vehicles, Rent delivery vehicles, Vansharing)
4. Change in business strategy (Partnership with other logistics operators, Merger with other logistics operators, Outsourcing to 3PLs)

Based on the urban logistics principles and by determining the necessary criteria, it can be considered which approach the operators might take (Awasthi, 2016).

LONDON'S LEZ

London's low emission zone (LEZ) was implemented in 2008. Today, the only LEZ in England is in London. Before London implemented LEZ, a "congestion charge" was applied to reduce traffic congestion in the city center, as well as to reduce air pollution and fuel inefficiency. But especially air pollution continued both in and around London. City authorities decided to implement LEZ to reduce air pollution in particular and in

London, it targeted heavy diesel vehicles such as trucks, vans, buses and minibuses that made up 25% of PM10 and 57% of NOx. Thus, minimum emissions standards were introduced for vehicles entering the London's orbital motorway (Ellison, Greaves, & Hensher, 2013).

In the early 2000s, London's air quality was considered to be amongst the worst for European cities. LEZ was created to improve the quality of the air. Standards have been set for vehicles entering LEZ and fines are imposed on vehicles and drivers that do not comply with these standards. In this way, the decision to renew the company's fleets was taken and the fleet composition in London was significantly affected. Conversion to smaller vehicles has increased and emissions from larger vehicles have decreased. An important problem is the increasing number of small vehicles that have negative impact on traffic. In terms of urban logistics, there should be a balance between traffic congestion and emission values. Another important problem is the vehicles used outside of LEZ. Old vehicles will serve the rest of the country while the fleet is being converted to enter the LEZ. It is necessary to take measures against this situation (Ellison, Greaves, & Hensher, 2013).

LEZS IN GERMANY

Many cities in Germany could not adapt to the EU emission threshold. PM10 and NOx, measured at 30% and 50% of the emissions, were derived from transportation sources. Germany took measures to solve air pollution based on traffic in urban areas, such as expanding public transport, using the orbital road, improving traffic flow and implementing LEZs.

41 German cities implemented LEZs. To implement the LEZ policy, Germany has categorized all vehicles into four classes based on EU-wide tailpipe PM10 emissions categories. These standards are based on vehicle features such as size, weight, type of engine, horsepower, intended use, number of seats, model, year and combined emissions of PM10 and other tailpipe pollutants. There are 4 different stickers in Germany. Vehicles entering LEZ are limited by their sticker color. The sticker categories are shown in table 1 (Wolff & Perry, 2010).

Tablo 1: German vehicle stickers

Sticker Categories				
	No sticker	**Red**	**Yellow**	**Green**
Requirement for diesel vehicles	Euro 1 or worse	Euro 2 or Euro 1 with particle filter	Euro 3 or Euro 2 with particle filter	Euro 4 or Euro 3 with particle filter
Requirement for gasoline vehicles	Without three-way catalytic converter	-	-	Euro 1 with regulated catalytic converter or better

Source: (Wolff & Perry, 2010) (http://www.tuev-sued.de/home_de, 2017)

The LEZ policy is being discussed in many different ways in Germany. It is very debatable whether it is an effective method to reduce air pollution. In addition, many companies that continue to trade in LEZ centers are forced to overhaul their vehicle fleet, complaining of excessive costs and reduced sales. Despite everything, LEZ is successful to meet EU threshold emission values. It also makes a positive contribution to the transformation of the fleet (Wolff & Perry, 2010).

CURRENT SITUATION IN TURKEY

Although Turkey has made great progress in terms of air quality, it is still behind international standards. The fumes from the fuels they use to ensure the movement of vehicles and the industrial wastes in the sectors pollute the environment. The share of highways in air pollution is 85%. In addition, leaded gasoline which is used extensively in Turkey increases air pollution considerably. The most important measures against heavy metal contamination of motor vehicles are to use unleaded gasoline. The use of catalytic converters and the introduction of diesel particulate holders are necessary for extracting exhaust emissions to the required values. In addition, old technology vehicles need to be checked.

In the last measurements made by the Ministry of Environment and Urbanization in 2015, the effect of air pollutants caused by road transport vehicles is shown in table 2.

Table 2: Road transport national emission values

	NOx (kt)	SO2 (kt)	PM10 (kt)
Heavy-duty vehicles and buses	241.4	0.2	4.0
Light duty vehicles	12.9	0.0	0.9

Source: (http://www.ceip.at/, 2017)

On road transport; NOx emissions increased by about 338.8% from 236.8 Gg in 2000 to 310.7 Gg in 2015. SO2 emissions increased by about 31.2% from 1.72 Gg in 2000 to 7.54 Gg in 2015. PM10 emissions decreased by about 1.5% from 9.89 Gg in 2000 to 9.75 Gg in 2015. The disparities between polluters released in road transport between 2000 and 2015 are significant. In particular, NOx emissions have increased dramatically. The PM10 emissions have been reduced slightly, but it is worrisome that PM2.5 emissions are still not measurable (Koksal, 2017). Stations should be built for PM 2.5 emission measurement.

According to the transportation sectors in Turkey, the share of highways in the domestic freight transport ratios was 89.5%, the share of railways 4.6% and the share of seaway 5.9%. By 2014, freight transport is being made with a total of 3,836,207 heavy vehicles registered in traffic (Dost, Terzioğlu, İlhan, Olgun, & Aydoğan Culha, 2016). Between 2004 and 2016, distribution of vehicles registered in Turkey by fuel type is shown in Table 3. When the table is examined, it is seen that diesel and gas vehicles are increasing strikingly and this affects the air pollution negatively.

Table 3: Distribution of cars registered to the traffic according to fuel type in Turkey, 2004 – 2016

Year	Total	Gasoline	(%)	Diesel	(%)	LPG	(%)	Unknown	(%)
2004	**5 400 440**	4 062 486	75.2	252 629	4.7	793 081	14.7	292 244	5.4
2005	**5 772 745**	3 883 101	67.3	394 617	6.8	1 259 327	21.8	235 700	4.1
2006	**6 140 992**	3 838 598	62.5	583 794	9.5	1 522 790	24.8	195 810	3.2
2007	**6 472 156**	3 714 973	57.4	763 946	11.8	1 826 126	28.2	167 111	2.6
2008	**6 796 629**	3 531 763	52.0	947 727	13.9	2 214 661	32.6	102 478	1.5
2009	**7 093 964**	3 373 875	47.6	1 111 822	15.7	2 525 449	35.6	82 818	1.2
2010	**7 544 871**	3 191 964	42.3	1 381 631	18.3	2 900 034	38.4	71 242	0.9
2011	**8 113 111**	3 036 129	37.4	1 756 034	21.6	3 259 288	40.2	61 660	0.8
2012	**8 648 875**	2 929 216	33.9	2 101 206	24.3	3 569 143	41.3	49 310	0.6
2013	**9 283 923**	2 888 610	31.1	2 497 209	26.9	3 852 336	41.5	45 768	0.5
2014	**9 857 915**	2 855 078	29.0	2 882 885	29.2	4 076 730	41.4	43 222	0.4
2015	**10 589 337**	2 927 720	27.6	3 345 951	31.6	4 272 044	40.3	43 622	0.4
2016	**10 656 778**	2 936 502	27.6	3 393 284	31.8	4 283 458	40.2	43 534	0.4

Source: (Turkstat, 2016)

In Turkey, the energy used by the transportation sector is about 20% of the total energy. In the railway, the energy consumption per unit work is 1 / 4-7 less than the highway. Diesel fuel or electricity is used in the railway while gasoline is widely used on the road. The pollution brought by the diesel fuel is rather less than the petrol. (www.udybelgesi.com, 2017)

There is no comprehensive air pollution legislation in Turkey to prevent and control the traffic-related air impacts discussed. Plans should be made to protect human and environmental health, such as the prevention of traffic congestion in urban plans and the establishment of closed areas for new traffic. Projects should be developed to provide healthy living environments for people (Dülgeroğlu, 2002).

Turkey has 20 cities with population of 1 million. Istanbul, the largest city of over 10 million people, is a complex and cosmopolitan city due to being connected to both sides of the Bosporus, being on the international transit route, as a center of industry, production and consumption. Turkey also has industrial cities such as Sakarya, Gaziantep, Bursa, Tekirdag and port cities like Mersin, Samsun and İskenderun. It is necessary to establish LEZ in many cities in Turkey, but no comprehensive study has been done. Especially Istanbul city is very suitable for applying LEZ.

CONCLUSION AND FUTURE WORKS

Urban logistics aims to provide an optimum balance between parties such as consumers, producers, logistics operators. It uses mobility, sustainability, viability and resistance principles to achieve its objectives. It aims to minimize adverse effects such as traffic congestion, harmful air pollutants, noise pollution, inefficiency, waste of time and to provide compromise between city residents and producers.

Low emission zones (LEZ) are one of the latest trends in the field of urban logistics. LEZ limits vehicle traffic by dividing the city into specific areas and by setting certain criteria. It aims to reduce air pollution, reduce traffic congestion and increase social welfare. LEZ has been successfully implemented in many different cities in Europe and its results have been examined. It has significantly reduced air pollution. It also made an important contribution to the renewal of the vehicles in the country. But it is thought-provoking that old vehicles will serve the rest of the country while the fleet transformation is being done to get into LEZ. Administrators should also give the private companies the necessary time and incentives for fleet transformation. The community should be informed and the advantages and disadvantages of LEZ should be discussed publicly.

Air quality threshold in Turkey is higher than in EU countries. Therefore, situations that are not considered polluted for Turkey are considered pollution for EU countries and therefore no measures are taken. The first step is to meet international standards for airborne pollutant thresholds. The most important disadvantage in Turkey is dependence on the highway. About 90% of freight transport is done by road. Coastal and rail transport in the country are possible. However, the necessary infrastructure and investments have not been made and the logistics sector has not been directed to other transportation alternatives. In this respect, it is also behind Europe. In recent years, new standards have emerged as a result of increased diesel and gas vehicles, and clear regulations are needed. In urban areas, complexity is important because of there is no sanction that restricts freight transport. Despite the recent developments in Istanbul, there is a negative picture because of not meeting with the sector representatives and creating excessive costs in the sector. LEZ will be an important alternative exit route for Istanbul and some cities. Conversion can be achieved through action plans and more environmentally friendly and efficient cities can emerge. London is a model city that has been quite successful in the adventure of LEZ which started in 2008. Germany is a successful example of what the country has done in the last decade. Academic work on LEZ should be increased and European standards should be achieved by creating regulations and action plans.

The more detailed literature review will be done in future studies. Criteria for determining LEZ will be determined. Each criterion will provide optimum benefit by giving specific weights. Detailed assessments and zone studies will be conducted in Istanbul. As a result of these studies, the application will be a reference for future studies.

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SALES FORECASTING BY USING INTERMITTENT DEMAND MODELS IN E-RETAILING

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Abstract – *Sales forecasting plays a more prominent role on the success and performance of a retailer. The accuracy of sales forecasting and stock decisions carries critical importance on both the reduction of stock-out costs and improvement of customer service level in retail sector. Different sales forecasting models are used for products with intermittent demand. At this point, Croston and Syntetos-Boylan are most widely used intermittent demand forecasting methods. In this study, Croston, Syntetos-Boylan and single exponential smoothing methods with parameter optimization are applied to forecasting intermittent demand. The performances of the proposed forecasting models are compared on data set taken from a e-retailer. Numerical results indicate that the proposed models give robust results and the parameter optimization significantly increases the forecasting accuracy of the proposed models.*

Keywords – Croston, Intermittent demand forecasting, Parameter optimization, Retailing, Syntetos Boylan, Single exponential smoothing,

INTRODUCTION

Demand forecasting is one of the most important problems for companies. Demand forecasting is always important for better inventory planning. The accuracy of sales forecasting and stock decisions carries critical importance on both the reduction of stock-out costs and improvement of customer service level. At this point, different demand forecasting models are used for products that are only ordered for a specific period.

Intermittent demand is random demand with a large proportion of zero values [1]. In other words, intermittent demand is characterized by infrequent sales events [2]. The demand is usually small in these cases and sometimes it changes highly. Such demand realizes in a variety of industries where spare parts are seldom demanded in aviation and military inventories, such as wings or jet engines [3].

Spare parts are usually demanded as intermittent or scattered. This makes the time series different from the usual periods due to the existence of several periodic periods with zero demand [4]. Intermittent demand occurs in this way. For intermittent demand, there are many examples including heavy machinery and related spare parts, aircraft service parts, electronic, marine spare parts demand. These inventory items make up 60% of total stock value [4]. Similarly, a large part of products have many time periods with zero demands in many retailers. At this point, how to develop more accurate sales forecasting methods becomes an important research topic.

Intermittent demand data is divided into 4 groups: erratic, lumpy, smooth and intermittent. Intermittent demand data is called "intermittent" demand when it contains a large percentage of zero values with random nonzero demand data. If the demand dimension is highly variable, it is called "erratic" demand. If the variability of the time interval between the two non-zero requests of demand size is high, it is called "lumpy" demand. In case the variability and time intervals between successive non-zero demands are low, the demand data type is called "smooth demand". Demand classification scheme is given in Figure 1.

As can be seen in Figure 1, CV^2 (coefficient of variation) and π_y^+ (probability of non-zero demand) coefficients are used for classification. These limits are generally suggested as $CV^2 = 0.49$ and $\pi_y^+ = 0.76$.

This study aims to compare the performances of Croston, Syntetos-Boylan and single exponential smoothing methods with parameter optimization for intermittent demand forecasting. The rest of this study is organized as follows: The next section provides a detailed review of the literature on the intermittent demand forecasting. In the third part, detailed information on Croston and Syntetos-Boylan are presented. The fourth part shows application steps of proposed forecasting models and application results on data set taken from a e-retailer to assess the efficiency of these methods. In the final part, the comparative results of the proposed forecasting methods are discussed.

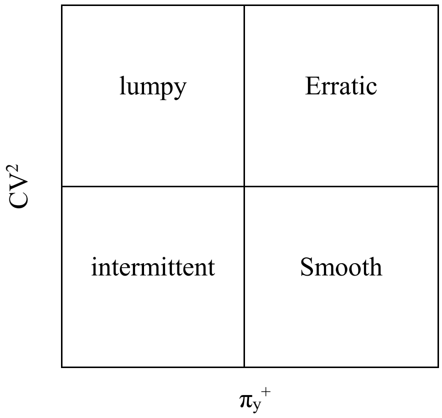

Figure 1. Demand classification scheme [5]

LITERATURE REVIEW

Although there are many time series forecasting methods for forecasting regular demand data, there are limited methods for intermittent demand data. In this section, studies in literature related to intermittent demand forecasting methods.

Firstly, Croston (1972) published an article about intermittent demand in 1972. It has proposed a procedure that independently updates the demand range between two non-zero demand and demand sizes. It has become the most frequently used technique in forecasting intermittent demand [5].

Willemain (1994) compared single exponential smoothing (SES) and Croston methods with their actual demand figures. Proposed forecasting methods were evaluated with mean absolute percentage error (MAPE), median absolute percentage error (MdAPE), mean absolute deviation (MAD) and mean square error (MSE). According to the results, Croston was a better choice. Croston's performance was found better when it compared with the actual case in the simulation [6].

Syntetos and Boylan (2001) compared the Croston model with the revised Croston model (Syntetos Boylan method) using simulation. In this study, ten different smoothing constants with 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1; five different demand interval with 2, 4, 6, 8, 10 and four different demand combinations ($\mu = 1$ and $\sigma = 0$, $\mu = 6$ and $\sigma = 1$, $\mu = 10$, $\sigma = 2$ and $\mu = 20$ and $\sigma = 2$) were used. Their results showed that the Syntetos Boylan method was successful forecasting approximately the expected demand for all the different factor combinations demanded per time period [7].

Eaves and Kingsman (2004) studied Royal Air Force's actual data with single moving average (SMA), SES, Croston and Syntetos-Boylan. The evaluation was made with forecast errors and stock keeping results and MAD, RMSE and MAPE indicators were used. The methods are optimized with the MAPE [8].

Regattieri et al. (2005) tested twenty forecasting methods including the Croston method for the spare parts of the aircraft and they compared performance of these methods. MAD, MAD / Mean, Min, Max and Max / Min criterion of forecasting methods were found in respectively. When the estimation methods were ranked according to the their forecasting error, the Croston method ranks second [9].

An important contribution to the Croston method used to calculate the intermittent demand forecasting was made by Syntetos and Boylan.

Syntetos and Boylan (2005) compared simple moving average, single exponential smoothing, Croston method and Syntetos Boylan method which they developed. In this study, The data sets are taken from monthly demand of 3000 SKUs of 2 years from the automotive industry. The average demand interval ranges from 1.04 to 2 months, the average demand ranges from 1 to 194 units. The correction constant value is introduced as a control parameter and values of 0.05, 0.10, 0.15, 0.20 are used. The delivery time is also taken as a control parameter, 1, 3 and 5 periods. The simulation was done for 3000 series. Mean error (ME), scaled mean error, RGRMSE (relative geometric root mean square error), percentage better (PB) and (percent best) PBt were examined and the results were evaluated. Syntetos Boylan method was found to be the best method according to scaled mean error and RGRMSE. Their results concluded that Syntetos Boylan method is the most accurate estimation method for faster intermittent demand [10].

Syntetos and Boylan (2006) compared the SMA, Exponentially Weighted Moving Average (EWMA) and Croston methods using customer service level (CSL) indicator. In this study, the data sample is composed of past monthly claims of 3000 SKUs and is taken from the automotive industry. The average demand interval is between 1.04 and 2 months and the average demand at the time of the unit is between 0.5 and 120 units. Smoothing parameters are 0.05, 0.1, 0.15, 0.20 are used. Their results showed that the Croston method has been found to give better performance for longer delivery times and higher correction parameter values [11].

Boylan and Syntetos (2007) compared the revised Croston model and single exponential smoothing with the Croston model. For all parameter combinations according to the MSE value, Croston found to be more accurate than the revised Croston and single exponential smoothing method [12].

Teunter and Sani (2009a) compared Croston, Syntetos-Boylan, Levén-Segerstedt (LS) and Syntetos (SY) methods. In this study, 10000 experimental demand data were generated using normal distribution. Their results showed that the LS method had very poor performance and the Croston and Syntetos Boylan method performed very well [13].

Teunter and Sani (2009b) developed a new method for products with intermittent demand. In this study, the performance of proposed model compared with Croston method using experimental data. It has been shown how ordering policies are used and how these methods are used in the calculation of order levels. The first results showed that the proposed new method performs much better than the Croston method. The level of service obtained by the new method is close to the target [14].

Syntetos and Boylan (2010) analyzed Croston, SES, SY and Syntetos-Boylan Approximation (SBA) methods. [15]. Syntetos et al. (2010) evaluated SES and SBA [16].

Teunter et al. (2011) compared the methods of Teunter–Syntetos–Babai (TSB) developed by authors. The sampling variation is handled with 10 runs of each control parameter combination. 3 cases were considered. In this study, ME and MSE were selected for performance measurement. The simulation is run for all combinations. TSB and SES trends were found to be higher than Croston and SBA. With the MSE performance of the SES being very poor, the TSB showed the best performance for the probability of demand the smallest update parameter [17].

Altay et al. (2012) compared the SES method with the SBA method. By using these methods, the effects of 3 different types of correlation on the inventory control and intermittent demand elements forecasting were investigated. Forecasting accuracy of these methods was measured using RGMAE and MASE. The SBA method has been shown to play an important role in periodic renewal policies by estimating order averages and variance [18].

Romeijnders et al. (2012) compared 7 methods, including Croston and SBA methods. 100000 repair data for 10 years which belongs to Fokker Services was used for the dataset. The first 7 years have been taken into consideration for the start-up period. 7-year data are divided into three categories. In this study, MSE, MAD, and ME performance measures were used. The moving average is used for 12 period. Correction parameters of Croston and SBA method were set at 0.2. When the simulation was run, Croston and SBA forecasted more than expected and had positive bias. When MSE was calculated for each iteration, SES method estimates performed better than the other methods [19].

Babai et al. (2014) compared Croston, SBA, SY, TSB, SES, zero forecast and Naïve method. It is stated that Croston method has positive bias and the percentage bias increases with the smoothing constant, the SY and TSB methods are not completely unbiased, the SBA method shows a little negative bias. In addition, the comparison of Croston and SBA variance was made, before the simulation that the estimated variance of the SBA method is lower than the variance of the Croston method. In this study, the data for 3000 SKUs covering 24 months from the automotive industry was used and the monthly demand for 500 SKUs from the Royal Air Force for 84 months was used. For performance measurement of the proposed methods, ME, MSE and MASE are used. Their results showed that the Croston method has performed well in general and that the SBA, SY and TSB methods do not differ greatly from the Croston method [20].

Pennings et al. (2016) used five datasets in their work. Forecasting methods including Croston have been compared. The proposed methods based on inventory performance and financial performance were examined. According to Croston method, when the investment increase of 4% occurred, the lowest income loss occurred in all methods. It has been shown that there is no clear superior method of Croston when investment and income are thought to be non bargain [21].

There are several study in the literature that involve the use of grey and fuzzy theory based methodologies to forecast intermittent demand. These studies can be summarized as follows:

Bao et al. (2004) studied more improved methods such as Croston method, based on the exponential smoothing method. This work proposed a new method to forecast the intermittent demand based on support vector machines (SVM) regression. The results were compared with the Croston method [22]. Chiou et al. (2004) applied GM(1,1) model to forecast the planning requirement of spare parts of 2003 after taking fourteen periodic items of planned material from 1999 to 2002. Through this study, they showed the GPM can conduct accurate prediction of spare parts especially in situations of insufficient data or resources within highly uncertain [23]. Bao et al. (2005) used exponential smoothing when dealing with intermittent demand. They proposed a new method to forecasting intermittent parts demand based on support vector regression (SVR). Details were presented and experimental result is given [24]. Jiantong and Biyu (2009) studied forecasting intermittent demand with no assumptions and missing data. They used Undulating Grey Model to forecast intermittent demand. They also analyzed the forecast accuracy, and found that UGM is a good way to address this issue [25]. Chen et al. (2010) proposed moving back-propagation neural network (MBPN) and moving fuzzy neuron network (MFNN) to effectively predict the CSP requirement so as to provide as a reference of spare parts control. They compared prediction accuracy with other forecasting methods, such like grey prediction method, back-propagation neural network (BPN), fuzzy neuron network (FNN), etc [26]. Froung et al. (2011) performed with simulated data to show that the neural network can be a promising tool to conventional Croston methods for predicting intermittent demand with performance measurements MSE and MAE [27]. Rahman and Sarker (2012) analysed a seasonal autoregressive integrated moving average (SARIMA), a multiplicative exponential smoothing (M-ES) and an effective modelling approach using Bayesian computational process in the context of seasonal and intermittent forecast [28]. Jiang et al. (2016) concentrated on the intermittent demand for electric power supply and studies the method of demand prediction. Markov arrival process for demand interval and Grey prediction model GM (1, 1) for demand quantity were used. According to analysis, the integrated approach mentioned in this paper surpasses existing methods in providing accurate prediction on data of product with intermittent demand [29]. Lei et al. (2016) combined the Multi-Aggregation Prediction Algorithm (MAPA) and the fuzzy Markov chain model to generate a new forecasting algorithm for forecasting intermittent demand. The results were compared with exponential smoothing and the new forecasting algorithm. The results showed that FMC-MAPA with an equal weight method in the time disaggregating process is the best forecasting method in this case [30]. Seeger et al. (2016) presented scalable and robust Bayesian method for demand forecasting in the context of a large e-commerce platform, paying attention to intermittent and bursty target statistics. Their method performed better than competing approaches on fast and medium moving items [31]. Takahashi et al. (2016) used time series data and proposed a method for forecasting intermittent demand with generalized state-space model. They used mixture of zero and Poisson distributions. They conducted comparison analysis to show the superiority of their method to the Croston, Log Croston and DECOMP models [32]. Jung et al. (2017) proposed a new bootstrap method that takes into consideration the unique characteristics of intermittent demand to improve forecasting performance. They concluded demonstrating the applicability of suggested new method with the results of a simple case experiment [33].

MODELS

In this section, mathematical structure and formulas of Croston and Syntetos-Boylan methods are given.

Croston Model

The Croston model is based on a repeated measure of the extent to which the gap between the demands of successive arrivals and the size of the demands is forecasted [18]. The notations of this model are as follows:

Y_t : demand in period t

T_t : actual demand interval in period t

Y_t' : forecasted average demand per period for period t + 1 in period t

T_t' : forecasted average demand interval in period t

z_t' : forecasted average size interval in period t

α, β : smoothing constants ($\alpha \geq 0, \beta \leq 1$)

$$\begin{cases} T_t' = T_{t-1}', \; z_t' = z_{t-1}', \; Y_t' = Y_{t-1}' & , Y_t = 0 \\ T_t' = T_{t-1}' + \beta(T_t - T_{t-1}'), \; z_t' = z_{t-1}' + \alpha(Y_t - z_{t-1}'), \; Y_t' = {z_t'}/{T_t'} & , Y_t > 0 \end{cases} \quad (1)$$

Syntetos Boylan Model

The Syntetos Boylan model is the result of adding a smoothing factor to the forecasts produced by the Croston method to reduce the bias due to forecasts. The display of the model is as follows:

$$\begin{cases} T_t' = T_{t-1}', z_t' = z_{t-1}', Y_t' = Y_{t-1}' & , Y_t = 0 \\ T_t' = T_{t-1}' + \beta(T_t - T_{t-1}'), z_t' = z_{t-1}' + \alpha(Y_t - z_{t-1}'), Y_t' = (1 - \beta/2)\frac{z_t'}{T_t'} & , Y_t > 0 \end{cases} \quad (2)$$

APPLICATION

In this section, firstly, the data set to be used for the application is introduced. The simple exponential smoothing and forecasting models mentioned in the previous section are coded in the MATLAB 2015b programming language.

Data Sets

Sales data from an e-retailer site was used for this study. This data provides information on 396 days of sales of 98 products. The products are sold some days and some days are not sold at all, and there is a lot of "0" sales. For this reason, product units conform to the intermittent demand structure. The demonstration of the application steps will be presented through a sample product. In this way; the sales figure of Product 1 and its sales graph are given in Table 1 and Figure 2, respectively.

Table 1. Sales data for Product 1

1-36	37-72	73-108	109-144	145-180	181-216	217-252	253-288	289-324	325-360	361-396
1	1	1	0	1	0	1	1	0	0	1
1	0	0	1	3	0	0	0	0	0	0
1	0	0	1	2	1	2	3	0	0	2
1	0	1	2	1	0	0	0	1	0	3
4	0	0	2	0	2	0	2	0	1	1
4	0	1	0	0	1	1	1	1	1	0
0	1	0	1	0	0	2	1	0	4	1
2	1	1	0	2	1	0	3	0	1	0
0	0	0	2	1	3	0	2	1	0	0
0	0	0	1	0	0	0	2	0	0	2
0	1	1	6	1	1	0	1	1	1	0
1	0	1	2	1	3	0	5	1	3	1
0	0	1	3	0	0	1	4	0	1	1
0	0	1	1	0	1	1	3	0	0	0
0	0	0	1	0	0	0	2	1	1	1
0	0	0	2	0	1	0	1	1	0	1
0	0	0	3	0	3	0	2	0	2	0
0	1	0	0	0	0	0	0	0	1	0
0	0	0	0	0	0	0	1	0	0	1
0	0	3	1	0	0	0	1	1	0	2
0	1	0	1	0	0	0	1	0	2	0
0	0	3	2	0	2	0	0	0	1	0
0	0	0	0	0	2	0	1	1	0	2
0	0	1	1	0	0	0	1	0	1	0
1	0	2	2	1	0	0	0	0	2	0
0	0	0	0	0	0	0	0	0	0	0
2	0	3	3	0	0	0	1	0	5	1
2	0	2	1	0	1	0	3	0	1	0
0	0	0	0	0	1	0	0	0	0	0
0	0	0	2	0	2	0	0	0	0	1
0	0	2	0	1	1	0	0	2	0	1
0	0	0	4	0	0	0	0	1	3	4
0	0	0	8	0	4	0	0	0	2	2
0	0	2	2	0	0	0	2	0	3	1
0	0	1	0	0	1	0	0	3	5	0
0	0	0	2	0	1	0	0	0	1	0

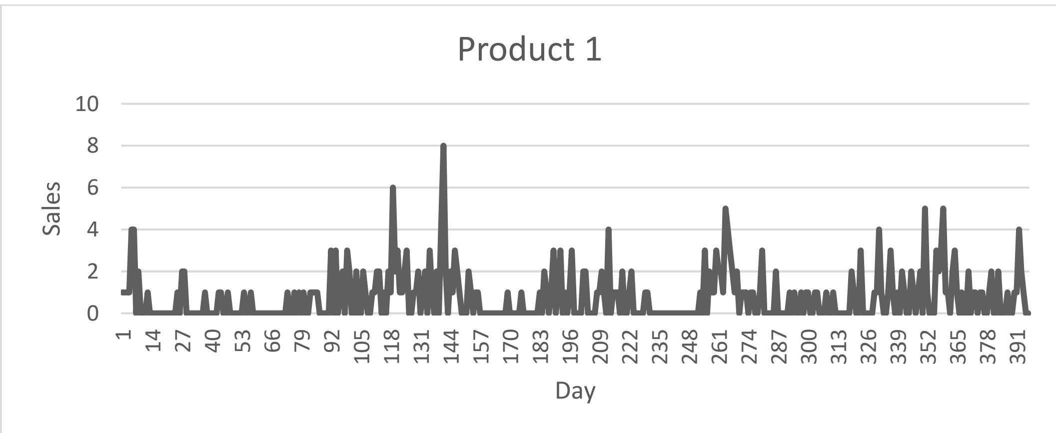

Figure 2. Sales graph for Product 1

First, 396-day sales data for 98 products with intermittent demand was transferred to the MATLAB 2011 program in matrix format with 396 rows and 98 columns.

In order to compare the performances of the models, performance measures such as MAPE, MAD were used as mentioned in the literature. However, these criteria are not appropriate because the sales data to be used contains "0" intensively. The mean absolute error (MAE) criterion will be used to compare the performances of the models in the study. MAE is defined as follows:

Y_i Actual sales

F_i Predicted sales

n The number of prediction data

$$MAE = \frac{\sum_{i=1}^{n} |Y_i - F_i|}{n} \tag{3}$$

Building Models and Results

In this study; six different forecasting models were used for the sales forecasts of the products. The application steps and results of these models can be explained as follows.

Model 1. Original Croston Model

The mathematical model of the Croston model is given in Models. The model is programmed on MATLAB programming language. As an example, MATLAB codes of Model 1 can be written as follows:

```
function [tahmin,mae]=croston(A,alfa,beta)
Z(3)=2;
T(3)=2;
Y(3)=1;
Actual=zeros((length(A)-2),1);
ind=find(A>0);
for k=1:(length(ind)-1)
   interval(k)=ind(k+1)-ind(k);
end
for j=3:length(A)
   if A(j)>0
      Actual(j-2)=interval(1);
      interval(1)=[];
   end
end
for i=4:length(A)
if A(i-1)==0
      Z(i)=Z(i-1);
      T(i)=T(i-1);
      Y(i)=Z(i)/T(i);
   else
      Z(i)=alfa*A(i-1)+(1-alfa)*Z(i-1);
      T(i)=beta*Actual(i-3)+(1-beta)*T(i-1);
      Y(i)=Z(i)/T(i);
   end
end
tahmin=Y';
for i=1:length(A)
   mae(i)=abs(A(i)-tahmin(i));
end
mae=mean(mae(3:end));
```

In this model, alpha and beta parameters are fixed as 0.2. The predicted sales and MAE value of each product was calculated using Model 1. The MAE value for Product 1 was found to be 0.852 by using Croston model. MAE values of 98 products were obtained with Croston model forecasts. In the model 1, the average MAE value is 0.938.

Model 2. Croston Model with Parameter Optimization

In Model 2, the function was developed with MATLAB programming language for the parameter optimization of the Croston model. The parameter optimization of the Croston model was found to be alpha=0.61 and beta=0.02 for the Product 1. Based on these predicted values, the MAE is calculated as 0.813. As the results of Model 2, the parameter and MAE values are calculated for each product. The average MAE of the Model 2 is 0.87276.

Model 3. Original Syntetos-Boylan Model

The mathematical model of the Syntetos Boylan is given in Models section. The MAE value for Product 1 was found to be 0.844 using Model 3. In this model, the average MAE value for all products is 0.931.

Model 4. Syntetos-Boylan Model with Parameter Optimization

The parameter optimization result of Syntetos Boylan model was found as alpha=0.88 and beta=0.67 for product 1. Based on these predicted values, the MAE was calculated as 0.807. The function has improved the parameters of the model and has reduced the error value. The parameter and MAE values are calculated for each product. The average MAE of this model is 0.87271.

Model 5. Original Single Exponential Smoothing Model

The single exponential smoothing (SES) model is programmed on MATLAB programming language. In this model, alpha is fixed as 0.2. The predicted sales and MAE values are calculated for each product by original SES model. The MAE value of Product 1 is 0.764. The average MAE of this model for all products is 0.860.

Model 6. Single Exponential Smoothing Model with Parameter Optimization

In this model, the function is developed for the parameter optimization of the simple exponential smoothing model. As the result of the parameter optimization of the single exponential smoothing model, alpha value for the Product 1 was found 0.21. Based on these predictions, the MAE is calculated as 0.762. A very small decrease in the MAE value compared to the previous model has occurred. In this model, the parameter and MAE values for each product are calculated. The average MAE of this model for all products is 0.852.

For Product 1, MAPE values obtained by the proposed models are given in Table 2. According to these results, Model 6 is the best forecasting model for Product 1.

Table 2. MAE values of the proposed forecasting models for Product 1

Proposed Model	MAE
Model 1	0.852
Model 2	0.813
Model 3	0.844
Model 4	0.807
Model 5	0.764
Model 6*	0.762

CONCLUSIONS

Sales forecasting plays a more important role on the performance of a retailer. The more accurate sales forecasting models have critical importance on both the reduction of stock-out and handling costs and improvement of customer service level. Intermittent demand is characterized by infrequent sales events, occurring at irregular intervals [2]. At this point, a large part of products have many time periods with zero demands in many retailers. In this way, this study aims to compare the performances of Croston, Syntetos-Boylan and single exponential smoothing methods with parameter optimization for intermittent demand forecasting. The performances of the proposed forecasting models are compared on data set taken from a e-retailer in Turkey. Based on all products, the mean MAE values for each model are given in Table 3.

As can be seen in Table 3, Model 6 gave minimum MAE value of 58 products. It was successful for the prediction. Model 2 is the model that gives the least MAE value in 28 products. Also, numerical results indicate that the proposed models with parameter optimization give robust results and the parameter optimization significantly increases the forecasting accuracy of the proposed models.

Table 3. Performance analysis of the proposed forecasting models

Model	Average MAE	Number of Best Forecasting Model
Model 1	0.93788	-
Model 2	0.87276	28
Model 3	0.93091	-
Model 4	0.87271	12
Model 5	0.86005	-
Model 6	0.85154	58

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ASSESSING THE EFFECT OF RELOCATING URBAN DISTRIBUTION CENTERS ON GOODS MOVEMENT IN AN URBAN CONTEXT - A MODELING APPROACH FOR DECISION MAKERS

Ahmet Balcıoğlu[1]

Abstract − *Urban logistics facilities (distribution centers, freight terminals, etc.) have been relocated from central city areas toward outer limits of cities as a result of land use requirements and urban renewal projects. This movement has brought up both costs and benefits in terms of urban logistics: while it results in the creation of new spaces better fitted for commercial uses in inner city areas, it might well increase the distance traveled to service retailers and commercial customers. This paper aims to present a modeling approach to quantify economic and environmental effects of relocating urban distribution centers on logistics networks. We model a generic logistics distribution network to analyze the changes in trip patterns, costs, energy consumption, and pollution, which are key to freight planning in urban logistics. We extend our generic model to two-echelon distribution network where satellite distribution centers are introduced between customers and urban distribution center. Then, further analysis is provided with an emphasis on the vehicle types at each echelon. In this context, we construct a simulation model to provide before (ex-ante) evaluations of various scenarios while utilizing two-echelon vehicle routing methods.*

Keywords − *Supply Chain Management, Logistics Sprawl, City Logistics, Designing Distribution Networks, Simulation, Decision Support Systems, Two-Echelon Distribution*

INTRODUCTION

Today, more than half of the world population lives in urban areas with a more than 70% in developed countries, and it is predicted to increase over 66% by 2050 [1]. Growing urbanization poses increasing need for a higher number of movements of goods and services in urban areas, which in turn yields a vast array of challenges mainly to overcome the negative impacts in economic, environmental, and social scales in city life [2] [3]. It is well acknowledged that freight transport is fundamental part of urban life and efficient organization of urban goods transport is crucial to the economy, environment, and the quality of life in cities [4] [5] [6] [7]. Designing an excellently functioning goods distribution network and maintaining sustainable development of logistics activities has been a real challenge for urban planners since the last few decades. Taniguchi et al. [8] defined City Logistics as "the process for totally optimizing the logistics and transport activities by private companies in urban areas while considering the traffic environment, the traffic congestion and energy consumption within the framework of a market economy." With the emergence of city logistics, many researchers and policy makers around world have placed numerous initiatives and scientific studies regarding urban transport and distribution to achieve sustainability, livability, and mobility in urban areas [2] [3] [5] [9] [10] [11].

Urban consolidation is one of the main solution schemes in city logistics as it allows efficient organization of goods transportation [12] [13] [14]. Accordingly, innovative and intelligent use of Urban Distributions Centers (UDC) is a popular example in city logistics in mitigating the negative impacts arising from goods transportation in urban areas [5] [13] [15]. UDC is defined by Allen et al. [16] as "*a logistics facility situated in relatively close proximity to the geographic area that it serves (be that a city center, an entire town or a specific site such as a shopping center), to which many logistics companies deliver goods destined for the area, from which consolidated deliveries are carried out within that area, in which a range of other value-added logistics and retail services can be provided*". A broad range of names is used to refer UDC functionality (e.g., logistics facilities, freight platforms, public distribution depot, consolidation center, city

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distribution centers, logistics platforms, logistics center, urban distribution terminals) in the literature. In this context, UDC and Urban Consolidation Center (UCC) are used synonymously in the remainder of this paper.

Direct and advanced distribution schemes are two categories arising in urban consolidation schemes related to UDCs [7] [17]. While direct schemes center on single-echelon Vehicle Routing Problems (VRP) [14] in which transportation is organized from UDC for city freight requirements, the latter encompasses more general two-echelon systems which aims to efficiently combine UDCs and intermediary logistics platforms (will be also referred as Satellites from here on) located at inner city area [17]. In two-echelon systems (see Figure 1); goods arrive at UDC where it is grouped and sent to satellite platforms via 1st-echelon vehicles, then there it is consolidated into smaller 2nd-echelon vehicles suitable for serving designated customers in dense metropolitan area [14].

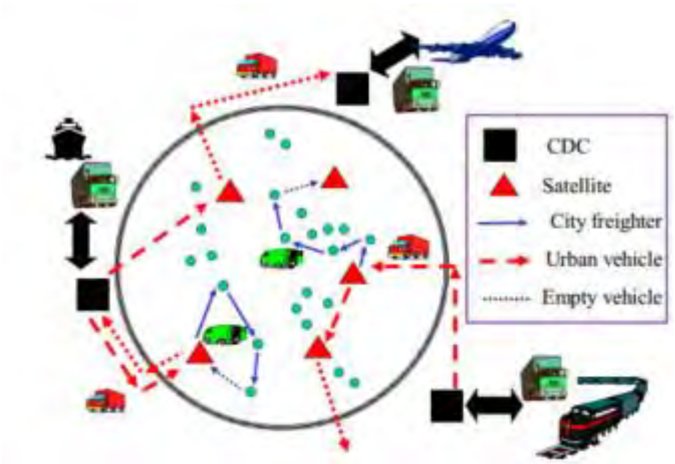


Figure 1. An example of a two-echelon distribution system from Crainic et al. [18] (as cited in [19])

The issue of logistics sprawl, which is defined as "the movement of logistics facilities (warehouses, cross-dock facilities, intermodal terminals…) outside of the city boundaries towards suburban areas" [20] has an impact on the distribution of goods delivered to city centers from suburban areas due to increase in distance traveled by logistics vehicles, thus generating congestion and air pollution [21]. Consequently, it is highly important to quantify the effect of logistics sprawl on logistics networks from a sustainability point of view, particularly looking at the tradeoffs between keeping land for logistics use inside freight intense central areas and moving outwards [22].

Modelling is a key tool in City Logistics to analyze predicted effects of various changes in urban distribution design [5] and before implementation assessment (ex-ante) is used to employ the best solution scheme available [23] [24]. This study proposes a modeling approach to support decision making by providing an "ex ante" evaluation of logistics locations when they are to move from one location to another in urban geography over a generic distribution network. In this way, we aim to quantify the effects on goods distribution due to change of geographic locations of UDCs in urban area, such as vehicle kilometers traveled, congestion, and air pollution. It is also a fact that there is no single best solution that suits all as the needs and the problems may change in terms of urban form and the geography of freight distribution, although underlying causes and effects of goods movement is similar [25] [26] [27]. Therefore, experimenting with different urban characteristics can be fruitful to obtain different insights. And, another aim is to develop and implement an integrated model combining several scenarios with optimization models, which will be a valuable tool at hand for our research interest in multi-echelon freight distribution systems in urban context.

The remainder of paper is built up as follows. The following section provides related work on design and assessment techniques of goods distribution in single-echelon and two-echelon network structure, and routing of vehicles in such setting. Then we continue with the description of problem and solution methodology, and the details of scenario used in this study. There then a generic case study is given and the results of simulation follows. Finally, the last section concludes with main results and comments for future research.

RELATED WORK

Modelling Approaches and Frameworks

Gonzales-Feliu et al. [28] propose an ex-ante assessment framework, which is based on locational accessibility analysis, in order to evaluate the suitability of the location of an urban consolidation center by taking into consideration the both city planning and transportation dimension. They focus on how inbound and outbound movements of goods are related in relation to the location of consolidation center. Furthermore, they define a location-based accessibility indicator by incorporating the less than truckload nature of urban freight transport, which contains several destinations in associated routes instead of direct trips. Suksri and Raicu [26] proposes a conceptual framework for the evaluation of urban freight distribution initiatives, with a multi agent system approach allowing to model the behavior and interactions of stakeholders involved. They describe the key stake holders and their objective as similar to that of Taniguchi at al [5]. Melo [3] defines a number of criteria on mobility and sustainability scale for the evaluation of urban goods distribution and presents a microsimulation study to characterize good distribution and freight traffic pattern with a vast array of cases. Comi and Rosati [29] presents a City Logistics Analysis and Simulation support System (CLASS) utilizing a scenario based approach to obtain critical indicators by analyzing land use, freight flows, and road usage.

Gonzales-Feliu and Routhier [30] presents a thorough analysis on construction and development of models related to urban goods movement, and lay out modelling approaches by highlighting their limits and usability with specific objectives in urban context. Moreover, they suggest that combining several modelling approaches might be fruitful as well as a challenge in developing procedures for model interaction, data collection, and communication among various schools. Gonzales-Feliu and Salanova [31] propose a method for strategic decision support evaluation of a collaborative urban freight transportation system, which has six modules to process required data, to run scenario, to build routes, to calculate environmental impacts, to assess risks involved, and feed all outcomes into a multicriteria analysis module to complete decision support system. Muñoz-Villamizar et al. [32] present an approach for comparing collaborative and non-collaborative decisions in a last-mile delivery scenario. Thompson and Hassall [33] analyze benefits of collaborative approach among suppliers sharing use of vehicles and distribution centers on a hypothetical urban distribution network.

Battaia et al. [34] give a modelling framework to evaluate efficiency of the UDC in a growing urban environment. They first utilize Inter-Establishment and End Consumer movements models, later transfer these movements to the UDC, and then use continuous approximation method [35] for the routing problem. Gonzales-Feliu and Salanova [36] study a simulation modelling approach in order to provide a scenario assessment from accessibility perspective in land use and transportation analysis. Comi [24] presents a simulation framework for supporting city logistics planners and experts in planning, managing and controlling urban delivery bays by allowing simulation of several schemes. Faure et al. [37] proposes a methodology in order to assess the economic viability of urban consolidation center in relation to the shape of city, and present their findings on how the location of urban consolidation center affects the profitability in circular, rectangular, and elliptical city morphology. Patier and Browne [38] present a robust, unified evaluation methodology to assess the effectiveness of a project by highlighting the variables and key ratios to take into consideration for sustainable development in city logistics.

Vehicle Routing Problems in Single-Echelon and Two-Echelon Distribution Systems

Vehicle routing is a fundamental tool for modeling and evaluating in urban distribution schemes [5]. The VRP is one of the most researched combinatorial optimization problems [39]. The VRP seeks to determine a set of routes for a fleet of vehicles under given constraints to minimize the transportation cost, by visiting each customer once by a designated vehicle to deliver the required goods [40]. Of special interest are capacitated VRP (CVRP) where vehicle capacity imposed and VRP with time windows (VRPTW) if a delivery time window is imposed. As this study does not intend to provide a synthesis of the existing literature on VRP, interested reader is referred to Toth and Vigo [39] and Golden et al. [41] where a detailed description of VRP and related variants are given with through presentation on solution methods.

VRP in single-echelon distribution systems resembles to classical problems widely studied in the literature [19], Cattaruzza et al. [42] classifies VRP arising in urban goods distribution and describes issues e.g., time-dependence, multi-level and multi-trip structures by analyzing approaches how to deal with them. Gonzales-Feliu at al. [43] first introduces Multi-Echelon VRP (ME-VRP) formally and then defines Two-Echelon Capacitated VRP (2E-CVRP) as delivery from depot to customers which routes through intermediate depots called satellites. Moreover, Gonzales-Feliu [44] presents a multidisciplinary examination of multi-echelon transport systems with cross-docking. The author provides an optimization analysis to compare single-echelon and collaborative multi-echelon scenarios, and a two-step algorithm, which constructs satellite clusters and routes respectively. In another work [45], the author presents main concepts of multi-echelon distribution with cross-docks, and a thorough review of multi-echelon based routing optimization problems.

Mancini [14] gives a detailed review of multi-echelon distribution systems involving routing problems in urban setting, which are Two-Echelon Location Routing Problem (2E-LRP), Two-Echelon Vehicle Routing Problem (2E-VRP), and Truck and Trailer Problem, together with exact and heuristic methods to solve them. Crainic et al. [46] define a fast clustering heuristic for 2E-VRP, by separating first and second level routing problems while handling flows through satellites. Their method uses a clustering and multi-depot VRP approach respectively as first phase, and then utilizes improvement heuristics by focusing on the routes generated. Hemmelmayr et al. [47] propose an Adaptive Large Neighborhood Search (ALNS) heuristic for 2E-VRP and 2E-LRP, which yields very efficient results on both problem types. Crainic et al. [48] address 2E-VRP and follow an experimental approach by using a fast clustering heuristic [46] to analyze the relationship among satellite and customer distribution, and associated costs for entire two-echelon distribution network highlighting the overall global cost. Crainic et al. [7] introduce an original class of problem type, which collectively plans distribution network and schedules all operations of fleet management while keeping synchronization of activities maintained in a multi-level context, namely two-echelon, synchronized, scheduled, multi-depot, multiple-tour, heterogeneous VRPTW. For a detailed survey on two-echelon distribution systems, reader is referred to Cuda et al. [49] and Gonzales-Feliu [45]

PROBLEM DEFINITION AND SOLUTION METHODOLOGY

Problem Definition

The main objective in this study is to analyze an urban distribution network in order to obtain effects on the costs (in terms of distance traveled and number of vehicles used) and the environment due to relocating UDC and intermediate Distribution Centers (DC) (also called satellites, and will be used interchangeably here on) as well as changing number of DCs in single and two-echelon distribution setting. It is important to highlight that transitioning to new location as a whole process, (e.g., inventory and order management, transportation costs, customer service continuity, etc.) is not in the scope of this study. The focus lays on city logistics related perspective. A two-echelon vehicle routing approach is adopted for investigating the problem under study. We model a distribution network utilizing a 2E-CVRP, as it is simple enough to implement and to track in terms of computational simplicity, yet quite satisfactory to present the distribution network for strategic and tactical planning purposes in the manner of CVRP [50]. We follow the definition of Gonzales-Feliu [51] for 2E-CVRP model, where flow of goods between UDC and customers are organized by utilizing intermediate satellites. This organization can be structured in two connected levels (also called *stage*), first of which concerns activities and entities between UDC and satellites, called as 1st Level (1L), second of which carries those between satellites and customers, called as 2nd Level (2L). This distribution structure has the following characteristics [48] [51]:

- Goods arrive to UDC, a high capacity facility located usually outskirts of the city, where they are consolidated to 1st-level vehicles.
- Each 1st-level vehicle visits a subset of satellites and travels back to UDC.
- At each satellite, usually low capacity facilities, arriving goods are transferred from 1st-level vehicles to environment friendly, smaller 2nd-level vehicles, which distributes to customers.
- Each 2nd-level vehicle visits at least one designated customer and returns to their departure satellite.
- All vehicles belonging to same level have the same capacity. Fleet size is fixed and known in advance for each level.

- There is one UDC and a fixed number of capacitated satellites. All customer demands are fixed, known in advance, and must be delivered in full.
- For the 2nd level, customer demands cannot exceed 2nd-level vehicles capacity and cannot be split.
- Location of the satellites is known with no prior assignment of customers.

We define a hypothetical distribution network resembling above features, which initially has one UDC and several customers (*retailers*) who are served from UDC on a daily basis. Later, UDC is moved to a new location and three satellite distribution centers introduced spread around previous location of UDC. We aim to optimize transportation costs of the new distribution structure in terms of traveling distances and number of vehicles used by using 2E-CVRP, and compare to that of initial distribution network to obtain insight for ex-ante evaluation.

Solution Methodology

The approach taken to investigate the problem has following steps (see Figure 2), some of which are program modules based on object oriented design principles: (1) Instance generator, which uses data analysis for parameter estimation, e.g., customer demands, load factors, road conditions, etc., then generates instances of distribution network for targeted test cases. (2) Scenario manager, by using generated instances, employs necessary models (exact or heuristic algorithms) according to configuration of each test case, and updates parameters to exhaust all scenario steps. This module interacts with every other module in the solution framework for synchronization of events. (3) Model controller has callable model libraries which implements heuristic and exact solution algorithms. (4) Report organizer, which guides logging, and formatting of outputs including graphical charts. (5) Assessment phase, where logical conclusions and targeted indicators are identified and further insight are formalized.

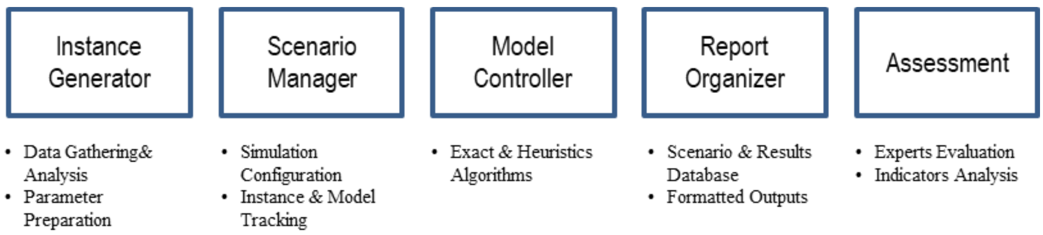


Figure 2. Conceptual framework for solution methodology

To solve 2E-CVRP, a two part heuristic method similar to that of Crainic et al. [46], was adopted. Implementation simplicity and tractability of model was favored over exact 2E-VRP algorithms, because NP-Hardness of VRP family would limit the size of model to small instances and computational time would make it impracticable. The heuristic model implemented is quite simple yet powerful for deriving insights about network structure and related movements in urban context. It decomposes the problem by solving CVRPs at 2nd level for each satellite and associated customers in the cluster, and then solves another at the 1st level between the UDC and the satellites. The procedural steps of the algorithm are as follows:

- (Step 1) Cluster customers around proposed satellites using a k-means clustering algorithm where k is the number of satellites and algorithm starts using satellite locations
- (Step 2) For each cluster (a satellite and assigned customers) solve classical CVRP
- (Step 3) Use total delivered weights at each satellite from step-2 and assign those as demand of respective satellite
- (Step 4) Solve another CVRP between the UDC and the satellites
- (Step 5) Check and adjust all flows and routing for complete network.

The route construction procedure at each level, which is a classical CVRP, uses a Mixed Integer Programing (MIP) model based on Toth and Vigo [39]. A construction heuristic based on parallel version of Clark and Wright's [52] Savings algorithm (CW-P) is implemented and used for larger instances of CVRP.

APPLICATION AND ANALYSIS OF RESULTS

This section illustrates the use of proposed approach in the hypothetical distribution network discussed above (see Figure 3). The CVRP model is programmed with GAMS 22.3 and solved by using CPLEX 10.1, and simulation framework including heuristics are coded with Java 8.0 SE. We use several case scenarios to compare obtained results in evaluating network changes, e.g., location of the UDC and introduction of new intermediate DCs under defined solution methodology. Problem instances are derived by changing the number of customers, demands, location and number of the facilities. Four scenarios are defined as follows (Table 1):

- (Scenario 1) This is also base scenario for benchmarking with other scenarios. There is one UDC and customers (30 - 250) served by city trucks with a freight carrying capacity of 2 tons. There are big trucks (inbound trucks) carrying 15 tons of freight to the UDC from external locations. 15 sets of customer demands and locations data are generated randomly for use at each instance.
- (Scenario 2) This is the same as scenario 1 except for the UDC, which is moved to the new location
- (Scenario 3) This is based on scenario 2 with the addition of 4.5-ton carrying capacity, medium trucks and 2 satellites, whose locations are assumed to be fixed in advance.
- (Scenario 4) introduces 3rd satellite in addition to scenario 3 and focuses on larger customer data sets, which has 100 to 250 randomly generated customers (locations and demands)

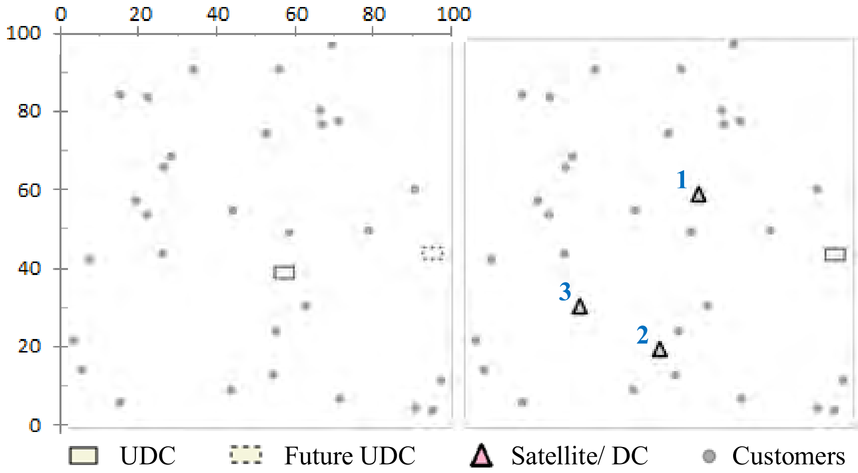


Figure 3. The hypothetical distribution network: single and two-echelon structure

Table 1. Scenario details

Scenario#	UDC***	Satellites***	Vehicles Type and Capacity*	Customer Size, Demand, and locations**
1	1, initial location	n/a	Vans/Pick Ups, 2 tons	30, 40, 50, 80, 100, 150, 200, 250
2	1, new location			
3	1, new location	2, fixed location	Vans/Pick Ups, 2 tons Small trucks, 4.5 tons	Demands ~ Uniform (100-300) Locations ~ Uniform (0-1000)
4	1, new location	3, fixed location		

* Medium size trucks with 15 tons of freight capacity are assumed for inbound transportation to the UDC
** Locations are generated for a 1000x1000 unit square area, and translated into 100 x 100 km square area
*** UDC is located at (600,400), will move to (950,450), and satellites 1, 2, and 3 are located at (600,600), (500,200), and (300,300) respectively

Comparison of Scenarios under Single-Echelon and Two-Echelon Schemes

First, scenario 1 and scenario 2 is run to obtain insights on what the effects in terms of distances traveled and number of vehicles used would be comparing distribution results of the UDC from two locations. The distribution is managed via CVRP for each instances of scenario 1 and 2. The results obtained for scenario 1 and 2 are depicted at Table 2.

Comparison of scenario 1 and scenario 2 show no difference in terms of number of routes traveled for servicing all customer groups, while mean distance traveled in scenario 2, in which the UDC is located at new location, increases (15-19%). Distance increase is expected as the new location of the UDC lies at the edge of customer region. The distance between the new and present location of the UDC, which is 35.3 km, will be traveled by heavier inbound trucks to supply the UDC back and forth in scenario 1. This movement will add to transportation activities of the UDC as ton-kilometers (tkm) driven, e.g., for 250 customer group, 5 trucks which are carrying a freight of 74.7 ton will yield 2642 tkm. Adding this value in scenario 1 gives (4385 + 2642) 7027 tkm, which is greater than 5661 tkm of scenario 2. Although scenario 2 has greater total distance traveled, ton kilometers indicates that new location is better (13-19%) when heavier inbound trucks to the UDC at scenario 1 is taken into consideration. This is, on the average, equal to 200 kg CO_2 emission per day [53] for 250 customer group.

Table 2. Comparison of Scenario 1 and Scenario 2

		Scenario 1 (UDC at Original Location)						Scenario 2 (UDC at New Location)			
Customer Group	Mean Freight Delivered (kg)	# of Routes		Mean Distance (km)		Mean ton-km		# of Routes		Mean Distance (km)	Mean ton-km
		Min	Max	inbound	delivery	inbound	delivery	Min	Max		
30	9099	5	6	71	935	322	789	5	6	1189	962
40	11866	6	8	71	1130	419	979	6	8	1456	1202
50	15272	8	10	141	1357	540	1233	8	10	1738	1485
80	23962	12	14	141	1881	847	1709	12	14	2454	2142
100	29785	15	17	141	2266	1053	2087	15	17	2953	2639
150	45107	23	25	283	3147	1595	2931	23	25	4163	3744
200	59683	30	33	283	3897	2110	3620	30	33	5155	4622
250	74745	37	41	354	4770	2642	4385	37	41	6333	5661

Scenario 3 and 4 under two echelon distribution scheme investigate introduction of two (satellite 1 and 2, see Figure 3) and three intermediate DCs suitably between the new location of the UDC and the customers. Routing at 1st level and 2nd level is carried out by vehicles with a capacity of 4500 kg and 2000 kg respectively. Scenarios are run for each customer group with 15 different data sets, which has randomly generated demand and location data. The observed mean results for all customer groups are presented at Table 3. There is no significant difference between 2-satellite scenario and 3-satellite scenario in terms of total distance traveled and total number of routes. However, it can be seen that 2-satellite distribution scheme yields slightly better ton-kilometers for all goods movement against 3-satellite scheme for groups over 100 customers (3-5%).

Table 3. Comparison of Two Echelon Scenarios, Scenario 3 and Scenario 4 (Mean Values)

		Scenario 3 (2 Satellites - #1 and #2)						Scenario 4 (3 Satellites - #1, #2, and #3)					
		1st Level			2nd Level			1st Level			2nd Level		
Customer Group	Freight (kg)	# of Routes	Distance (km)	Ton-km	# of Routes	Distance (km)	Ton-km	# of Routes	Distance (km)	Ton-km	# of Routes	Distance (km)	Ton-km
30	9099	2	242	436	6	812	618	3	314	474	7	755	568
40	11866	3	304	561	8	998	804	3	351	648	8	942	760
50	15272	4	369	691	10	1201	1014	4	459	821	10	1087	908
80	23962	6	541	1085	14	1632	1417	6	653	1280	15	1445	1284
100	29785	7	651	1335	17	1987	1787	7	780	1584	18	1798	1615
150	45107	10	955	2043	25	2722	2419	11	1130	2368	26	2494	2285
200	59683	14	1252	2714	32	3314	3029	14	1485	3152	33	3072	2866
250	74745	17	1559	3352	41	4022	3661	17	1834	3902	41	3756	3488

Figure 4 depicts results concerning all four scenarios. Results indicate that scenario 1 has the least distance traveled while scenario 2 has the most. Scenario 2 gives the least ton-kilometers movement and the rest shows higher pattern close to each other, only scenario 3 in differentiation at larger customer groups. The number of 2nd level vehicles of scenario 3 and 4, and those of scenario 1 and 2 looks similar, however number of inbound trunks in scenario 1 and 1st level vehicles in scenario 3 and 4 increases number of vehicles used in respective scenarios. Figure 5 shows a distribution solution for 50-customer instance in all four scenarios.

One can note that scenario 1, 3, and 4 differ from scenario 2 in the design as the former ones brings larger volume of goods to the center (the UDC or satellites) while the latter starts off at the edge of customer zone. This emphasizes the importance of keeping larger trucks away from city center. Our results show that, scenario 2 outperforms the other three scenarios in carbon emission by producing 20% less on the average.

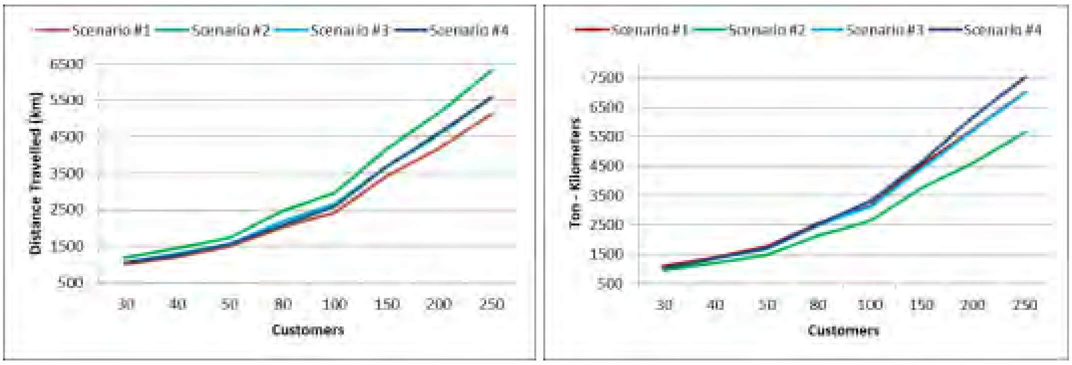
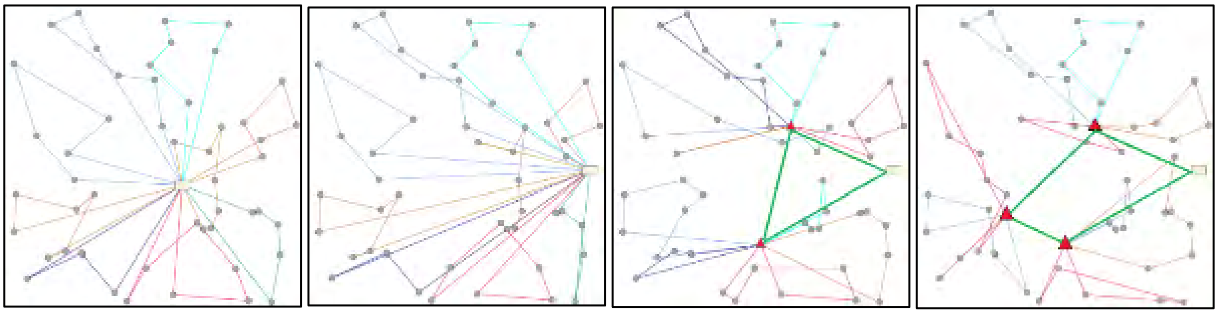


Figure 4. Comparison of 4 scenarios in terms of total distance traveled and ton-kilometers



Scenario 1 Scenario 2 Scenario 3 Scenario 4

Figure 5. A routing solution for 50-customer scenario instances

CONCLUSION

In this study, we proposed a methodology based on 2E-VRP, which utilizes a heuristic approach by solving CVRP at each level (in single and two echelon distribution scheme), to analyze and better understand the effects of UDC relocation in terms of goods movement in urban context (e.g., traveled distances, ton-kilometers, CO_2 emission). The aim was to get an "ex-ante" assessment to support policy decision making for all actors in city logistics, and to this end, we designed a hypothetical distribution network with four scenarios (#1 with the UDC at original location, #2 the UDC at new location, and #3 and #4 with intermediate 2 and 3 satellites respectively). The results show that the new location of the UDC in single echelon scheme (scenario 2) outperforms other scenarios by producing lesser ton-kilometers, number of vehicles, and CO_2 emission. We conclude (according to our assumptions of the hypothetical distribution network) that this totally concurs with the concept of keeping larger trucks out of city limits and routing goods with smaller trucks in the city.

This study indicates further analysis requirements by considering several other scenarios regarding the location and operating principles of satellites in 2-echelon distribution scheme. In our study, number and location of satellites were fixed and known in advance, and no time window or satellite synchronization was taken into consideration. Therefore, it would be useful to run scenarios by changing number and location of satellites and by implementing models with time management. Adding an integrated Geographical Information System (GIS) module would help debugging and presenting scenarios on real geographical data. Finally, a real life case study would be useful in verifying modeling approach and validating test results as well.

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A SIMULATION BASED MULTI-CRITERIA APPROACH FOR THE ANALYSIS OF SUSTAINABILITY FACTORS IN SUPPLY CHAINS

Fatih Tüysüz[1], Nurdan Yıldız[2]

Abstract **−** *Increasing global awareness of environment by the society and strict governmental policies have made organizations focus on sustainability issues. It can even be considered that sustainability has become one of the most important dimensions of competition. Maintaining sustainability is of strategic importance and requires careful management and planning. One of the important points in this strategic planning process is analyzing sustainability factors. In this study, we present a simulation based multi-criteria model for analyzing the sustainability factors in supply chains. The model integrates Monte Carlo simulation technique and Decision Making Trial and Evaluation Laboratory (DEMATEL) method. The presented approach enables to both analyze and reveal the causal relationships among sustainability, and also prioritize them according to their level of influence. The obtained results can be helpful in many strategic decisions and actions regarding sustainability.*

Keywords **−** *DEMATEL, Simulation, Supply Chain, Sustainability Factors.*

INTRODUCTION

Sustainability which can be defined as "*the development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs*" [1] has become one of the most important dimensions of competition. Supply chain (SC) can be defined as the sum of the processes from raw material purchasing until it reaches the customer after transformation [2]. Despite the economic contribution to the country, the supply chain activities cause various negative effects on the environment, such as pollution, waste, emissions etc. [3]. Sustainable supply chain management (SSCM) is that all the processes that make up the supply chain are operated without damaging the environment. Sustainability practices in the companies enable them to increase their efficiency, reduce their costs and use their resources effectively. In addition, they gain competitive advantage through society and organizations by paying more attention to environmental issues [4]. Besides, legal regulations about sanctions and the tendency towards green products by the society are pushing companies to the environmental regulations in order to have competitive advantage [5].

Maintaining sustainability is of strategic importance and requires careful management and planning of economic, social and environmental issues [6]. Organizations have to adapt their external and internal operations and activities to be more environmentally and socially responsible to maintain economic sustainability [7]. This requires the organizations to strategically analyze and understand the sustainability factors which can be characterized by complex relations [8]. Sustainability factors which can be qualitative or quantitative should be evaluated in a systematic way in order to improve decision making, identify strategic direction and determine productivity improvement opportunities [9]. Multi-criteria decision-making (MCDM) methods enable to evaluate both qualitative and quantitative factors. There are different MCDM methods and approaches in literature used for sustainability evaluation. The most recent studies can be found in [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20], [21].

Hence, this study presents a simulation based multi-criteria decision model for analyzing the sustainability factors in supply chains. The model integrates Monte Carlo simulation technique and Decision Making Trial and Evaluation Laboratory (DEMATEL) method. The presented approach aims at both analyzing and revealing the causal relationships among sustainability factors, and also prioritizing them according to their level of influence. The main contribution of the proposed methodology is that the integration of simulation into the DEMATEL method may increase the capability of DEMATEL method by enabling to represent uncertainty and variability inherent in the subjective judgements of decision makers.

The organization of the paper is as follows. In the next section, simulation-based DEMATEL method is presented. Then, an application of the simulation-based DEMATEL method on the influencing factors of SSCM is given. Finally, the conclusions are presented.

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SIMULATION BASED DEMATEL METHOD

DEMATEL method which was developed at the Geneva Research Centre of the Battelle Memorial Institute [22], [23] is based on matrix calculations and is used for finding direct and indirect causal relationships, and the strength of influence between the factors. DEMATEL has four main steps which are generating the direct relation matrix, normalizing the direct relation matrix, obtaining the total relation matrix and producing a causal/effect diagram [23]. There are different applications and extensions of DEMATEL method that can be found in [24], [25]. We propose a simulation integrated DEMATEL method for revealing the causal relationships among sustainability factors, and also prioritizing them according to their level of importance. Monte Carlo simulation technique is used to represent the variability and the uncertainty inherent in DEMATEL calculations. The algorithmic steps of the proposed approach are as follows;

Step 1. Determining the evaluation criteria and defining the linguistic scale: The evaluation criteria are established and an interval valued linguistic scale to better represent the ambiguities of human assessments is determined. Each element of the linguistic scale is defined as a uniform random variable with parameters *(a, b*). The probability density function for uniform distribution is defined as in Eq. (1).

$$f(x) = \begin{cases} \frac{1}{(b-a)}, & a \leq x < b \\ 0, & otherwise \end{cases} \tag{1}$$

where a is the minimum value and b is the maximum value. Table 1 presents the linguistic scale and the corresponding uniform variable.

Table 1. Linguistic scale and the corresponding uniform variable

Linguistic Term	Uniform Variable *(a, b)*
Very High Influence	(3.5, 4)
High Influence	(2.5, 3,5)
Low Influence	(1.5, 2,5)
Very Low Influence	(0.5, 1,5)
No Influence	(0, 0,5)

Step 2. Establishing the direct relation matrix: To measure the relationship between criteria shown as $C = \{C_i | i = 1, 2, \dots, n\}$, a group of experts are asked to make pair-wise comparisons in terms of liguistic scale given in Table 1. The initial direct relation matrix $X^k = [x_{ij}^k]$ is obtained, where k is the number of experts, $x_{ij}^k = [a, b]$ is the uniform random variable and $x_{ij}^k = [0, 0]$ for for *i=1,2,..,n.*

Step 3. Simulating the direct relation matrix: For each expert *k*, each element of the direct relation matrix which is defined as uniform random variable is simulated. Then, the average values are calculated for each element of X^k.

Step 4. Combining all direct relation matrices: All the direct relation matrices are averaged by using Eq. (2) and the aggregate matrix *Z* is obtained.

$$Z = \left(\sum_{i=1}^{k} A^k\right)/k \tag{2}$$

Step 5. Calculating the normalized direct relation matrix: The normalized direct-relation matrix *D* can be computed by normalizing the aggregate matrix *Z* as given in Eq. (3).

$$D = Z/s \tag{3}$$

where $s = max\left[max \sum_{j=1}^{n} z_{ij}, max \sum_{i=1}^{n} z_{ij},\right]$.

Step 6. Establishing the total relation matrix: After obtaining the normalized aggregate matrix *Z*, the total relation matrix *T* can be found by using Eq. (4).

$$T = D + D^2 + D^3 + \cdots + D^m = D(I - D)^{-1} \tag{4}$$

where $m \to \infty$ and *I* is the identity matrix.

Step 7. Calculating the sum of rows and columns: The sum of rows and columns are separately denoted as d and r within the total relation matrix T as in Eq. (5). For $T = [t_{ij}],\ i,j \in \{1,2,\dots,n\}$

$$d = (d_i)_{n\times1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times1} \text{ and } r = (r_j)_{1\times n} = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} \quad (5)$$

Step 8. Analyzing the results: d_i+r_i shows the total effects given and received by factor i and indicates the degree of importance that factor i plays in the entire system. If d_i-r_i is positive, the factor i affects other factors and is assigned to the "cause" group. If d_i-r_i is negative, then the factor i is affected by the others and assigned to the "effect" group.

APPLICATION OF SIMULATION BASED DEMATEL METHOD

In this study, Monte Carlo simulation technique integrated DEMATEL method is proposed for analyzing the causal relationships among sustainability factors in supply chains, and also prioritizing them according to their level of influence. Firstly, the sustainability factors were obtained by considering the literature which are presented in Table 2.

Table 2. Sustainable Supply Chain Factors

Code	Factor	Explanation
F1	Reduction of energy consumption [26], [27], [28], [29], [30], [31]	Decreasing the amount of energy such as fuel, electricity that are used in the all supply chain
F2	Reducing of packaging [32], [27], [29], [30], [33]	Minimizing of packaging Use/product of recyclable or reusable packaging.
F3	Minimization of waste and other polluting factors [26], [32], [30], [31]	Minimization of air emission, solid, liquid wastes etc.
F4	Avoiding the use of hazardous substances [26], [28], [30]	Reducing the amount of hazardous substances /materials used in production
F5	Environmental design of product/process [6], [26], [32], [27], [29], [30], [33]	Use of environmentally friendly materials and technology in manufacturing. Design of products for recyclable and reusable.
F6	Innovations in transportation possibilities [32], [29]	Selection of transportation methods, technologies and vehicles that less damages the environment.
F7	Efficient transportation planning [28], [30], [33], [34]	Optimization of loads, return loads. Minimizing the distance/route of transportation.
F8	Efficient inventory management [28], [29]	Optimizing the amount of inventory, Optimizing storage space, Warehouse location selection.
F9	Reducing use of resource and materials [28], [30], [31]	Decreasing the amount of resource such as raw material, water that are used in manufacturing
F10	Improvement of environmental cooperation with suppliers [27], [28], [33]	Imposing higher greener standards on suppliers and training them, Cooperation with suppliers implementing environmental management system.

After determining the sustainability factors, 8 experts who have knowledge and experience in supply chain field evaluated the effect of each factor on each other on a pairwise basis using the linguistic scale given in Table 1. The linguistic evaluations of each expert are expressed in uniformly distributed numerical intervals and the evaluation matrix of each expert is simulated separately with 1000 runs to prevent the impact of random variations. Averages of simulated matrices are calculated and a single direct relation matrix is obtained as given in Table 3.

Table 3. Direct relation matrix

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	0	1.2532	2.7516	1.0039	1.9079	1.9029	1.9078	1.7797	2.7147	2.2181
F2	2.8428	0	3.1582	1.4663	2.4698	1.6902	1.6926	2.0697	2.3768	2.1274
F3	2.3662	2.0027	0	3.0007	2.9005	1.4411	1.3179	1.3743	2.6869	2.9386
F4	1.8783	1.4038	2.6268	0	2.9049	1.8421	0.5324	0.9372	1.6607	2.2477
F5	2.2146	2.6873	3.2848	3.4698	0	2.9403	1.3097	1.3765	2.4681	3.2526
F6	1.9962	1.0326	2.3707	1.3792	1.7158	0	3.3770	1.8121	0.8425	2.1842
F7	2.9345	1.5619	1.7831	0.6867	0.7812	2.8426	0	2.3465	0.7855	1.9398
F8	2.8403	2.2503	2.2495	0.4684	0.8766	1.9130	2.4722	0	1.3429	1.8759
F9	2.7209	2.0949	2.9732	1.6881	2.1872	1.7779	1.4362	2.2209	0	2.3452
F10	2.6285	1.6875	2.9679	2.2512	2.8148	2.9348	2.3462	2.2508	2.0607	0

Then direct relation matrix is normalized using Eq. (3). Finally, total relation matrix is calculated using Eq. (4) and is presented in Table 4.

Table 4. Total relation matrix

Factor	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
F1	0.3048	0.2736	0.4303	0.2650	0.3341	0.3386	0.3041	0.2950	0.3439	0.3771
F2	0.4504	0.2537	0.4888	0.3121	0.3897	0.3653	0.3251	0.3338	0.3666	0.4132
F3	0.4367	0.3332	0.3789	0.3725	0.4123	0.3620	0.3119	0,3110	0.3809	0.4461
F4	0.3571	0.2668	0.4105	0.2183	0.3600	0.3218	0.2390	0.2488	0.2964	0.3643
F5	0.4751	0.3878	0.5467	0.4214	0.3442	0.4515	0.3475	0.3437	0.4073	0.4992
F6	0.3636	0.2509	0.3952	0.2620	0.3088	0.2528	0.3445	0.2831	0.2601	0.3576
F7	0.3777	0.2544	0.3553	0.2195	0.2590	0.3401	0.2095	0.2891	0.2438	0.3295
F8	0.3884	0.2895	0.3859	0.2223	0.2743	0.3179	0.3094	0.2105	0.2757	0.3399
F9	0.4381	0.3272	0.4739	0.3136	0.3734	0.3615	0.3107	0.3331	0.2702	0.4128
F10	0.4700	0.3383	0.5110	0.3595	0.4243	0.4350	0.3714	0.3604	0.3741	0.3590

d and *r* denote sum of column values and sum of row values in total relation matrix respectively. The results are presented in Table 5. Values of *d-r* and *d+r* show the cause and effect relation among the factors respectively. Positive value of *d-r* show that the factor effects the other ones while the negative value of d-r shows that the factor is influenced by the other factors. As seen in Table 5, while F1, F3, F6, F7 are influenced by the other factors, F2, F4, F5, F8, F9, F10 are in causal group that have effect on factors.

Table 5. The prominence and cause-effect relations for the sustainability factors

Code	*d*	*r*	*d+r*	*d-r*
F1	3.267	4.062	7.329	-0.795
F2	3.699	2.975	6.674	0.723
F3	3.746	4.376	8.122	-0.631
F4	3.083	2.966	6.049	0.117
F5	4.225	3.480	7.705	0.744
F6	3.079	3.546	6.625	-0.468
F7	2.878	3.073	5.951	-0.195
F8	3.014	3.008	6.022	0.005
F9	3.615	3.219	6.834	0.396
F10	4.003	3.899	7.902	0.104

Figure 1 displays the cause and effect relationships among the sustainability factors. Factors below the x-axis are affected by other factors. While F3 is the most important factor, when *d-r* values are taken into consideration, it is also a factor which is influenced by other factors. This may be due to the fact that waste and other pollutants are a factor that can occur at almost every stage of the supply chain. The factor that is most influenced by other factors is "the reduction of energy consumption" and this can be seen in Figure 1. "Reducing of packaging" and "environmental design of product/process" are the two most influential factors on the other factors and the result of the improvements to be made in these two factors will have more impact on the whole chain. Therefore, the companies can pay more attention to these two factors for achieving a sustainable supply chain.

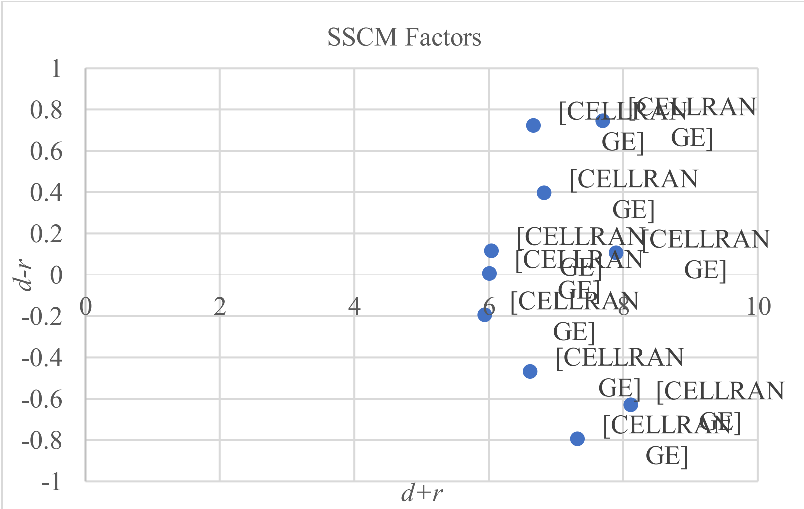

Figure 1. Cause and effect relationships among factors of SSCM

Since *d+r* value shows the degree of role each factor plays, *d+r* values can be utilized by normalizing them for prioritization of the factors. The importance of each factor is shown in Table 6. As seen in Table 6, the importance of the ten factors can be prioritized as F3 > F10 > F5 > F1 > F9 > F2 > F6 > F4 > F8 > F7 based on normalization of *d+r* values given in Table 5. The results show that "minimization of waste and other polluting factors" is a primary factor to be considered by companies with the value of 11.73% followed by "improvement of environmental cooperation with suppliers" (11.42%), "environmental design of product/process" (11.13%), and "reduction of energy consumption" (10.59%) respectively, while "efficient transportation planning" is the least important factor with the importance value of 8.60%.

Table 6. Factors of SSCM and their level of importance

Code	Factor	Importance (%)	Rank
F1	Reduction of energy consumption	10.59	4
F2	Reducing of packaging	9.64	6
F3	Minimization of waste and other polluting factors	11.73	1
F4	Avoiding the use of hazardous substances	8.74	8
F5	Environmental design of product/process	11.13	3
F6	Innovations in transportation possibilities	9.57	7
F7	Efficient transportation planning	8.60	10
F8	Efficient inventory management	8.70	9
F9	Reducing use of resource and materials	9.87	5
F10	Improvement of environmental cooperation with suppliers.	11.42	2

CONCLUSION

This study presents simulation based DEMATEL method for analyzing and assessing sustainability factors in supply chains. Simulation integrated DEMATEL method is proposed for revealing and analyzing the cause and effect relations of SSCM factors and also for the prioritizing them according to their level of influence. Since the proposed simulation integrated DEMATEL method takes into consideration the uncertainty and variability arising from the subjective judgements, it is an effective method that can be used in SSCM strategic planning process. Although the presented methodology was applied for analyzing the SSCM factors, it can also be used for many other real life problems to improve decision making, and also its integration with other methods and approaches such as analytic network process, balanced scorecard etc. can be considered for further researches.

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DIGITAL TRANSFORMATION OF SALES AND OPERATIONS PLANNING IN B2B ENVIRONMENT

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Abstract *– Sales and operations planning, a 30-year framework; sub-processes, requirements, roles and responsibilities of S&OP have been discussed over and over. It has revised many times; throughout the years new process steps have been developed and companies constantly improved it by learning from each other. Especially in the last 15 years, companies have put S&OP in the middle of planning processes and devoted considerable resources, however many companies still cannot benefit effectively from the benefits of S&OP. Even if it is a process that does not have a lot of challenges, implementing and maintaining S&OP efficiently still continues to give companies rough times. Being only process-based or tool-based concentrate causes this planning transformation to be overlooked that S&OP is as primarily a matter of change management. Especially in the digital world where speed is increasing hyperbolic and in the business environment competition is evolving, the implementation of the S&OP becomes more difficult. Therefore, traditional methods should be watched and the blessings of the digital world in the supply chain should be reflected in tactical processes such as S&OP. In this paper the contribution of the digital transformations to the S&OP process is examined with best practices in B2B environment and the further development points are determined.*

Keywords – Business to Business, Digital Transformation, S&OP, Sales and operations planning

1. INTRODUCTION

The consequence of rapid digitalization of the world is that human life has entered to very different route than used to be. The reflection of this change in the business world takes place far beyond imagination. The steam-powered spinning machines are developed in a textile factory in British countryside in the 18th century, has ignited the fire of Industrial Revolution moreover the business processes have changed irreversibly. The change in industry had followed by mass production in 19th century and automatization in 20th century. Also with digital transformation it has been continuing go beyond the ordinary. The difference of this transformation from the other revolutions is that it affects all business processes not just production processes. Nowadays, from human resources to logistics, from budgeting to production, digitalization on processes is trendiest topic of companies.

Exponential rapid development in digitalization has led to the integration of unspoken technologies in business processes over the last few years. Also, with these developments, processes in the supply chain are also rapidly transformed. From purchasing to customer delivery, the processes are transformed one by one. In today's competitive environment, companies which not apply the benefits of digitalization in their supply chain, shouldn't expect good results in future. On the bright side, companies provide continuous improvement in customer service levels and costs by changing business manners with developments in technologies like advanced robotics, cloud computing, machine learning etc.

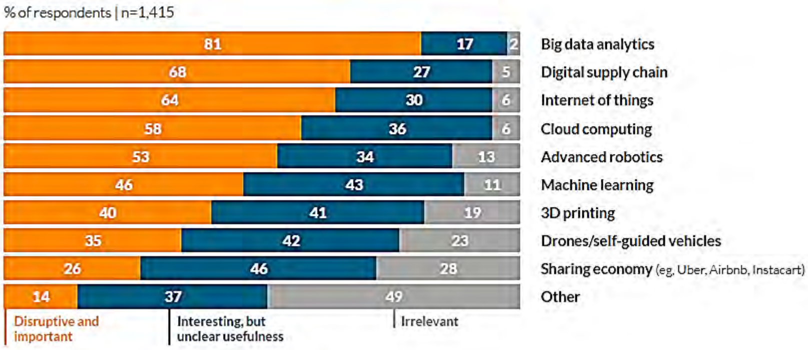

FIGURE 1 "Disruptive and Important" technologies with respect to supply chain strategy (SCM World,2016)

In the SCM World's survey, which is one of the most important supply chain institution in the world, supply chain managers demonstrate big data analytics as the most disruptive and important technology. It is

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followed by the digital supply chain with digital goods, money and information flows, and IOT (Figure 1) [1]. In the same surveys have been conducted since 2014, the percentages of defining technologies as disruptive and important have increased by about 20 points. It shows that managers are better able to realize that now they can find the answers of their needs in these technologies.

1.1. Sales and Operations Planning

The companies carry out numbers of planning and implementation activities on different horizons in order to carry out their processes more efficiently across the suppliers to the customers. The planning horizons vary from 5 years to 1 day. These planning processes are divided into three as strategic, operational and tactical according to the significance and duration. Most companies set the Sales & Operations Planning process at the center of planning for the linkage between the 5-year corporate strategic plan & annual business plans and the company's daily plans.

S&OP is a cross functional process and also a tactical process that takes place in monthly cycles on a 3-18 month horizon. Over the years, the companies understood the progress and benefit of the process, which was firstly developed by Dick Ling in the 80s, and focused on improving S&OP sub-processes [2]. With SCM groups, consulting firms and various organizations, S&OP sub-processes have become more explicit and process actions become more prominent. Execution of S&OP, which does not have too many complex actions when defined on paper as a process, is more difficult than envisaged. Almost all units in the company have to contribute to the process at some point moreover this cross- functional process needs to be monitored at the C level. High need of integration and participation makes process management difficult.

S&OP is the integrated planning of the resources of the organization by the units in order to be used efficiently in the future. The S&OP is a routine process that effectively ensures collaboration between departments on the identified horizon. The goal is to reach a single medium and long-term plan that will guide the firm and be agreed upon by all relevant units within the organization. Sales and operational planning balances critical resources such as workforce, capacity, materials, time and capital so that market needs can be met effectively and profitably. Sales and operational planning increases collaboration within the organization by enabling different units to focus on a single plan [3].

The S&OP has 5 main objectives:

- Increasing customer service level to reduce costs and increasing supply chain performance by lowering inventory levels
- Establishing a common plan for balancing supply and demand across product groups, including all units
- Efficiently planning current/new product requests, optimizing capacity and increasing collaboration between departments
- Ensuring that common reporting processes and performance criterias are used throughout the company
- Continuous tracking of common KPIs that enable different units to focus on the same targets

The S&OP monthly cycle has 6 main process steps (Figure 2) [3], [4]. The process starts with data preparation. The first step is to read the data from the systems to use in S&OP templates and transfer them to templates. Then, previous period KPI reports are made and planning is done considering these KPIs. In addition, market intelligence data are analyzed and prepared for demand planning.

Product portfolio progresses parallel with data preparation. In this step, the product development team identifies new products that will enter the market and products to be delisted. At this time, the cannibalization effect of the new products moreover ratios and products will be transferred from demands of the delisted product, should be determined in advance. Another step in product portfolio planning is that the marketing unit sets up a campaign / promotion schedule, and the effect on the demand of these marketing activities must be determined throughout the planning horizon.

In step 3, the sales team performs demand forecasting at the required level through the prepared data and marketing activities. The details of this demand plan may change throughout the horizon. For example, while demand forecasts are being prepared at the SKU level for the first 2 months, for the remaining period, can be made on product group basis. This detail requirement must be determined according to production and supply lead time durations during process design. After preparing the demand plan at the SKU level in the required time and detail to prepare the production and procurement plan, long term demand forecast at the level of product group is determined to provide the rough capacity planning and high level resource planning.

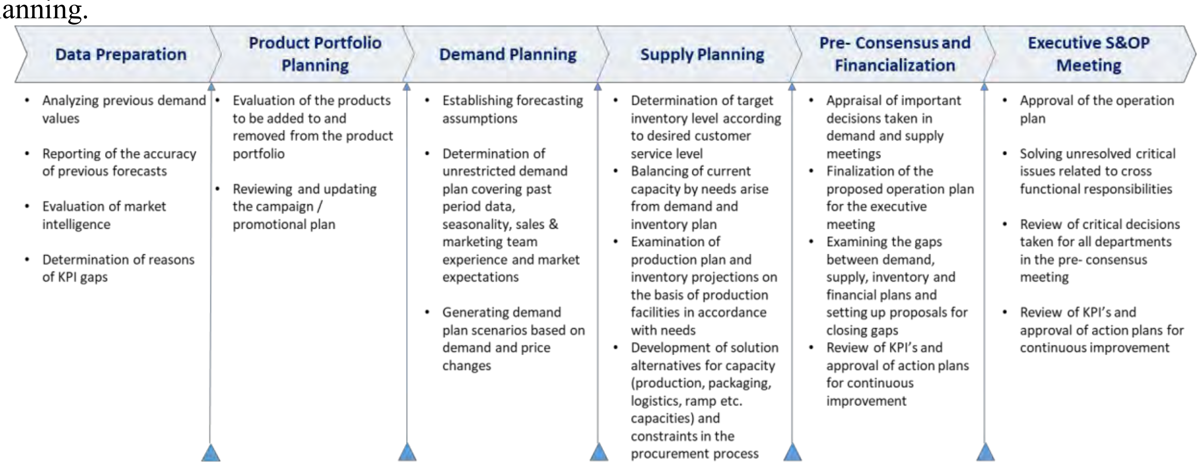

FIGURE 2 6 Steps of S&OP Monthly Cycle

There is a set of data that the supply team needs before the production / procurement plan is worked in line with the demand forecasting. The firm's inventory policy and production constraints are the variables that are required for the operational plan to meet the demand. Operation plan is to be developed meets the specified demand plan and inventory policy according to the current situation, while meeting the production constraints (optimum lot size, route, line availability, etc.). During this study, operating team creates production scenarios by determining production variables (number of employee, shift, working hours, machine, etc.) according to capacity occupancy. Planned production, inventory and supplied demand quantities are calculated with the scenarios throughout the horizon as the output of this study.
Before the executive S&OP meeting, the operations and sales teams gather and discuss the problems through the plans that are being worked on, and agree the scenarios that can be advanced. By the financial transformation of the agreed scenarios, projections of revenue, cost, profit and inventory amounts are calculated if each scenario is realized. An income statement for each scenario is created. Then an agenda is prepared for the Executive S&OP meeting. Budget, financial statement gap analysis and KPIs are reported to form the final version of the agenda.
At the Executive S&OP meeting, the final future plan of the company is agreed by reviewing each scenarios. The actions are determined by examining the critical issues on the plan. At the same time, actions are identified for performance indicators not performed good results. As a result of the decisions, the final plan all units will follow is agreed upon.
In this paper pain points of traditional S&OP process are going to be analyzed, and matched with current digital solutions. As a result, the map of digital transformation of Sales and Operations Planning will be displayed as a framework. This paper consists of 5 main part. In the problem definition part, S&OP process steps are going to be examined and the improvement areas of process steps will be defined. After definition of problem, the previous works try to answer similar cases are going to be researched. Proposition of this paper is going to follow literature review. In that part, implementation of S&OP process in a production company is going to be reviewed and the effects of digital transformation to the improvement areas will be reflected. In the sequel the framework - map of digital transformation of S&OP – is going to be asserted.

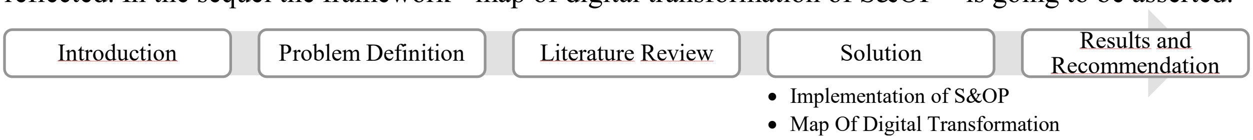

FIGURE 3 The Organization of the Paper

2. PROBLEM DEFINITION

Although S&OP seems to be a process with simple steps, execution without information technologies support presents difficulties for companies because of increased the weight of scenario work by involving of financial transformation in the post-2010. Without information system support, the process emphasized in section 1 is done entirely on electronic spreadsheets. However, this situation increases the workload on the units and affects the health and sustainability of the process. Therefore, units reduce their commitment on the process, stretch compliance with the process schedule, or renounce some of the process steps. In progress of time, KPI performances are declining and efficiency of the scenarios is decreasing. The result is less profitable and lower compatible plans. Consequently, the use of systems to support the end-to-end process is crucial for today's S&OP.

The Supply Chain Trend group, an international supply chain organization, asks about the problems of various sized firms applying S&OP from various sectors in the S&OP Pulse Check survey that are conducted every year [5]. Responses of the 59 company executives who surveyed the 2017 questionnaire about the roadblocks in the S&OP can be seen in the figure 4

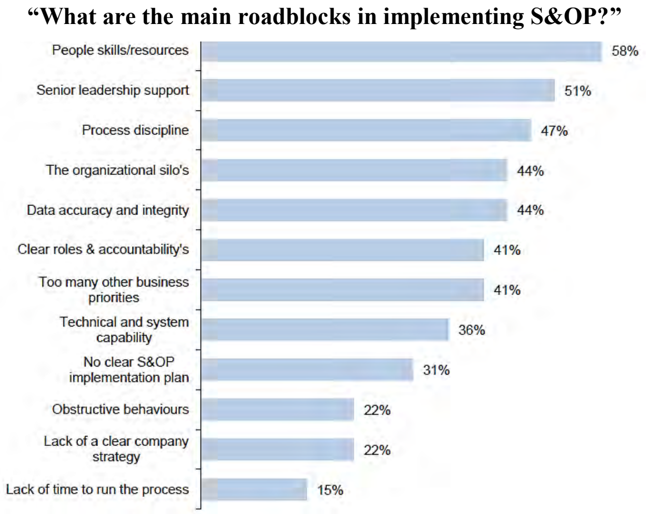

FIGURE 4 Supply Chain Trend S&OP Pulse Check Survey (N:59) (2017)

Although the most important roadblocks seem like human resource management, lack of system is the main reason to most of these problems. Effective use of IT has a direct impact in matter such as people skills / resources, data accuracy and integrity, technical and system capability, lack of time to run process, too many other business priorities (Figure 4).

One of the other questions of this survey is the usage of technology. 51% of the 59 respondents stated that they need S&OP systems and that the innovations in this area is weak.

If the results of survey are considered deeply, in particular, the problems that firms face the most difficulty in S&OP process design can be highlighted as change / employee management and technology usage.

In that case which S&OP activities need system support and how the system should use in this activities? This question is the main focus area of this paper.

3. LITERATURE REVIEW

Although the S&OP is a framework launched in the 1980s, in recent years, it has been under more scrutiny by academic circles. So, compared to other topics, there is not much academic researches involved. However, consulting firms or companies are frequently trying to explain some issues about the S&OP. Moreover when the subject is defined as the digitalization of S&OP processes, the research frame is getting smaller.

Demand planning is one of the focus of the studies of S&OP. If get away from the S&OP frame and focus only on the demand planning function, a lot of research could be found. In the demand planning process, traditional forecasting techniques like Smoothing Algorithms, Holts & Winters, and Autoregressive Integrated Moving Average can be done more easily with statistical tools. Also, forecasts with lower error and learning models can be built up with the development of machine learning, decision trees, artificial neural networks, multi linear regressions, Bayesian methods. However, it is very important for these model to maintain clean, reliable, detailed data. When the target variable to be achieved (demand quantity) is determined, it is more possible to reach better forecasts with the model that is fictionalized based on effects of the decision variables (exchange rate, weather, population, purchasing unit price, demographic structure of the market, number of workdays etc.) to target variable and the correlation between decision variables. In addition, factors such as campaigns/promotions can be measured more effectively and by arranging

campaigns/promotions parameters, the change of demand in future can be estimated. All such analyzes are called predictive analytics. However, to do this kind of analysis requires use of specialized tools (SAS Enterprise Miner, SPSS, HANA, etc.) generated for this purpose [7].
In this regard, in 1998 David E. Goldberg and John H. Holland have shown guidance on the use of genetic algorithms with machine learning, and the effects of supply chains have been directly observed in the following years [8].
In 2004, Real Carbonneau, Kevin Laframboise, and Rustam Vahidov compared the use of machine learning techniques with supply chain variables to investigate the use of more complex techniques to improve forecasting success, reduce costs, and provide greater customer satisfaction. Neural networks and support vector machines techniques were used in this research as well as traditional methods such as naive forecast, moving average, multiple linear regression. As a results they studied out machine learning techniques suits well for supply chain target and decision variables [9].
In the master thesis prepared in 2015, it was investigated that besides models mentioned above, decision trees, Bayesian, and artificial neural networks, which can be used in non-linear data sets, can be used in predictive analytics studies. In this point, it has been seen that the gradient boosting methodology, a derivative of the decision tree algorithm, neural networks and multi linear regressions are a successful models for predictive analytics. For the different data sets in this case for different product groups best fitted predictive model can be chosen for forecasting demand. This create responsive demand plans for different environments [8].
The relationship between S&OP's and Big Data analytics yet another up-to-date technologies is topic under discussion. For major organizations, the size of the information required for demand forecasting, the information generated by the company and the information to be used for the supply plan is increasing rapidly. Even if predictive models can produce successful outputs, it is more important and difficult to extract useful information from the huge and enormously increasing size of data. In a research report on Big Data analytics published by APICS, one of the world's most important Supply Chain platforms, it is mentioned that with the help of Big Data, optimal decision support systems that cannot be provided by current information technologies will be maintained and information gap between suppliers and customers in supply chains will be reduced majorly [10]. Also in the report, the global supply chain leaders been asked some questions and answers were analyzed. As a result of the analysis, it is predicted that the development of different data formats and systems will sustain to more processed data and more processed data will lead more elaborative optimization of the stock levels, demand management and production scheduling. At this point, productivity is expected to increase in the processes required by S&OP or integrated planning.
In the question asked to executives "what areas of supply chain information should deliver more actionable information and insight?", 79% of the respondents answered as "Forecasting, planning and scheduling across supply chain". For "which benefits they would expect if supply chain and operations management data became more accessible across their organizations?" question, %78 of respondents answered as "Planning and decision making such as S&OP would improve across the organization" (Figure 5). In the same survey, "Top three areas that would benefit the most from big data" question is answered as "forecasting, S&OP or operation planning" with more than %40 percent for each.

"What areas of supply chain information should deliver more actionable information and insight?"

"Which benefits they would expect if supply chain and operations management data became more accessible across their organizations?"

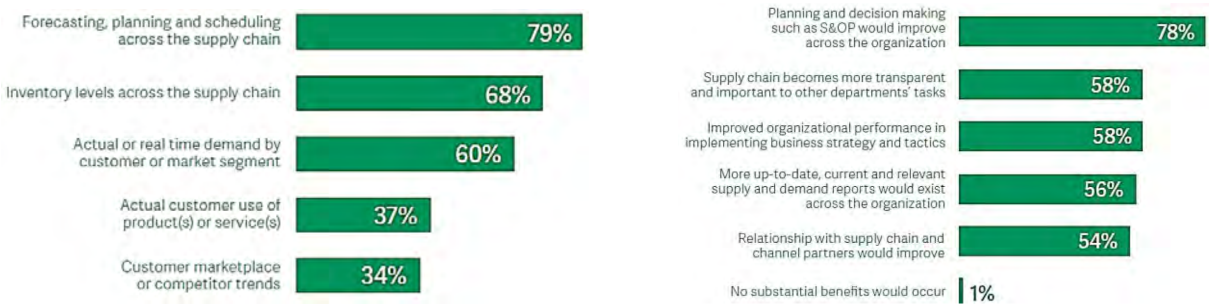

FIGURE 5 Data Analytics & S&OP (APICS, 2015)

Like demand planning, inventory planning is another input to supply planning and an also one of the main improvement areas. One of the most important planning issues are determining the stock strategies that will

minimize inventory & storage costs while maintaining the desired customer service level. Herein, the multi-echelon inventory optimization approach has been developed to reduce the costs of the entire supply chain, not to make special optimizations to processes or stockpiles as is the traditional single-echelon methodology. The most important aspect of Multi-Echelon Inventory Optimization is to optimize globally the trade-off between inventory related costs and service level. In this regard, inventory and cost reasons are examined. Furthermore, production strategies (make-to-stock, make to order, finish to order) are determined on a product basis, and the inventory locations and quantities to be kept are determined based on this production strategies. With selected models and algorithms, inventory strategies are periodically updated in a data-driven manner and optimization is continuously ensured [11] Significant improvements are achieved with the multi-echelon inventory optimization tools generate operation research models which evaluates variables such as production lead times, inventory locations, distribution channels, transport links, demand and demand fluctuations for multiple layers of the supply chain (Logility, 2017).
Two researches at Chalmers University concentrated on the use of advanced planning and scheduling systems in the S&OP process [12][13]. The mathematical algorithms or logic used by the APS systems and the ability to operate what if scenarios in S&OP process and constraint-based optimizations have been seen as supporting competencies for the S&OP system. The relationship between the S&OP steps and the APS functions and benefits are stated in the article can be seen in Table 1 (Linea Kjellsdotter Ivert and Patrik Jonsson 2010).

TABLE 1 Potential Benefits of APS System to S&OP (Ivert and Jonsson, 2010).

S&OP activity	Aim of the activity	Potential APS system support	Potential benefits
Activity 1 Activity 2	Creating the sales forecast Creating the delivery plan	Statistical forecast methods, demand planning tools able to integrate different departments/ companies	Results in a reliable demand plan, visualization of information, makes information easy to access, resulting in good knowledge about the supply chain
Activity 3	Creating a preliminary production plan	Calculating an optimized production plan in a LP model for the three production sites, what-if analysis if demand is changing	Results in an optimal production plan, makes it possible to identify/ analyze future events, allow quantifiable what-if analyses, visualization of information, makes information easy to access
Activities 4 and 5	Adjust and settle the production plan	Calculating an optimized production plan in a LP model for the three production sites	Gives a common an optimal production plan, visualization of information, makes information easy to access, simplifies planning activities
S&OP meeting	Identify risks and discuss reaming and unsolved issues	Visibility of information	Makes it possible to analyze the problem picture as a whole, makes it possible to identify/ analyze future events, visualization of information, makes information easy to access

In a study practiced in Vestel Electronics, a Turkish technological product producer, the effects on the firm of a decision support system to be established in the S&OP process have been measured [14]. With the help of the developed mathematical model supported decision support system, the planning period has been reduced, the efficiency of the S&OP process has been increased, the number of meetings in the process can be increased and the success level in the scenario works has been increased. Planning accuracy has been improved because DSS can work better than manual methods with customer orders and market data. As a result of the MRP works, the needs have been optimized and inventory levels have been reduced. In addition to these gains, process visibility and traceability have been increased and the tension in the planning process has been reduced (Z. Caner Taskin, Semra Ağralı, A. Tamer Ünal, Vahdet Belada, and Filiz Gökten-Yilmaz, 2015,).

4. DIGITAL TRANSFORMATION OF S&OP

S&OP can be seen as a cumbersome process however with the need of the emerging market and competition conditions of today even though it is continuously improved over the years. Addition the financial

transformation step to the S&OP, converted it to integrated business planning and turned it to more compelling business process. At this point, which points of S&OP can benefit from digital transformation of processes and what are the effects of this transformation on the firm, should be examined.
In this sense, a S&OP process, implemented at a motor manufacturer firm, will be examined and a map of the technologies that can be used in the S&OP process will be created by starting from the improvement points of implemented process.

4.1. The Implemented S&OP Process

A low voltage electric motor producer company sells products to the dealers or/and OEMs. The company has two types of production strategy. Standard products are produced with make-to-stock and special products are produced with make-to-order strategy.
The Sales and Operations Planning process steps which include improvement points that are designed and implemented by Consulta Management Consulting in this firm and are as follows.

Demand Planning:

- Generating channel and product / product group based sales forecasts for 12 months by receiving sales forecasts from OEM customers, adding market forecasts & estimates for dealer channels by salesmen
- Examining KPI gaps of previous periods
- Consolidating sales forecasts of salesmen and generating cumulated sales forecast by the sales and marketing manager
- Creating best case, worst case and ordinary demand plan scenarios by changing parameters for channels and product groups
- Sharing demand plan scenarios with operation team

Supply Planning:

- Examining previous period performance by analyzing KPI gaps
- Updating master data of new entrant products
- Updating related sales, inventory, production data from ERP tables
- Calculating starting inventory volumes by product for planning horizon
- Updating target inventory days by product
- Calculating suggested production volume based on formula consists of current inventory, current production, current order volume, target inventory days and demand plan
- Creating unconstrained supply plan by balancing suggested production volume with economic lot size
- Constraining supply plans according to process/machine/line based capacity gauges and creating supply plan scenarios by changing capacity parameters like overtime, shift number etc.
- Calculating inventory plan by supply plan, demand plan and starting inventory volume
- Calculating fulfilled demand volume and sharing it to finance department with inventory plan

Financial Transformation:

- Updating product price list and costs
- Calculating gross revenue using satisfied demand volume and price list
- Defining discount and bonus rates for each channel
- Calculating product based costs (route, raw material, Cost of Goods of Sold)
- Creating income statement for each scenario
- Financialization of inventory volumes and calculating inventory days through horizon

Executive S&OP Meeting & Agenda Preparation:

- Establishment of process KPI reporting
- Preparation of presentation deck
- Preparation of previous S&OP meeting decisions and actions
- Discussion of critical issues, identification of action steps and responsibilities
- Evaluation of sales and planning strategies and scenarios
- Determining the final plan that the units will follow by selecting the most appropriate scenario

By designing this process, cooperation among business units has been increased, inventory levels have been reduced and customer satisfaction has been targeted to be increased. Some of these goals have been achieved, but in order to achieve further development, the process structure needs to continue to be developed. Considering the employee, technology and time constraints, the problems in this process are listed as below.

- Demand forecasting accuracy is not at the desired level
- Inability run high-quality scenarios due to time constraints and operational daily works
- Targeting more decrease in inventory levels
- Deviation at discount assumption
- Non-systematically created production policy
- Master data update takes much time
- Problems with validation of different Excel files, master data contradictions
- The difficulty of working in large size and number of excel files

4.2. Map of Digital Transformation of S&OP

This designed process provides a good theoretical and practical application of the S&OP in general practice. But if the current situation and company size are considered, the above mentioned problems will also arise in most well-designed S&OP processes in this competition environment. Under current conditions the cause of this problems is spreadsheet-based management is not enough to cover all needs of S&OP fundamentals. At this point, the sub-process steps to be covered by information technologies in the process should be examined. When all these solutions are combined, a decision support system will be established for the executives and they will be able to allocate more value-added jobs such as analyzing at decision points, working on the scenario instead of collecting and cleaning data and preparing spreadsheets.
In this context, the process steps are examined; and which researched digital solutions can be used in the S&OP sub-processes are shown in the following Table 2.

TABLE 2 Benefits of Information Technologies to the S&OP Sub-Processes

Process Step	Required IT support	Function	Expected Benefit
Demand Planning	Big Data & Data Mining • Cleaning • Clustering • Classification	• Collecting the data from all channels, reaching meaningful data and creating information from piles of data	• Extracting useful information from massive size data in order to ensure model accuracy to increase demand forecast accuracy
	Machine Learning • Create algorithms on target and independent variables • Genetic algorithms	• Due to determining the independent variables and examining the correlation between them, statistically estimating the demand in the future	• Statistical estimation based on new learning algorithms instead of traditional methods to increase the accuracy of demand forecasting
	Predictive analytics • Artificial Neural Networks • Multi-layer perceptron • Support Vector Machines	• Effective calculation of the effects on demand of the independent variables controlled by the firm and selection of the most appropriate forecasting models based on product group/channel	• According to understanding how tactical prices, promotions, campaigns, etc. will affect the demand, studying what-if scenarios (It is the most mature step of S&OP demand planning process.)
	Business Intelligence	• Analyzing KPIs, accuracy of budget and demand forecasting, performing GAP analysis with dashboards • Determination of critical alert algorithms	• GAP analysis, monitoring of critical condition alerts, revision of statistical estimation with expert opinion
Inventory Planning	Multi Echelon Inventory Optimization • Network Topology • Deterministic Models • Stochastic Models	• Optimize the place, quantity and strategies of inventory to ensure the highest advantage by lead times, demand, customer service level, costs, and deviations of these variables	• Determining best inventory strategies and quantities for each layer in supply chain in accordance with demand, lead time and production constraints • Identifying best spot in the tradeoff between cost and service levels
Production Planning	Advanced Planning and Optimization • Advanced Planning and Scheduling • Supply Network Planning • Master Production Scheduling	• Production planning according to the requirements determined on the demand and inventory plan • Synchronization of production plan with raw material, semi-finished product, production and capacity constraints • Determination of how much of the needs will be covered by production at what location	• Ability to change and monitor the effect of changes of sources like shifting, overtime, employee number, outsourcing volume, machine number on production volume • Prepare what if analysis to meet the production constraints and capacity constraints while meeting the demand and inventory plan
Financialization	Business Intelligence	• Calculation of estimated income according to the requested demand, determination of gross profit by calculating estimated costs • Stock amount conversion	• Calculate net income more accurately by automatically determining the discounts and premiums which can be gross income calculated over the list prices, based on product and channel

			• Financialization of inventory amount by estimated and actual costs
S&OP Process Flow	Business Intelligence	• Data consolidation • Process follow-up • Approval mechanism • Alert mechanism • Standard templates • Data flow • Collaboration	• Data consolidation through a BI tool enables all units to use the same data • Creating standard templates to minimize the need for spreadsheets • Design of workflow and data flow on a platform, establishment of approval and warning mechanisms, reduction of added value work in the S&OP process and minimization of human error • Improving clearance and accuracy of data that are generated during the process and transferred via BI
KPI Reporting	Business Intelligence	• Automatic reporting of identified KPIs	• Automatically calculating dashboards created for process KPIs with up-to-date data, reducing spreadsheet complexity, increasing KPI reporting reliability, reducing workload

When the information technology methods written in the table 2, are combined with S&OP processes, digital transformation of S&OP can be easily mapped. In the following framework map, digital transformation of S&OP can be traced (Figure 6).

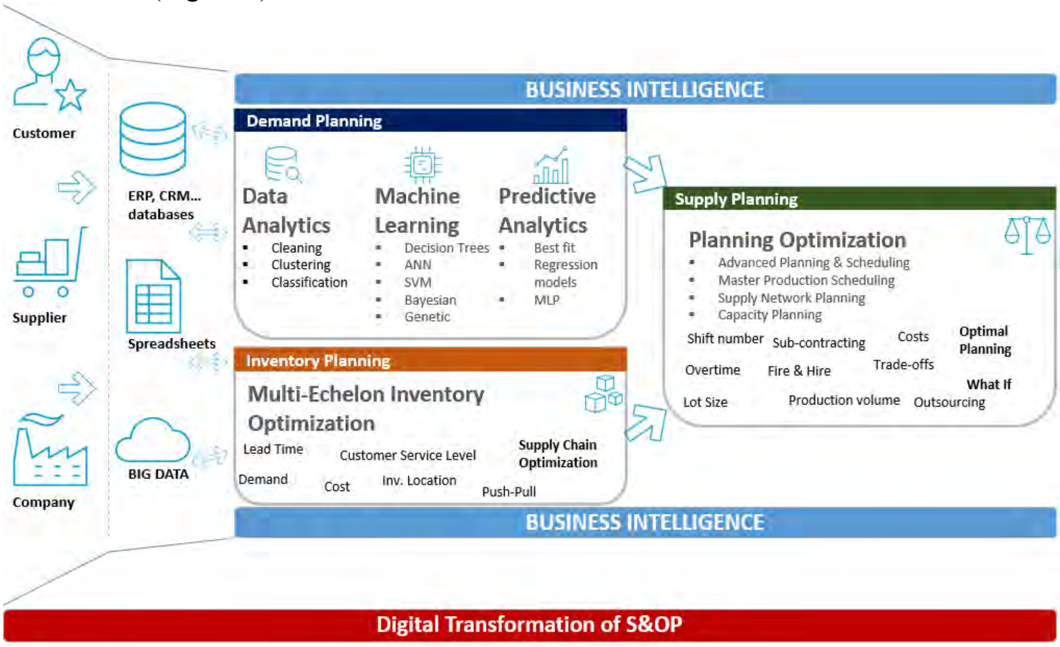

FIGURE 6 Digital Transformation Map of S&OP

5. RESULTS AND RECOMMENDATIONS

Although sales and operation planning fundamentals have been developed for many years, it seems that traditional methods are not enough to meet the offered service level while keeping up with the rapidly changing technological and competitive environment. As a result, it is not expected that the planning processes will not be influenced by developing information technologies.
The use of data required to optimize tradeoffs between customer service level, inventory cost and quantity, production efficiencies and quantities exceeds human competence. The effects of big data analytics on firm planning come into play in this regard. The evolution of Sales & Operations Planning, which begins with big data, will reduce gap between market and organization, and it also will help to better understand of forecasting and managing demand with the use of data mining, machine learning and predictive analytics. In the growing supply chains, multi-echelon inventory optimization models that are examine whole chain thorough global to local are taking the place of the single-echelon model as a cost-and-flexibility advantage in inventory management. The aggregate supply planning of needs created from these two sub-processes can also be done with operations research models again instead of electronic spreadsheets. It's realized that creating what-if scenarios will provide the greatest benefits for the company by setting tradeoffs between planning variables, at desired process speed that cannot be done with electronic spreadsheets. The business intelligence tool is in effect when the process is financed and managed. The use of the same data set in all

analyzes, the creation of dataflow and workflows, the management of emergency alerts and confirmation mechanism with a BI tool will reduce data pollution in the process, minimize unnecessary workload and enable S&OP participants to make more detailed analyzes at decision points. Usage of BI at the S&OP Executive Meeting will support decision making process by prepared KPI & financial templates, drill-down analysis to understand the causes of critical issues.

The decision support system that will be created with the help of digital transformation of S&OP map will not only increase efficiency in the decisions to be made but will also create a more suitable environment for change management and human management. Manipulative actions will be reduced and a cleaner agreement environment will be created between the units.

The digital transformation of S&OP may also develop in different forms, however just like Industry 4.0, it is going to be a must, and companies that couldn't not adapt to it will have difficulty in competition.

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CREATING PRODUCT GROUPS AND AGGREGATING STOCK KEEPING UNITS (SKUs) FOR DAIRY PRODUCT

Seyithan Yıldız[1], Batuhan Kocaoğlu[2]

Abstract *– When planning the product and production line in the supply chain, it is necessary to aggregate the products in order to provide a collective view and to plan sourcing and machine groups within the production hierarchy. After we aggregate the categories, we will have our product groups and machine parks; so product structures and capacity requirements can be expressed in product categories. Demand forecasting and raw material procurement can be planned according to these categories in the first stage. In this study, how to create product groups for collective planning, methods, options and factors (production trails, production or consumption type, quality values etc.) in the sales operation planning (S & OP) process will be examined first. Then, a methodology will be presented by examining the methods and options for how disaggregation of forecast results, SKUs (disaggregation), based on product groups created. Applicability of the developed methodology to the product structure of a company that produces milk and dairy products will be examined. The goal is to create a method for better aggregation and disaggregation.*

Keywords *– Aggregation, Disaggregation, S&OP*

INTRODUCTION

The most important issue within the supply chain is the demand forecast. Demand forecasting can also be done by aggregating products and making aggregate demand forecasts by distributing groups of all items. The aggregation and disaggregation ensures a consistent planning approach throughout the firm. The sum of the values in the detail level is always equal to the sum in the collection level.

After we aggregate the categories, we will have our product groups and machine parks; so product structures and capacity requirements can be expressed in product categories. Demand forecasting and raw material procurement can be planned according to these categories in the first stage.

In this study, how to create product groups for collective planning, methods, options and factors (production trails, production or consumption type, quality values etc) in the sales operation planning (S & OP) process will be examined first. Then, a methodology will be presented by examining the methods and options for how disaggregation of forecast results, SKUs (disaggregation), based on product groups created. Applicability of the developed methodology to the product structure of a company that produces milk and dairy products will be examined. The goal is to create a method for better aggregation and disaggregation.

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DEFINITION AND PURPOSE OF THE AGGREGATION AND DISAGGREGATION

Definition of Aggregation and Disaggregation

Aggregation refers to the function whereby key figure values on detail level are automatically summed up at runtime and shown or planned on aggregated level. If, for example, you display the forecasted demand for a region in the interactive planning table, you see the forecasted demand that the system has summed up for the various distribution channels, product families, brands, and customers, for that particular region.

Disaggregation refers to the function that automatically provides the details of a key figure value from aggregated level on detail level. If, for example, you forecast the demand for a particular region, the system breaks the value down immediately into the distribution channels, product families, brands, products, customers, and so on in this region.

Aggregation and disaggregation ensure a consistent planning approach throughout your organization. The sum of the values on detail level always equals the total on aggregated level. Key figure values are always saved on the lowest level of detail. If aggregates exist, the data is also saved on this aggregate level.

Definition of S&OP

A process to develop tactical plans that provide management the ability to strategically direct its business to achieve competitive advantage on a continuous basis by integrating customer focused marketing plans for new and existing products with the management of supply chain. The process brings together all the plans for the business (sales, marketing, development, manufacturing, sourcing and financial) into one integrated set of plans.

Another definition of S&OP is; S&OP is a senior management decision-making process that ensures that the tactical plans in all business functions are aligned and support the business plan. In other words, S&OP is about piloting your daily operations and monthly plans toward your long-term business goals. It's about getting everyone headed in the same direction – including your contract manufacturers, suppliers, distribution, partners, and customers.

S&OP means different things to different people. It's been called:

- The heartbeat of a company
- Top management's handle on the business
- A company's command and control system

A platform for continuous improvement that sits between the strategic business plan and the tactical day to day operations.

The Purpose of Aggregation and Disaggregation

Production planning consists of two steps: aggregate planning and disaggregation. Aggregate planning is done at the types' level with an objective of minimizing the total costs that include production cost, inventory holding cost and labor cost.

In the dairy plant, each type has its own production cost, inventory holding cost and labor cost. As an example, the milk production cost is less than the cheese production cost while it has more inventory holding cost. All these costs are included in the objective function of the aggregate planning to minimize the total cost. The output of the aggregate planning is the number of units to be produced of each type during each period.

Disaggregation is done at the family level. The purpose of disaggregation is to determine a production schedule for the families with the objective of minimizing the setup costs that are incurred during production changes from one family to another. In addition, it also aims at maintaining consistency and feasibility between production decisions that were made during aggregate planning and during the process of disaggregation itself. In the dairy plant example, changing the production from the cheddar cheese family to the cottage cheese family has a certain setup cost. The disaggregation objective is to minimize the total setup cost within the production schedule by minimizing the number of setups.

The Advantages of Aggregate Plan

The advantage of the aggregate approach to a detailed one may now be cleared. These advantages can be divided into three distinct categories.

The first category considers the costs of data collection to support the model as well as the computational cost of running the model. As the number of items increases, this effort can become unwieldy, leading to deterioration of the data used in the planning process and therefore the output. In most cases, this cost of data collection and preparation will far outweigh the cost of computation. This is important to note as the cost of computation continues to decrease and it becomes feasible to solve enormous linear or nonlinear programming problems. Aggregation items can significantly reduce the cost and effort in demand, forecasting and data preparation in addition to decreasing the computational cost.

The second category considers the accuracy of the data. Unless all items are perfectly correlated, an aggregate forecast of demand will have reduced variance. Since decision on regular time, overtime, hiring, and firing, other production rate chances are based on the total production quantity demanded, increased, forecast accuracy, on the total demand should improve the decision-making process.

Finally, and perhaps from an implementation standpoint, most importantly, aggregation leads to more effective managerial understanding of the model's result. When 10.000 items are being planned simultaneously, the sensitivity of the results to changes in individual item demands may be complex. There are too many combinations of changes to consider. The manager may never be able to see the overall picture but, instead, be lost in the details.

In addition, at this level of managerial planning, most marketing forecasts are made by product group and decisions made by product line or manpower class. These are the budgeting decisions, not lot sizing decisions for next week. It is crucial that the decision variables and sensitivity analysis that can be carries out correspond to those with which the managers deal.

Problem Definition

One of the biggest problems with 12-18 month forecasting and scheduling is the accuracy of demand. Demand forecasts made on SKU basis will not be consistent, costs will be inconsistent and accuracy will be reduced.

It will take a long time to work between thousands of SKUs, careful attention will not be given. This will cause both the inefficiency of the work and the great loss of time. So, there will always be mistakes and inconsistencies in the plans.

In summary, estimating demand among thousands of SKUs causes significant time and resource losses. In long periods such as 12-18 months, it leads to inconsistencies in the targets and increases costs.

Proposed Methodology

The main step of methodology for aggregation is in the below.

1. Basic product groups will be identified. This step will be based on the basic definitions of goods.
2. Then, the basic categories will be parsed. The following yes/no questions should be answered to make this separation. The order of importance may differ from company preferences.

a. Are there any differences in the production technique?
b. Are there any differences in the quality values of the raw materials used?
c. Are there any differences in product quality values?
d. Are there any differences in marketing method?
e. Are there any differences in sales channels?
f. Are there any differences in consumer preferences?
g. Are there any differences in consumption channels?

3. After the groups made according to the above questions; ask them again the same questions until there is no sharp differences in each group.

CASE STUDY: CREATING PRODUCTION GROUPS AND AGGREGATING

General Information about Company

The subject of this study is one of the leading milk and dairy products companies in Turkey. They have regional offices, warehouses and distribution networks in different cities of Turkey.

Most of its products are consumed domestically and also exported to the Middle East and Turkic Republics.

Contents of Study

In this study, how to create product groups for collective planning, methods, options and factors (production trails, production or consumption type, quality values etc) in the sales operation planning (S & OP) process will be examined first. Then, a methodology will be presented by examining the methods and options for how disaggregation of forecast results, SKUs (disaggregation), based on product groups created. Applicability of the developed methodology to the product structure of a company that produces milk and dairy products will be examined. 113 SKUs of the firm will be examined. Aggregation can be done as raw materials, raw materials quality values, production schemes, consumption product or product presented on the market. In this study, different main groups will be formed and one of these groups will be selected. After this main group is selected, the 113 SKU will be disaggregated to these groups.

Solution Approach and Applied Methodology

An integrated plan is needed to increase the accuracy of forecasting, to calculate the costs correctly and to make realistic planning for the future. For this purpose, aggregation groups should be formed. The following methodology will also be followed to create aggregation groups.

Step 1: Basic product groups will be identified. For example, cheese is said to be more than 1,800 varieties in the world and will start in Step 1 as 'Cheese' as a group. Similarly; Regardless of the type of production, quality and consumption habits, our other groups will also be grouped by their base names. They are ‘Cheese, Yoghurt, Milk, Ayran, Cream and Butter’.

Step 2: In this step, for each basic category, the production type, quality and consumption style will be separated. For example, Ayran will drink widely at home and out of home. Bottle Ayran is consumed at home, Glass Ayran is consumed out of home like restaurant, cafe etc. So, we need to distinguish Ayran group as 'Bottle Ayran' and 'Glass Ayran'. For Milk, both the mode of production and consumption habits of daily milk and long-lasting milk are completely different. So, we will group them in the form of 'Pasteurized Milk' and 'UHT Milk'. In this way, different subgroups are created for all the basic groups.

Step 3: A sub-group can be created according to methods like those in Step 2. As an example, we have created a Homogenised Yogurt group from the Yogurt. We can split it into full fat and half fat yogurt. Or we could create another group that is a house type yoghurt.

In addition to the above steps, within each product group, the methodology is also described under the all aggregation groups. This method can be applied for all milk and dairy products producers.

When such groupings are made, the categories in the existing processes of different departments within the company should be examined. Different departments such as production, sales, finance, procurement are grouping differently in their internal processes. With reference to these, more integrated groups can be created.

Create Aggregation Group

In this study, there are 113 SKUs to examine. To make aggregation group will proceed according to the mentioned methodology. Total list of SKUs is at the Appendix 1.

The main groups mentioned in Step 1 will be identified. These main groups are generic definitions, and for the purposes of any grouping, are largely the decomposition from the definition of the product at first sight. So, the basic name or category of a product is defined by most general dictionary definition. It is like naming a Book, just as a Book, regardless of its type. So, the main criterion here is the general definition of the product. These are;

- Yoghurt
- Cheese
- Milk
- Ayran
- Cream & Butter

Now we are going to Step 2 to create the actual groupings.

We divide yogurt category into two group as crusted yogurt and homogenized yogurt.

Table II – 2 Aggregation Groups for Yogurts

YOGURT
1- Crusted Yogurt
Plastic Pan - 6 SKU
Plastic Bowl - 5 SKU
Plastic Bucket - 1 SKU
2- Homogenised Yogurt
Homogenised Full Fat - 6 SKU
Homogenised Fatty - 2 SKU
Homogenised Semi Fat - 9 SKU
House Type - 6 SKU

The reason why we divide 2 groups in this way is that the production of 2 categories is completely different. Moreover, these two groups are totally different in terms of consumer habits and different marketing strategies are applied. In this way, we have grouped products both in terms of sales and in terms of production. The only disadvantage of this grouping is that they are semi-oily and full-fat yogurt. In fact, the production patterns of these two categories are exactly the same, only the milk quality values used are different. So, they are examined together, so as not to increase the number of groups.

Table III – 4 Aggregation Groups for Cheese

CHEESE
1- White Cheese - 14 SKU
Full Fat, Semi Fat, Light Cheese in different pot
2- Yellow Cheese
Kashar Cheese - 6 SKU
Buffet Type Melting Cheese - 2 SKU
3- Process Cheese
Labne - 7 SKU
Spreadable Cheese - 3 SKU
4- Traditional Cheese - 9 SKU

We divided the cheese category into 4 groups. In this group, white cheese and yellow cheese are completely different in quality and production processes, different from sales strategies and marketable ones. In Process Cheese, they are more specialized and processed products in the production technique. Traditional Cheese is; Hellim, Yuruk, Village, Braided, Mozzarella, Tongue, Civil and Smoked cheese.

Table IV – 3 Aggregation Groups for Milk

MILK
1- Flavored Milk
Banana, Strawberry, Chocolate Milk - 4 SKU
2- UHT Milk
Fatty Milk - 5 SKU
Semi Fatty Milk - 4 SKU
Light Milk -1 SKU
3- Pasteurized Milk
Bottle Milk - 2 SKU

We divided the milk category into four groups. They are Flavored, Pasteurized and UHT. The reason for the separation of pasteurized milk is the short shelf life. The other milk has a shelf life of 6 months; Daily milk shelf life is only one week. Separation between UHT and Flavored Milk is clearly for flavored. Flavored Milk includes Banana, Chocolate and Strawberry flavors.

Table V – 2 Aggregation Groups for Ayran

AYRAN
1- Bottle Ayran - 3 SKU
2- Glass Ayran
Buttermilk (Yayık) - 3 SKU
Fatty - 3 SKU

We distinguished the Ayran category by 2 groups. This is because the consumption places are completely different. Bottle Ayran is consumed at home, while Glass Ayran is consumed out of home like restaurant, café etc. While the price politics and marketing tactics are totally different, the management process is completely different.

Table VI – Aggregation for Butter & Skimmings & Creams

BUTTER & SKIMMING & CREAM
Butter - 6 SKU
Skimmings - 3 SKU
Cream - 2 SKU

In this category; butter, cream and skimming are produced from raw milk fat. So, we will consider it as a single group instead of dividing it into groups. Since all products are produced in raw milk fat and there is no large volume for production, logistic and sales; they will be grouped together.

So, in this study, our aggregation groups are in the following.

1. White Cheese
2. Process Cheese
3. Traditional Cheese
4. Yellow Cheese (Kashar Cheese)
5. Flavored Milk
6. UHT Milk
7. Pasteurized Milk
8. Homogenised Yoghurt
9. Crusted Yoghurt
10. Bottle Ayran
11. Glass Ayran
12. Butter/Skimming/Cream

CONCLUSION AND RECOMMENDATIONS

From this work, a product group of dairy and dairy products and the aggregation method were identified. And according to this aggregation method, product groups were disaggregated. The main purpose is to move faster and make decisions in processes like S & OP process, demand forecast, rough production plan. It will take a very long time to generate the demand forecast separately for hundreds or thousands of SKUs and make the whole production plan, the accuracy will be low.

In this way, processes with high speed, simplicity and high accuracy can be achieved.

This work was made specifically for milk and dairy products, taking into account machine tracks, consumption habits and production patterns. Each product has its own quality values (fat, protein, total dry matter, etc.), which can also be taken into consideration when working. Also, different combination methods can be tried in different sectors and product groups.

This work has provided a basic aggregation and can be the starting point for a company that produces milk and dairy products. Groups were made according to the consumption pattern for some products, production pattern in some groups, and both in some groups.

In this study, the departments of procurement, logistics and finance departments are not available. For example, some of the products are carried at +4 degrees while others can be moved at room temperature. So, logistics, procurement, or financial perspective lines can be included in this grouping in the next studies. In this way, a richer grouping of all the departments will be made.

On the other hand, we have not distinguished most products according to their quality values. For example, half-fat and full-fat products are grouped together. This is also the reason for the production. Consumption habits are thought to be different and a different aggregation methodology can be developed according to the market researches to be done.

For further studies, disaggregation methodology of the created groups (outputs of developed S&OP plans), will also be studied. In addition, the aggregation groups will be studied on how to make an aggregate plan and its methodology.

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Appendix 1: The List of Production SKUs

No	Code	Definition
1	111010	Yoghurt Hom FF Bowl 1500 G
2	111020	Yoghurt Hom FF Bowl 1250 G
3	111030	Yoghurt Hom FF Bowl 1000 G
4	111040	Yoghurt Hom FF Bowl 750 G
5	111050	Yoghurt Hom FF Bowl 500 G
6	111060	Yoghurt Hom FF Bowl 200 G
7	115010	Yoghurt Hom FF Bucket 9 KG
8	118010	Yoghurt Hom Fatty Bucket 2250 G
9	118011	Yoghurt Hom Fatty Bucket 2250 G Labeled
10	121010	Yoghurt House Type Drum 5 KG
11	121020	Yoghurt House Type Drum 4 KG
12	121030	Yoghurt House Type Drum 2 KG
13	121031	Yoghurt House Type Drum 2 KG Labeled
14	121040	Yoghurt House Type Drum 1 KG
15	121041	Yoghurt House Type Drum 1 KG Labeled
16	131010	Yoghurt Hom SF Bowl 1500 G
17	131020	Yoghurt Hom SF Bowl 750 G
18	131030	Yoghurt Hom SF Bowl 500 G
19	131040	Yoghurt Hom SF Bowl 150 G
20	131050	Yoghurt Hom SF Bucket 1750 G
21	135010	Yoghurt Hom SF Bucket 18 KG
22	135020	Yoghurt Hom SF Bucket 9 KG
23	135030	Yoghurt Hom SF Bucket 2250 GR
24	135040	Yoghurt Hom SF Bucket 2 KG
25	151022	Yoghurt CRM 1500 G
26	155010	Yoghurt CRM Pls Pan 5 KG
27	155020	Yoghurt CRM Pls Pan 2 KG
28	155030	Yoghurt CRM Pls Pan 1500 G
29	155040	Yoghurt CRM Pls Pan 1 KG
30	155041	Yoghurt CRM Pls Pan 1 KG Labeled
31	157010	Yoghurt CRM Bowl 1500 G
32	157020	Yoghurt CRM Bowl 1250 G
33	157030	Yoghurt CRM Bowl 1 KG
34	157040	Yoghurt CRM Bowl 750 G
35	157050	Yoghurt CRM Bowl 500 G
36	158010	Yoghurt CRM Bucket 2000 G
37	211010	Cheese White FF Tin 17KG
38	211020	Cheese White FF Tin 5 KG
39	211030	Cheese White FF Tin 1 KG
40	211040	Cheese White FF Tin 500 G
41	211060	Cheese White FF Vacuum Pack 250 G
42	214010	Cheese White FF Pls Box 1 KG
43	214020	Cheese White FF Pls Box 500 G
44	215010	Cheese White FF Round Bucket 7 KG
45	215020	Cheese White FF Round Bucket 4 KG
46	215030	Cheese White FF Round Tin 500 G
47	217010	Cheese White SF Tin 17 KG

No	Code	Definition
58	311040	Milk UHT Fatty 500 ML
59	311050	Milk UHT Fatty 200 ML
60	321030	Milk UHT Light 200 ML
61	331010	Milk UHT Semi Fatty 10 L
62	331020	Milk UHT Semi Fatty 1 L
63	331030	Milk UHT Semi Fatty Eco Pack Quad 1 L
64	331040	Milk UHT Semi Fatty 200 ML
65	345010	Milk with Banana 27 Pcs 200 ML
66	345020	Milk Strawberry 27 Pcs 200 ML
67	345030	Milk Chocolate 27 Pcs 200 ML
68	345040	Milk Chocolate 6 Pcs Pack 200 ML
69	351010	Milk Pasteurized Bottle 1 L
70	351020	Milk Pasteurized Bottle 500 ML
71	411010	Cheese Kashar FF Block 700 G
72	411012	Cheese Kashar FF Block 700 G Other
73	411020	Cheese Kashar FF Picnic 500 G
74	411030	Cheese Kashar FF Fresh 400 G
75	411040	Cheese Kashar FF Fresh 250 G
76	415010	Cheese Kashar FF Block 2 KG
77	441010	Cheese Buffet Type Melting 2 KG
78	441012	Cheese Buffet Type Meltin 2 KG Other
79	461010	Cheese Labne Bucket 3 KG
80	461020	Cheese Labne 500 G
81	461030	Cheese Labne 200 G
82	461050	Cheese Labne 200 G Licensed
83	461070	Cheese Labne 1000 G
84	461080	Cheese Labne 400 G
85	463010	Cheese Labne 15 G
86	465010	Cheese Spreadable 200 G
87	465030	Cheese Spr Fresh 200 G Licensed
88	467010	Cheese Spreadable Fresh 15 G
89	471010	Cheese Braided Vacuum 250 G
90	473010	Cheese Mozarella Block 2 KG
91	476010	Cheese Tongue Vacuum PVC 250 G
92	478010	Cheese Civil Erzurum Vcm PVC Pack 250 G
93	481010	Cheese Smoked 300 G
94	521010	Ayran Buttermilk 12 Pcs Cup 300 ML
95	521020	Ayran Buttermilk 20 Pcs Cup 200 ML
96	521030	Ayran Buttermilk 20 Pcs Cup 180 ML
97	525010	Ayran Fatty 20 Pcs Cup 180 ML
98	525020	Ayran Fatty 20 Pcs Cup 200 ML
99	525030	Ayran Fatty 12 Pcs Cup 300 ML
100	531010	Ayran Pls Bottle 2 L
101	531020	Ayran Pls Bottle 1 L
102	531021	Ayran Pls Bottle 1L Labeled
103	613010	Butter Block 1 KG
104	613013	Butter Block 1 KG Other

48	217020	Cheese White SF Tin 1 KG
49	217030	Cheese White SF Pls Box 1 KG
50	220010	Cheese White Light Pls Box 500 G
51	254010	Cheese Hellim Vacuum PE Pack 250 G
52	255010	Cheese Yuruk Bucket 9 KG
53	255020	Cheese Village Pls Pack 500 G
54	261010	Cheese Yuruk Tin 1 KG
55	311010	Milk UHT Fatty 10 L
56	311020	Milk UHT Fatty 1 L
57	311030	Milk UHT Fatty Quad Eco Pack 1 L

105	615010	Butter Buttermilk 500 G
106	615020	Butter Buttermilk 250 G
107	631010	Butter Bowl 15 G
108	631020	Butter Bowl 10 G
109	911010	Skimmings 850 G
110	911030	Skimmings 8 Pcs Pack 200 G
111	911090	Skimmings 8 Pcs Pack 200 G Labeled
112	921010	Cream 1 L
113	921020	Cream For Breakfast 200 ML

ACCESS POINT LOCATION SELECTION PROBLEM FOR A LOGISTICS COMPANY

Gizem İlhan[1], Ceren Eroğlu[2], Zehra Düzgit[3], Ayhan Özgür Toy[4]

Abstract *– We consider the location selection problem for access points where two phases of shipment process, namely pick-up and delivery of packages, will be carried out aiming to increase accessibility by customers. The company will sign a contract with the existing shops such as newsagent's shops, pharmacies, supermarkets etc. to provide access point service for the company. When a package cannot be delivered to the customer, it is sent back to the hub and dispatched for the second time, which is called "send-again". In order to determine the locations of access points, two major criteria are considered: distribution of package volumes and the rate of send-again according to locations. The number and the location of access points must be determined such that all service demand is satisfied and total cost, including send-again cost, is minimized. This problem is modelled within the frame of set covering approach.*

Keywords – access point, location selection, logistics, set covering

INTRODUCTION

This study focuses on access point location selection problem of a logistics company which provides domestic and international package services and supply chain solutions in global.

Package flow process consists of two phases: picking up the packages and delivering the packages. The residential customers can release packages to branch offices of the company or they can create calls via call center for the packages to be picked up by a courier. After the call is created by the customer, related package center directs courier to the customer for picking up operation. Corporate customers have opportunity to send notice via an online platform. The collected packages are sent to hubs where the evening operation is processed. In the evening operation, packages are sorted according to the delivery points and then, they are loaded into the appropriate courier vehicles according to their delivery address. Each courier is responsible for a specific district or neighborhood.

The delivery process continues until 18:00 on the same day and the packages which could not delivered to the customer, either due to a customer originated or company originated problem, are sent back to the hub and loaded second time to the lines. The situation in which the package did not reach the customer is called "send again". The entire package flow process is explained in Figure 1.

In addition to existing branch offices, the company wants to make contracts with access points, like local shops around residential customers such as coffee shops, groceries, dry cleaners, florists, where they can get or drop their packages easier within a closer distance. By this way, undelivered deliveries can be rerouted to an access point or customers may opt to get their packages from access points directly, without making multiple attempts regarding send again packages.

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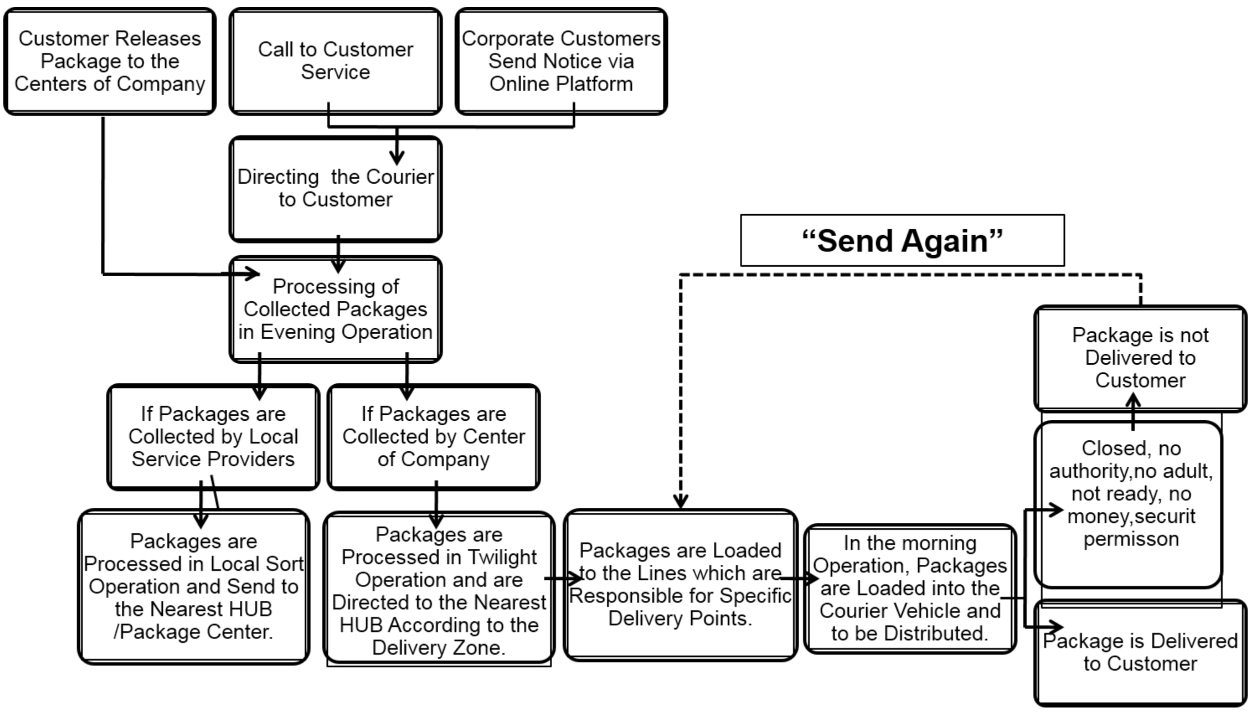


Figure 1. Package Flow Process

PROBLEM DEFINITION

The aim of the study is to determine the number and the location of access points to be opened with minimum cost, so that all customer points are matched with at least one access point within a given distance. These access points will be places, where customers may pick-up and deliver their packages but, these will not be new branch offices that company will build or rent. The company will sign contracts with existing shops such as newsagent's shops, pharmacies, supermarkets etc. to provide access point service for the company.

To be able to determine the number and the locations of access points, two major criteria should be considered:

- Distribution of package volumes
- Rate of send again according to locations

The access points should be primarily located on the areas where the demand density and rate of send again are high. The effectiveness of location selection is measured by the closeness to the customer. Therefore, the distribution of the demand over demand zone should be considered when selecting optimal location.

The reason for considering send again while choosing the optimal access point locations is to identify the problematic areas over demand zone and to increase accessibility at those areas through opening new access points so that, the extra costs caused by send again situation could be decreased.

The send again packages are sent back to hub to be loaded to the lines which are responsible for specific delivery points and to be processed in morning operation while loading packages to the courier vehicles. The consequences of this situation are:

- Increase in operation time in hubs
- Increase in the work load of operation worker
- Increase in work load of courier due to visiting same address more than once
- Decrease in the number of packages that can be delivered in the following day
- Increase travelling cost

Instead of returning undelivered packages to the hub and joining the same operations twice, if the packages could be left to some point for later delivery by the customer, the cost per package and the other problems that originate from send again could be solved.

The goal of this study is to increase the accessibility of the company by its customers through opening new access points for delivery and picking up, and to enhance the process from sender to receiver.

LITERATURE REVIEW

Facility location decisions are critical issue for wide range of companies and logistics companies are one of them as locating hubs and branch offices are strategically important. So, in this section we go through facility location, hub location and covering problems in literature in terms of their classification and applications.

[1] provide a review about models for covering problems in facility location, by classifying literature in terms of set covering problems and maximal covering location problems. [2] study and relate the covering problem and the central facilities location problems. Under the scope of covering problem, the total cover problem and the partial cover problem are investigated. By generalizing the partial cover problem, an equivalent central facilities location problem is obtained.

In [3], three different techniques are applied to solve set covering problem. Firstly, a mathematical model of set covering problem is introduced and solved by using optimization solver, LINGO. Secondly, the Genetic Algorithm Toolbox available in MATLAB is used to solve set covering problem. And lastly, an ant colony optimization method is programmed in MATLAB programming language.

[4] classifies location problems into 4 classes as: facility location, p-median, p-center and covering problems. A continuous stochastic facility location problem is considered and three different methods are proposed to select a facility location so as to minimize stochastic setup and transportation costs, given an interval on the number of opened facilities.

A case study takes place in [5] to select the location of logistics center for a province. Different site selection methods are explained, including the center of gravity method which is implemented for the problem to minimize total transportation cost.

[6] focus and categorize hub location problems and several mathematical models are given for variants of the problem. Solution approaches are also classified as exact methods, heuristics and meta-heuristics. [7] gives a literature review on location of logistics hubs, by examining models and solution approaches.

[8] present a survey regarding facility location problems, by classifying location problems, including covering problems.

DATA ANALYSIS

There are two types of data on hand which include data for 720,000 delivered packages during a particular month:

Monthly Total Delivery

Monthly Total Delivery data keeps date, country, street name, street number, city name, package driver name and package barcode number information for each delivered package. In addition to these, there is also a column which shows GPS codes of each delivery point.

Monthly Send Again

Monthly Send Again data shows the first scan date, delivery date and delivery points' coordinates information for the each re-send package within a month.

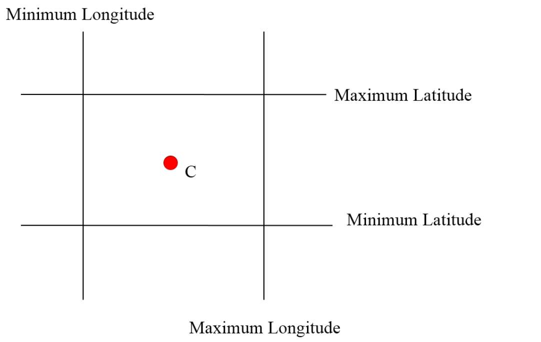
DATA PROCESSING

Before explaining the proposed solution approach, the big data is processed to be able to integrate it into the solution:

Partitioning Demand Points

The first step is to group each demand point with respect to their physical closeness on the map. Each courier is responsible for a particular demand zone which contains the demand points that are really close to each other. According to Total Delivery data, 720,000 packages were delivered by 227 different couriers. This means that, Istanbul could be partitioned into 227 demand zones as a starting point.

The following step is to find the center of these demand zones. For this purpose, the extreme latitudes and the longitudes were found for each driver in the raw data. The centers were specified by centroid method as shown in Figure 2.



C = (Max. Latitude - Min. Latitude, Max. Longitude - Min. Longitude)

Figure 2. Centroid Method

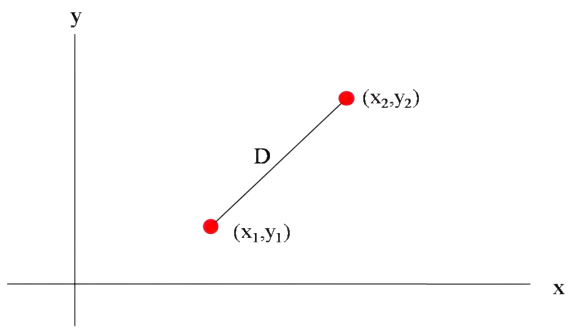
After finding the center of demand zones, all deliveries in that demand zone are assigned to the center of that zone by pivoting raw data with respect to driver names. By this way, these center points become aggregate demand zones.

Calculating the centroids of demand zones is an essential part because, if there were no other constraints, the easiest way to improve accessibility would be opening an access point in the center of each demand zone. However, this is not the case. The centroids of the demand zones can only be shown as candidate points for becoming access points.

Calculating Distance Between Centroids of Demand Zones

After converting the data into the compact aggregate form, the following step is to calculate distances between these possible access points and demand points because one of the most important factors, that affect which access point will serve which customer point, is the distance between them.

The method which is used to calculate distance between centroids is Euclidean distance formula. As shown in Figure 3, according to the Euclidean distance formula, the distance between two points in the plane with coordinates (x_1, y_1) and (x_2, y_2) is computed.



$$D = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2}$$

Figure 3. Euclidean Distance

The distance between two latitudes is 111 km and is same everywhere on the Earth surface while the distance between the two longitudes is gradually decreasing from Ecuador to poles. When the location of Istanbul on the Earth surface is considered, it is seen that the distance between the two latitudes is 84 km.

Finally, after applying this procedure for each pair, a distance matrix is obtained which shows the distance between each possible access point and each demand zone.

MATHEMATICAL MODEL

This problem is modeled within the frame of the set covering approach. A mathematical model is constructed to select the best access points subject to company policies. General Algebraic Modeling System (GAMS) is used to solve the problem.

Sets

The model is built on two sets, i and j, whose definition and domain are given below:

i: Candidate access points (i = 1, 2, 3, ...,227)

j: Aggregate demand zones (j = 1, 2, 3, ... ,227)

Decision Variables

There are three decision variables to solve this problem which are; Y_i, $X_{i,j}$ and $F_{i,j}$. As shown in (1), Y_i is a binary decision variable being equal to 1 if access point i is chosen to be opened (0, otherwise). If an access point is opened, it might be matched with aggregate demand zones and $X_{i,j}$ is a binary decision variable reflecting the assignment of demand zone j to access point i, as shown in (2). As shown in (3), $F_{i,j}$ specifies the number of packages that are released to access point i from demand zone j.

$$Y_i = \begin{cases} 1, & if\ the\ i^{th}\ access\ point\ is\ opened \\ 0, & otherwise \end{cases} \tag{1}$$

$$X_{i,j} = \begin{cases} 1, & if\ \ the\ i^{th}\ access\ point\ is\ matched\ with\ j^{th}\ aggregate\ demand\ zone \\ 0, & otherwise \end{cases} \tag{2}$$

$$F_{i,j} = number\ of\ packages\ released\ to\ access\ point\ i\ from\ aggregate\ demand\ zone\ j \tag{3}$$

Parameters

The parameters of the model are listed below:

- $D_{i,j}$: Distance between access point i and demand zone j
- A_j: Aggregate demand in demand zone j
- S_j: Number of send again packages in demand zone j
- T_j: Planned maximum distance between demand zone j and its matched access points
- K_i: Amount of money paid by the company per package to access point i
- L_i: Monthly fixed cost paid by the company to access point i, in case it is opened
- C1: Fuel and maintenance cost of courier vehicle per km during delivery and pick-up processes
- C2: Cost of send again per package
- M: Sufficiently large positive number

Parameter $D_{i,j}$ is a 227 x 227 matrix and shows distances between access point i and demand zone j, as computed in data processing part. Through pivoting Monthly Total Delivery and Monthly Send Again data with respect to demand zones, A_j shows aggregate demand and S_j shows number of send again packages.

This problem is a coverage required set covering problem and T_j presents planned maximum distances between demand zones and their matched access points. The parameter is specified with respect to package densities of each demand zone. The upper and lower bounds for the distances were determined by the company as being 1 and 5 km. The distance categorization according to aggregate demands is shown in Table 1.

Table 1. Planned Maximum Distances

Aggregate Demand (Packages)	Distance (km)
0 – 2000	5
2000 – 5000	4
5000 – 15000	3
15000 – 30000	2
> 30000	1

The company will pay a fixed monthly fee to the shops that provide access point services, and an additional fee for each package that they receive or deliver. The monthly fixed cost paid by the company to an opened access point i (L_i) and the amount of money will be paid per package (K_i) will directly affect the decision that access point i will be opened or not. It was decided that these fees could be proportional to the price of rental shops in same neighborhood. For each candidate access point location, a market research is done that is based on real estate index and the renting prices per square meter is found. Later, we asked for the average fees for the monthly and per package payments that the company is willing to pay at most. Average fixed monthly fee is given to be 500 TL and average per package payments is given to be 1 TL. The median value of monthly renting prices was found, each candidate point's monthly rental was grouped as being equal to, less than or greater than the overall median value of monthly renting prices. Then, payments to be made for each access point are calculated according to the conditions in Table 2.

Table 2. Access Point Payment Conditions

Monthly renting price (TL/m^2)	Monthly fixed payment (TL)	Per package payment (TL)
= Median Value	500.00 TL	1.00 TL
< Median Value	Directly proportional to renting prices. (250.00 TL – 500.00 TL)	1.00 TL
> Median Value	Directly proportional to renting prices. (500.00 TL – 622.55 TL)	Directly proportional to renting prices. (1.00 TL – 2.51 TL)

Constraints and Objective Function

Within the framework of this problem, every aggregate demand zone should be matched with at least one access point as shown in constraint (4). Constraint (5) ensures that every access point has an area within a pre-defined radius as discussed earlier. Constraint (6) guarantees that an access point can be matched with a demand zone if an only if it is opened. Constraint (7) states that the number of packages released to the all access points by a demand zone equals the total demand of that zone. Constraint (8) enables that a delivery may take place by a customer zone through an access point if and only if that customer zone is matched with that access point.

$$\sum_{i=1}^{227} X_{i,j} \geq 1 \qquad \forall j \tag{4}$$

$$X_{i,j} * D_{i,j} \leq T_j \qquad \forall\, i,\ \forall j \tag{5}$$

$$X_{i,j} \leq Y_i \qquad \forall\, i, \forall j \tag{6}$$

$$\sum_{i=1}^{227} F_{i,j} = A_j \qquad \forall j \tag{7}$$

$$F_{i,j} \leq M * X_{i,j} \qquad \forall i, \forall j \tag{8}$$

The objective is to minimize costs that are monthly fixed costs and variable cost per package related to opening new access points. Moreover, objective function should force model to minimize the distances between access points-customers and to increase the number of customer zone-access point matches at the points where the send again is more likely.

$$Min\ Z = \sum_{i=1}^{227} Y_i * L_i + \sum_{i=1}^{227}\sum_{j=1}^{227} F_{i,j} * K_i + \sum_{i=1}^{227}\sum_{j=1}^{227} X_{i,j} * D_{i,j} * C1 - \sum_{i=1}^{227}\sum_{j=1}^{227} X_{i,j} * S_j * C2$$

OUTPUT ANALYSIS

Based on the outputs, decision variable Y_i (opened- closed status of i^{th} possible access point) is equal to 1 for 205 candidate access point locations, out of 227 possible locations. This indicates that, number of 205 access points are enough to increase accessibility to pre-defined standards.

In the objective function, monthly total fixed cost for all opened access points and cost that company has to pay to access points per package constitutes access point cost. Besides, there are two more cost components which are cost related to distance and send again cost. In fact, the fourth component related to send-again can be assumed to be a saving for the company since the courier will not have to carry the package again and that much send-again cost will not occur anymore. Table 3 represents objective function cost components in detail.

Table 3. Breakdown of Cost Components in Objective Function

Cost component	Value (TL)
Monthly Total Fixed Cost	66,385.95 TL
Total Variable Package Cost	726,915.70 TL
Cost Related to Distance	13,519.32 TL
Total Cost	806,820.97 TL

SENSITIVITY ANALYSIS

In the proposed mathematical model, L_i stands for monthly fixed cost paid by the company to access point i, in case it is opened. A sensitivity analysis is conducted to analyze different variations of L_i, by taking it as a fixed number for all neighborhoods, whose results are summarized in Table 4. Two different values are taken: 500 TL and 1000 TL. The value of 500 TL is determined as the average value that company is willing to pay monthly. 1000 TL is taken as the maximum cost for the company is willing to pay at most if the access points is opened. Once the fixed cost is taken as 500 TL for all possible access points, the number of opened access points turns out to be 201. When the fixed cost is taken as 1000 TL for all possible access points, the number of opened access point is 164 under this scenario. When the fixed cost paid to access points increases, the number of opened access points decreases.

Table 4. Scenario Analysis

	Scenarios	
	L_i =500	L_i =1000
Number of Opened Access Points (out of 227)	201	164
Monthly Total Fixed Cost	100,500.00 TL	164,000.00 TL
Total Variable Package Cost	726,915.70 TL	726,915.70 TL
Cost Related to Distance	13,477.05 TL	11,847.95 TL
Total Cost	840,892.75 TL	902,763.65 TL

CONCLUSION

In this study, a mathematical model is developed to find the optimal locations of access points, which will be opened in addition to existing branch offices of the logistics company. The objective is to increase accessibility and to enhance package flow process, from both customer and company's point of view. The parameters and constraints are constructed by considering company requirements to come up with an access point network. Finally, a sensitivity analysis is carried out so as to compare outputs based on different fixed cost structures for the model. It is observed that instead of taking the same fixed cost for all access points, it is better to consider a varying fixed cost to be paid to access points, based on the neighborhood information.

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A LITERATURE REVIEW OF DIGITALIZED SUPPLY CHAIN AND LOGISTICS 4.0

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Abstract *– Digital supply chain and logistics 4.0 are also becoming more and more important for companies that are concerned with the subject of Industry 4.0, and want to develop next-generation processes. Since the necessity of the nowadays competition firms have to adopt their operations digitally. Literature of these emerging concepts is not sufficient. This paper aims to fill that gap with a fresh literature review and outlines major of research in the field. Further, it discusses specific features of digitalized supply chains and logistics 4.0 as well as importance of existing research; this should stimulate further researches.*

Keywords *– Digital supply chain; industry 4.0; logistics 4.0.*

INTRODUCTION

Supply chain and logistics are inseparable parts of business. Any improvement on one of them affects the other as so future developments considered together. There have been lots of definition of conventional supply chain and logistics until now but next-generations need new concepts when we talked about digital business. Although those concepts are part of Industry 4.0 concept. Idea began to develop beginnings of 2011 in Germany [1-3]. We understand from industry 4.0 is digitization and integration of complex production and operational networks. It is the last stop of technological development of industry series. Industry 4.0 is a collective aggregation of concepts of technology and value chain organizations. It is based on the concept of cyber-physical systems, the objects, the internet and the internet of services. This structure greatly contributes to the formation of the vision of smart factories. The first industrial concept (1.0) emerged with mechanical production systems using water and steam power. With the second industrial concept (2.0), mass production was introduced with the help of electric power. In the third industrial concept (3.0), production was further automated by the use of digital revolution, the use of electronics and the development of IT (Information Technology). Final industrial concept (4.0) is to achieve a higher level of operational efficiency and productivity; industry 4.0 encompasses numerous technologies and associated paradigms, including Radio Frequency Identification (RFID), Enterprise Resource Planning (ERP), Internet of Things (IoT), cloud-based manufacturing, and social product development [4-9]. With Industry 4.0, modular intelligent factories are aimed at tracking physical processes with cyber-physical systems, creating a virtual copy of the physical world, and making decentralized decisions. The Internet of objects and cyber-physical systems will be able to communicate in real time with each other and with people in cooperation. Both internal and cross-organizational services will be provided through the services' internet and will be evaluated by users of the value chain. That concept links too many industrial areas such as supply chain and logistics. Supply chain takes digitalized supply chain and logistics takes logistics 4.0 names when the industry 4.0 concept based.

The usual production planning and production management department in the smart factory is no longer valid. Instead, there is an integrated approach for machines to share information among them, make predictions, and identify the next steps in the process. Information must flow in real time between machines; so it can be a permanent effect on continuous production. This modern production method does not end on the doors of intelligent factories at all. An integrated, order-oriented production approach that spans the entire supply chain from raw to finished industrial products requires not thinking company-wide and sharing information properly by the logistics. Logistics 4.0 is the integration of cyber-physical systems (CPS) and internet of things (IoT) into logistics promises to enable a real-time tracking of material flows, improved transport handling as well as an accurate risk management, to mention but a few prospects [10]. Logistics 4.0 requires ease of access, quick information processing, security, and, most importantly, all of this in one place. Logistics companies often want to have a single system which will provide the company with everything that is available in several or more systems operated by one employee. Logistics 4.0 is not only very safe since it works on the principle of network of connections and contacts. It is also intuitive to use, suggests counterparties and further actions in operating systems.

Paper follows second part with logistics 4.0 definitions and third part with some applications are given an example for logistics 4.0, fourth part digitalized supply chain concept is given and final part conclusion and some future issues are given.

LOGISTICS 4.0

Logistics has achieved three innovative changes to date. The first innovation was the late 19th century to the 20th century "transport machinery". Since ancient times, shipping centered on shipping is the key to massive long-distance transport although it was left to the railway network, improvement of the railway network, practical use of the truck (freight car), the shipping capacity on the land has been greatly strengthened. On the other hand, regarding ships as the steamship / machine ship spread, the stability of flight has improved greatly. It can be said that the 20th century was the beginning of mass transit age [11-15]. The second innovation is "automation of cargo handling" from the 1960s. Automatic warehousing practical application of logistics equipment such as storage and automatic sorting, cargo handling work in the warehouse was to be partially mechanized. Port handling by diffusion of container ships can be said that mechanization is also a big change.

The evolution of IoT will greatly reduce the work that requires "human intervention" in each area of the supply chain. New technologies such as automatic operation and warehouse robot replace the process that required operation or judgment by "person" to machine. Its destination is in realization of complete automation / mechanization [13-16]. Nonetheless, not all processes will be automated / mechanized in a short time. Transiently, due to realization of partial automatic operation and utilization of powered suit, we do not need special experience, skill, physical fitness, long working hours etc, we anticipate that "non-3K conversion" of logistics operations will proceed. As a result, the cost performance of logistics should improve steadily and in stages[18].

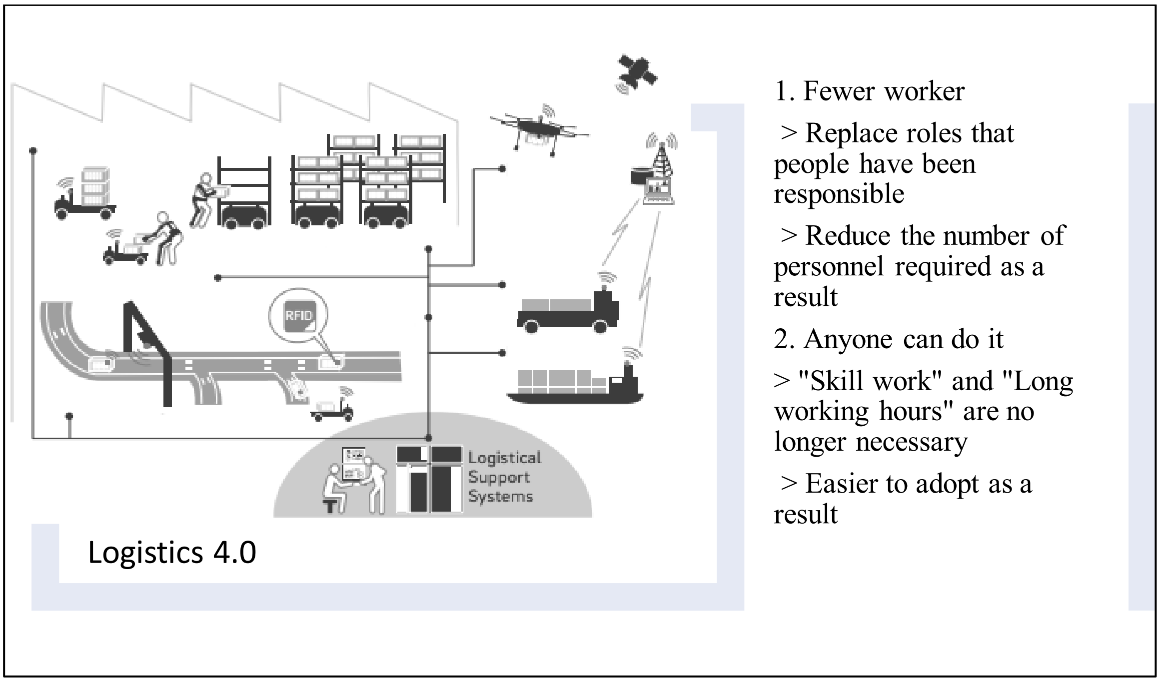

Figure 1. Logistics 4.0 integration [11]

With logistics 4.0 labor saving, the logistics process that brings about the greatest change is truck transport. The share of track share in domestic cargo transport is over 90% on a ton base and even over a ton-kilometer it is over 50%. And, in Japan where personnel expenses are high, the driver's labor cost accounts for nearly 40% of the cost for truck transport. In other words, realization of automatic operation has a large impact on the cost structure of physical distribution.

Daimler, the world's largest truck maker, is working on the development of automatic driving trucks with the goal of practical use until 2025. The automatic driving truck "Freightliner Inspiration" released in 2015 can automatically run on a high speed road with high traffic volume at 80 km / h. Test runs have already started on public roads in Germany and the United States, and the patterns are also released to the media. Of course, it is not possible to realize the "unnecessity of drivers" one after another. Daimler's "Freightliner Inspiration" is also aiming at realizing automatic driving on expressway first. The immediate goal is to realize partial automatic driving on the premise that driving of the driver is necessary due to incompleteness of the road surface indication or unseasonable weather. In addition to technical problems, it is necessary to revise the law and the automobile insurance system, and it is necessary to overcome various hurdles before realizing complete automatic operation.

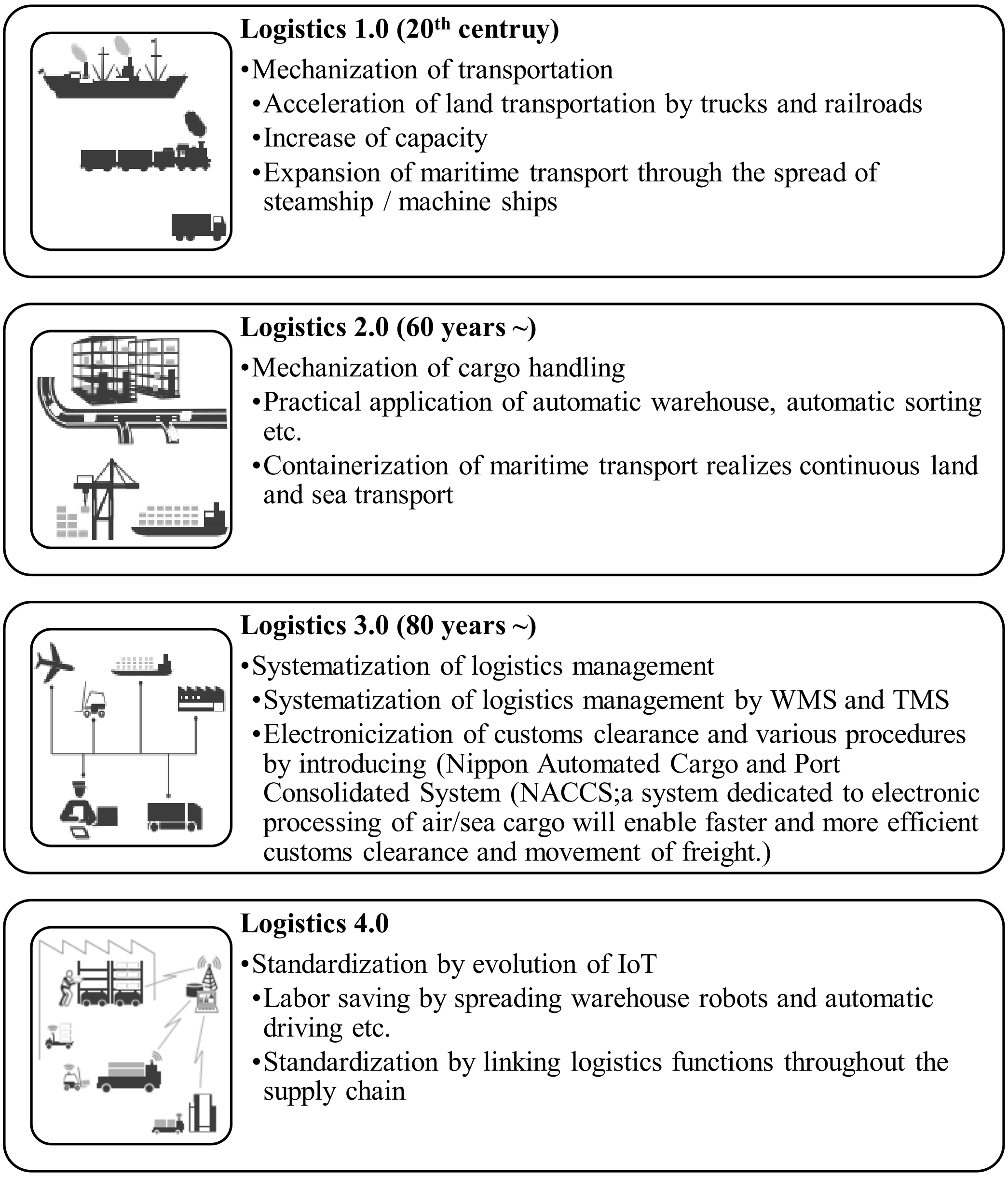

Figure 1. Development of logistics 4.0 [11]

As described in Fig. 1, logistics 4.0 evolution started with basic transportation modes includes trucks, ships, and railways in 20th century. Then, mechanization of cargo terminals activities made logistics 2.0 in 1960'. Third evolution of logistics could be seen by systematization of logistics managerial activities such as electronicization of customs clearance, automated cargo and port consolidated systems in 1980's. And finally we are in logistics 4.0 transition.

LOGISTICS 4.0 APPLICATIONS

In the 1970s, distribution systems such as automatic warehousing and automatic sorting also popularized in world, automation of cargo handling advanced mainly at the manufacturer's stock base. However, it cannot be said that the extent of its diffusion was limited. Because it is a dedicated system conforming to the shape and characteristics of the target cargo, it was difficult to use in a business warehouse that handles a variety of shippers' luggage. The emergence of warehouse robots can dramatically expand the scope of automation in this cargo handling operation. Because it is possible to replace the work that "person" currently supports with a machine as it is. Technological innovation that reduces the labor burden of workers is at work at hand. Cyberdyne 's powered suit "HAL" to assist the wearer' s muscle movement, and ZMP 's trolley robot "CarriRo" to automatically track workers, new logistics equipment's utilizing IoT are spreading. Though these physical distribution devices do not eliminate "human intervention", it can be said that the steps for labor saving are progressing steadily [11].

However, even partial automatic operation on highways will surely have a corresponding impact on the cost structure of logistics. It is because it can relieve long-distance drivers from heavy labor of long-term driving. It is also possible to sleep while driving and to respond to orders. There may be more part-time drivers for a specific section, just "just on the truck". As a result, the labor cost of the truck driver should definitely drop.

In the delivery of the last one mile, practical application of drone is progressing steadily. Amazon is leading the way forward. In order to deliver products ordered by customers within 30 minutes, we are conducting a test flight for practical use of the drawn delivery system "Amazon Prime Air" in each country. Amazon acquired the robot manufacturer Kiva Systems in 2012 and is pursuing radical automation of picking process [11].

Evolution of IoT brings about the effect of widely connecting all functions and information on logistics. By connecting the entire supply chain from procurement / production to retail / delivery, it becomes possible to grasp where and how much things are in real time [19]. By sharing logistics functions and information between companies and industries, it becomes possible to flexibly reorganize logistics companies and transportation means / routes. By connecting information other than "things", it becomes possible to judge the optimum logistics more comprehensively. In other words, Logistics 4.0 can be said to be an innovation of society as a whole by standardizing logistics infrastructure.

DIGITALIZED SUPPLY CHAIN

DSC pioneer the transfer of all possible processes to digital media, from the processes of the supply chain management departments to the processes of the internal customers to the demand management, the order letter delivered to our suppliers, and the cooperation with our suppliers in the digital environment. In this way, it is enabled enable to companies to use their resources more efficiently and gain competitive advantage. This is only part of the electronic tender, many global or local companies make their own solutions, and most of them prefer to buy this service from the outside. However, as in any case, some companies' purchasing or sales organizations in this area are approaching abstaining and/or protecting this issue. But to put it very clearly, it can paid the price of our protectionist approaches very seriously as companies. While the level of maturity varies according to each sector, now need to keep a warm eye on these kinds of procurement, knowledge and culture level of supply chain organizations. It is also the same sentences in sales departments. Companies quickly move away from old habits and find their selves in the new digital world. It is impossible to imagine that we can go to the bank for every money transfer nowadays, even if we are able to work in electronic environment and how many of our business with the state in the last few years can run in electronic environment. Consider whether companies are going to pay for tax or try to find a worker to be able to pay for it or decide which is preferable to pay electronically. In the same way, companies must ensure that transactions related to suppliers are carried out in a very intensive electronic environment. Now it is inevitable for companies to be able to compete in the digital world by adapting all their processes to the digital world without being concerned with this position alone. In addition, there is a huge market potential waiting for it [20].

DSC advantages can be listed as:

• Increased transparency in reclamation
• Reduction of related costs due to quickness in application
• Market transparency and healthy data bank
• Sharing relevant documents with all participating companies
• Equal approach to all participating companies
• Ease of inspection
• Facilitate opening to new markets
• Reduction of sales costs
• Transparent competition
• The transparency of the market and therefore the freedom of movement of companies
• Equal access to all relevant data

With the digitalization of supply chains, businesses will be able to quickly and cost-effectively adapt to the increasing complexity of networks with globalization, the increasing diversity of customer expectations, and changes in customer demand. As it can be seen at Table 1, digitalization and supply chain management levers and challenges could be grouped as digitalization of the business model and digitalization of supply chain management.

Table 1. Areas of digitalization and supply chain management [19]

Areas for digitalization of the business model	**Select digital supply chain management levelers and challenges**	**Areas for digitalization of supply chain management**	**Select digital supply chain management levelers and challenges**
Connected products	New SCM requirements for smart products. Shorter lead times and price changes for electronic components	Supply chain integration	IT integration across all areas of company. IT integration with supply chain partners. Paperless freight document.
Embedded services	New spare parts and service requirements Setup of online monitoring and second or third level support	Supply chain automation	Smart packaging informing and acting on conditions of goods inside Radio or GSM tagging and tracing of goods
Shared products, product as a service	Disposition and capacity management of rented products Product and product parts monitoring and replacement planning	Supply chain reconfiguration	3D printing and additive manufacturing E-platforms for direct carrier selection and transactions Use of app-based e-platforms for express and parcel courier deliveries
Omnichannel distribution	Direct sales (bypassing wholesalers or via online) to users and consumers with smaller lot sizes	Supply chain analytics	Big data analytics for SCM improvement

Importance of the supply chains success can be described as: today, change is very rapid and uncertainty is a fundamental characteristic of business conditions. Supply chains need to be agile in order to adapt to predictable and unpredictable changes. Agility of the supply chains represents the ability to react quickly to changes. Agility can react to change in a timely and appropriate manner, to take advantage of changes and to make changes [21]. Today, supply chains are not enough to be flexible. Agility is the ability to quickly adapt to unplanned and sudden changes in market opportunities and pressures, while flexibility refers to the ability to change rapidly from one state to another.

Digitalization of the supply chain; all non-physical entities in the supply chain are the online implementation of operational dimensions. The digitalization of the supply chain is not limited to the use of paper and automation. In the process of digitalizing the supply chain, supply chain processes must be restructured, unnecessary steps must be removed, and decision-making processes must be accelerated and better decisions must be made [22]. Examples of digitalization in the supply chain can be intelligent contracts, ordering over the internet, sending and receiving e-bills, open source operating systems, digital signatures, ERP systems, CRM systems, RFID, Internet of objects and cloud computing technology.

Necessity of digitalization of the supply chain is: in recent years, competition has become more difficult, globalization, rapid technological development, increased complexity of networks in the supply chain, and shortened product life cycle [23]. Development enterprises need to re-watch their supply chain strategies. To compete in these conditions, businesses must be able to effectively manage their supply chains. Effective management of the supply chain is not possible without real-time information sharing and coordination among the members of the supply chain. The members of the supply chain must be able to access the necessary information in time to coordinate their activities.

Some benefits of the digitalization of the supply chain are [20, 21]:

- Better monitoring of the supply chain's performance will enable better identification of cost elements.
- Costs will be reduced by eliminating unnecessary steps in the supply chain and increasing the activities of the processes.
- Customers' purchasing behavior will be better tracked and responses to changes in customer expectations can be reacted much more quickly. Personalized products will be available to customers.
- Customer dissatisfaction can also be taken online and thus the efficiency of the process can be increased. After-sales services can be developed.
- With real-time reports, the performance of the supply chain can be better monitored and the problems that can be experienced in the processes can be detected faster and the necessary measures can be taken quickly.
- Inventories will be better managed and inventory costs will be reduced.
- Relationships established with suppliers will be developed.
- The shortening of the time between the ordering of the customers and the receipt of the product will be ensured.
- Transportation and distribution costs can be reduced.
- Paddle presentation of new products will be faster.
- Sustainability will be ensured and the negative impacts on the environment will be reduced.

The digitization of the supply chain enables the reduction of inventory costs, management costs, distribution and transportation costs. Maximum efficiency in the supply chain can be achieved by removing the uncertainty in the supply chain, thereby reducing inventory levels in the supply chain. Reducing uncertainty in the supply chain will reduce the stock holding requirements of the enterprises, and will also reduce inventory transportation costs. Reducing paper use and removing unnecessary steps will increase the effectiveness of processes. As the use of paper is reduced and the handwriting, storage, and delivery of paper documents are reduced, the costs associated with these activities will be reduced. Reducing the number of vehicles and warehouses in the supply chain will also facilitate the management of the supply chain and reduce distribution costs and inventory costs [24].

Table 2 shows the implications of digitization on supply chain and the digitalization of supply chain processes also plays a crucial role in meeting customer expectations. A store at the end of the supply chain can instantly see whether a customer's desired store or in other stores and determine whether the customer's request will be met quickly. If it is determined that the existing store is not in stock or other stores are in stock, it can be determined that the customer product will be delivered in a very short time. With the digitalization of the supply chain, customers need to be able to demonstrate their responsiveness through immediate monitoring of purchasing behavior. Businesses are more sensitive to customer expectations and that customers can meet their demands faster than their competitors.

Table 2. Implications of digitalization on supply chain IT system [19]

Classic IT systems for supply chain management	**Degree of change caused by digital**	**Examples of digital supply chain transformation.**
Demand forecasting and planning	Very high	Integration of big-data predictive analytics
Inventory planning and management	Very high	Integration of big-data predictive analytics Analytics-based dynamic supply chain segmentation
Warehouse management	High	Fitness for augmented reality Better integration of manual and robotics processes
Network and routing optimization	Very high	Integration of big data predictive analytics External interfacing for automated updating of capacities and schedules
Transport management	High	Integration with advanced procurement systems Seamless interfacing with e-platforms for booking and reservations as part of the standard configuration
Tracking and event management	High	Implementation of more sophisticated machine judgment Advanced scenario planning, Process-integrated risk management
Freight document handling and archiving	Very high	End-to-end freight document handling Interfacing and integration of all documents and document handling systems
Transport and logistics procurement	High	Collaborative optimization App-based spot-market trending to truck brokers and truckers Seamless interfacing with TMS systems
Interfaces with suppliers, customers, and supply chain service providers	High	More standardization of interfaces (including due to more shipper-carrier interaction and more independent providers of specialized supply chain service), E-platform proliferation

With the digitalization of the supply chain, data can be accessed much more quickly and precautions can be taken for problems that may be experienced. Customer needs and expectations will be better analyzed and customer expectations will be met more quickly. Records will be recorded and tracked instantly, enabling faster and better decisions to be taken and a competitive advantage. With real-time sensors, all supply chain members can make decisions in a timely manner to improve the performance of the supply chain and thus become proactive. For example, with information on the traffic congestion, the route can be changed and the time to be lost in the traffic can be reduced during the delivery of the products to the customers, and the delays that may occur in delivery of the products can be minimized. Due to the inadequate and delayed sharing of information in the supply chain, the whip effect can be removed. Procurement times can be reduced and orders between supply chain members will be based on more realistic data. Planning of orders, ordering, fleet management, stock control and transportation route planning with cloud based service; Increases the visibility of the supply chain, enables quick decisions, and offers significant opportunities in reducing costs.

CONCLUSION

With digitalized supply chain and logistics 4.0, it is no doubt that sector will be eliminated and standardized. Innovative solutions such as fully automatic operation and open platforms are also required to have a major impact on the logistics business. The problem is that we do not know when the change is "when" and "where". For example, automobile manufacturers and suppliers anticipate that automated driving will be put to practical use in the 2020's, but the timing at which general automation on expressways is widely generalized is inevitable. Even though we are going to suppress employment of track drivers in anticipation of automatic operation in the future, it is difficult to make long-term plans at the moment.

The price of the RFID tag is estimated to be less than 0.16 Turkish Lira in 2020. It is realistic to attach RFID tags to all reusable logistics equipment such as containers and pallets. Nevertheless it is not necessarily reasonable to proceed with the exchange of physical distribution equipment targeting 2020. In the near future, if the cost reduction to a level that can be disposable is to proceed, strategic investment should be carried out assuming to use the RFID tag like a barcode. In the case of automatic operation, the development status of the law and the automobile insurance system is also subject to monitoring in addition to the development situation of each manufacturer. In the case of RFID, we should pay attention not only to the price of the tag but also to the development status of tag attachment devices and database systems. It should also be considered that differences in timing of dissemination will occur depending on industry type and region.

The logistics company should look directly at the progress of "industrialization of logistics equipment" by Logistics 4.0. Labor savings inevitably reduce the "processes that change performance by people". Standardization reduces logistical differences between companies and industries. In other words, logistics facilities, facilities, and systems will be equivalent, logistics quality will be equivalent.

Trucking is a typical labor-intensive project. When we consider 99% of the trucking carriers in world are small and medium enterprises, fully automatic operation is put into practical use; labor such as a truck driver becomes unnecessary. If logistics functions and information are widely shared, track operation will be leveled as a society as a whole. As long as you can carry it with ordinary trucks, no matter which logistics company you order, there will be no difference in price or quality. In extreme terms, the shipping company will only be providing a logistics infrastructure called a truck. Truck makers and leasing companies may become involved in the transportation business as a "truck provider".

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EXTRACTING VALUE FROM THE BIG DATA IN SUPPLY CHAIN: A REVIEW OF APPLICATIONS

Esra Yaşar[1], *Tuba Ulusoy*[2]

Abstract – *Big Data is comprised of extremely large data sets that are difficult to manage and analyze. However, nowadays, in order to reach their goals, firms are looking for the techniques and tools for handling big data efficiently. The main aim of the firms is to sustain their profitability by understanding the customer needs right and competing with rivals. For this reason, they should manage supply chain by considering the data collected from all the stages in the chain. In this study, we present applications that are used big data collected from different kinds of channels, such as social media, the Web, and smartphone applications, to minimize risks and uncertainties and to maximize customer satisfaction.*

Keywords – *Big Data, customer satisfaction, risks, supply chain, uncertainties*

INTRODUCTION

The concept of Big Data emerged in Cox and Ellsworth's articles entitled "Application-controlled demand paging for out-of-core visualization" in 1997 [1]. The term of "Big-Data" was coined to capture the profound meaning of this data-explosion trend, and indeed the data has been touted as the new oil, which is expected to transform our society [2]. Today, with the progress of technology, many various data have been generated and the management of the data has started to become increasingly difficult. Since the data now coming out of standard dimensions generated Big Data, the concept has emerged in this way and scientific studies on management of Big Data have begun. But the data that have non-standard dimensions make it difficult for the administrators to decide. Moreover, problems have arisen about collecting, storing, and analyzing of Big Data. Because of these problems, Big Data has gained importance for companies and it has become a focal point for managers to make decisions. Big Data consists of 6 components which are mainly volume, value, variety, velocity, veracity, and variability whose definitions are given below [3].

Volume: It expresses the size of each type of data coming from different sources [4]. As an example of the volume component, International Data Corporation (IDC) statistics show that the data to be owned in 2020 will be 44 times greater than it was in 2009 [5].

Variety: Due to the diverse sources of data, the heterogeneity of the data has led to the creation of a variety of dimensions [6]. The data can be classified as structured data and non-structured data.

Velocity: It represents the speed of the data. Since the data is generated very quickly, it is transferred to the database continuously and very quickly.

Veracity: It ensures that the data are safely stored and flows into the database.

Variability: This component of Big Data indicates that the data are constantly changing.

Value: It is the most important component of Big Data. Value can be extracted from Big Data by using different types of analyzing techniques to help decision makers in companies.

Supply Chain Management (SCM) is the management of information, finance, and material flows to maximize the value which is generated by the chain that is generally comprised of customers, retailers, wholesalers, manufacturers, and suppliers [7]. In recent years, there has been an increasing interest in Big Data concept related to Supply Chain (SC), since it is recognized that the decisions will be made by using data analysis can make the company more profitable. Therefore, the data that flows among SC stages, such as potential

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customers, the needs of customers, the availability of products, should be analyzed correctly and it should be considered while making decisions.

LITERATURE REVIEW

Big Data is not a new concept [8]. However, studies based on analyzing Big Data bring new opportunities to extract the hidden values in it [9].

Today's world organizations are competing on analytics, because they have realized positive outcomes of effective data analysis. Analyzing data effectively provides facilities to following issues; what customer wants, what prices those customers are willing to pay, which factors make people to buy more [10].

Technological developments make changes in the four phases of the value chain of Big Data which are data generation, data acquisition, data storage, and data analysis [9]. These changes increase the volume of data in various fields, so new challenges occur in organizing and managing data sets efficiently [11].

The value is one of the most important properties of Big Data. However, Big Data has both valuable and valueless information in it [8]. To extract the valuable part from the Big Data, some analyzing techniques that are generally based on statistics, computer science, and mathematics are used. Optimization methods, statistics, data mining, machine learning, visualization approaches, social network analysis, data fusion and data integration are the analyzing techniques whose relationship is shown in Figure 1.

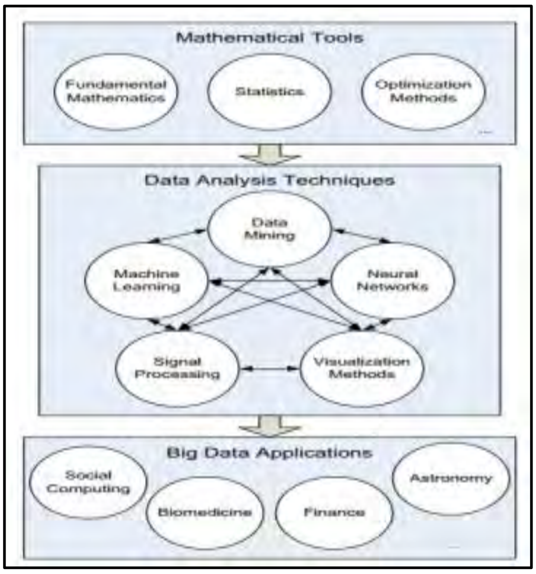

Figure 1. Data Analyzing Techniques [11]

APPLICATIONS IN SUPPLY CHAIN MANAGEMENT

Swaminathan emphasized that enhancing visibility, adjusting demand and capacity fluctuations in real time, and understanding customer behaviors can be achieved by the companies that built the infrastructure and processes to collect, organize, and analyze the Big Data in logistics. This also provides a competitive advantage for shippers, third-party logistics providers, and carriers [12]. When the studies related to Big Data applications in SCM are reviewed, it can be recognized that these studies emphasize similar aspects.

In this section, we present some applications that are used in Big Data collected from different kinds of channels, such as social media, the Web, and smartphone applications, to minimize risks and uncertainties and to maximize customer satisfaction by collecting under different headings.

1. **Risk Management & Sustainability Applications**

Risk management in Supply Chain has various objectives such as achieving sustainability and gaining resilience. According to Christopher& Peck [13], creating more resilience supply chains can decrease risk that is defined by March and Shapira [14] as "the variation in the distribution of possible outcomes, their likelihood, and their subjective values" [15]. Supply chain resilience can be defined as the ability of a supply chain network to return to its original state soon after a disruption, like earthquakes, floods, tsunamis, and hurricanes. Investments in resilience can provide competitive advantage to firms [16, 17, 18].

Green Supply Chain Management [GrSCM] and sustainability in SCM are the other issues that are covered in this section. Decreasing hazardous effects of SCs on the environment is assumed as one of the approaches to achieve SC sustainability [19].

The fast growth of industrialization caused some problems that threat environment, human beings, and animals. These threats increased concerns and led to be given significant importance to green and sustainable SCM research [20].

In GrSCM, product design, material sourcing, selection, manufacturing processes, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life are considered without neglecting environmental issues. GrSCM does not only consider environment but also profit of business [21].

One of the most recent studies about Big Data used in GrSCM is conducted by Zhao et al. [22]. The data of a local supply chain network of a sanitary product in Sichuan Province, China, is used to verify the multi-objective optimization model to minimize carbon emission, economic cost, and the inherent risk caused by handling hazardous materials. The parameters of the model are derived from Big Data that are imported into Spss 19.0. Mean of each data set is determined as a parameter that is used in the model. Although the model has some limitations, the solution of it presents improvements in GrSCM and long-term commercial success.

Similar to this study, earlier studies that are related to Big Data applications in GrSCM generally try to minimize adverse effects of supply chain network on the environment by using different approaches. Also, maximizing economic benefits is another aim of these studies [22].

The study whose details given below is an example that shows the benefits of Big Data analysis in SC sustainability.

Papadopoulos et al. point out the role of Big Data in explaining disaster resilience in supply chain for sustainability by using unstructured and structured data gathered from different sources [23]. 36422 items called as unstructured data are collected from Twitter, news, Facebook, WordPress, Instagram, Google+, and YouTube. The structured data used in this study is gathered from 205 managers involved in disaster relief activities after Nepal earthquake in 2015. The conclusion of Big Data analysis shows that swift trust, public private partnerships, and quality information sharing are important factors for supply chain network that may enable it to achieve sustainability.

A considerable amount of literature has been published on risk management and sustainability. In Table 1, we present the most recent studies based on Big Data applications which try to minimize risks and maintain sustainability in SCM.

Table 1. Risk Management & Sustainability Applications in SCM

References	Application Area	Approach	Data Source
Badiezadeh et al. [2017]	Supply chains of 9 Iranian company that produce tomato pastes	Data Envelopment Analysis [DEA] and Network Data Envelopment Analysis [NDEA] are used to assess sustainability of supply chains	Gathered from the companies
Kaur &Singh [2017]	Carbon sensitive supply chain	Both Mixed Integer Linear Program [MILP] and Mixed Integer Non-Linear Program [MINLP] are used to develop sustainable procurement and transportation model	Real time data from buyer and supplier side that includes costs, capacities, lead time, and emissions.
Wu et al.[2017]	Taiwanese Light-Emitting Diode [LED] Industry	Fuzzy and Grey Delphi methods are applied to identify attributes and Big Data is transformed into a manageable scale to see the impacts of these attributes on Supply Chain Risks and Uncertainties [SCRU].	Quantitative data from firms' operations, qualitative data from management, and social media data

2. Value Creation & Understanding Customer Needs by Using Big Data

Managers assume the data as an important driver of innovation and a significant source of value creation and competitive advantage. Today, tweets, videos, click streams, and other unstructured data are more accessible so they can provide useful information to understand customers' preferences and needs [27]. However, the problem is how to extract hidden and valuable information from the huge amount of data. Therefore, Big Data analysis tools can become beneficial to understand customers' behaviors to analyze and transform them into valuable insights [28].

Unstructured data is a big problem so traditional supply chains use structured data. However, it is accepted that unstructured data, such as customer service, call center data, Twitter data, warranty, return information, customer rating and review data, is the most important data that is promising for Supply Chains [29].

Morabito emphasized the importance of Big Data in his work and reviewed amazon.com as an example of its use [30]. Amazon.com uses collaborative filtering engine [CFE] to analyze what products a customer purchased before, what items added to online shopping cart or to wish list, which products the customer reviewed and rated, and what items the customer searched commonly. Hence, the results are used to recommend additional products to other customers while buying those same items. It has been said that amazon.com has sold about three-quarters of its orders in this way [30].

Table 2 shows the most recent studies that deal with value creation and understanding customer needs by using Big Data in SCM.

Table 2. Value Creation & Understanding Customer Needs by Using Big Data in SCM

References	Application Area	Approach	Data Source
Singh et al.[2017]	Food Industries	Text analysis using a support vector machine [SVM] and hierarchical clustering with multiscale bootstrap resampling	Three weeks of data from Twitter
Suroka et al.[2017]	Micro, small and medium-sized enterprises within the United Kingdom	A survey is conducted to investigate the challenges that SMEs face while handling and trying to "add value" through the analysis of customer data	Survey respondents from industry
Xie et al.[2016]	4 firms from different sectors in China	The study proposes a process model that describes how big data is transformed from resources into cooperative assets in value co-creation processes	Data gathered from top executives, top management team members, as well as frontline employees
Choi[2016]	Amake-to-order [MTO] fashion supply chain	A mathematical model is constructed to examine the value of Quick Response	Social media observations and behaviors of fashion retailer
Tan et al.[2015]	Company SPEC, a leading eyeglasses manufacturer based in China	Deduction graph technique is used to analyze Big data for new production innovation and operations improvement.	*Existing customers' preferences and characteristics *Videos and photos of available eyeglasses products *Social media clues on potential new product ideas.

CONCLUSION

In this study, only the most recent studies addressing issues of risk management, sustainability, value creation, and understanding customer needs in SCM have been reviewed. It is aimed to show how the firms solve some problems that occur in Big Data analysis related to these issues mentioned above. But the studies are not limited to the given here, so the scope can be expanded in future research.

According to Palmer [37], Big Data resembles the crude oil. Unless the oil is distilled, it is valueless. Similar to it, the data is valuable when it is analyzed [37]. Analyzing Big Data in a reasonable time and extracting valuable information from it can provide big opportunities to the firms that are operated in different sectors. Besides, the studies that are presented in this paper show that efficient Big Data analysis can help the SCs to manage risk, to understand customer needs, to enhance competitiveness, and to maintain sustainability.

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LOW VOLUME STORE PLANNING FOR WORKLOAD BALANCING AND TRUCKLOAD

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Abstract *– In this study, it is aimed to decrease the number of days planned to be shipped in stores with low sales volume, to create a balanced work load and to increase vehicle occupancy capacity .Particularly, Less than Truckload problem is analyzed and model in this study. The techniques used in this study showed that adaptability can be achieved with shipment and store planning as well as green supply chain environment to minimize Less than Truckload (LTL) as well as gas consumption. A mathematical model was created in the direction of multi objective problem and solved in the GAMS environment. Moreover, scenario analyzes were made and the study was tested on five specially identified regions on Turkey.*

Keywords – Warehouse Management, Store Planning, Workload Balancing, Truckload

INTRODUCTION

Modernization of supply chain with the internet of things (IoT) has been a crucial part to play in the matter of logistics as management becomes more efficient and able to control and lead more data than it ever was. This technological advancement is meant to make profit easily and turns supply chain more competitive environment as companies can easily invest and earn from this area. Thus, companies have decided to invest their infrastructure to become agiler in the matter of reaching customers' need at right time with right price to charge. Especially, modern customer demands quality and price in any product [1] [2] and price cutting with the best quality becomes a more crucial tool to get ahead of rivals. Therefore, supply chain and logistics are the best possible place to start.

A supply chain covers a raw material and product ordering/production and accommodation as well as product distribution, vehicle occupancy rate, vehicle type and etc. which directly change the price to the customer as well as the profitability of product [3]. However, today supply chain is aimed to reduce waste /loss of resources and this stands for the fact that right product is offered to customers. To achieve such a high goal, not only information technology and management should be capable to provide necessary information but also able to act upon the decision.

One of the best examples of this situation comes from ZARA, the most profitable apparel company as they follow the trends through stores and their suppliers always are ready to complete orders. Such collaboration has been rewarding ZARA with double digit profit since 1990 [4]. This is an important indicator to see supply chain as dependent pieces and the only way to control fluctuations of demands (the bullwhip effect) is to act together. Such a group can only aim to achieve sustainability. Moreover, this collaboration for ZARA provides an environment to less discounted product, less inventory cost and quick response to trend because ZARA keeps tracks of customer's reaction and management acts upon the need of customer instead of what ZARA could desire.

Therefore, this study is to show the benefit of providing right product to customer's need and offer a basic methodology to achieve such a difficult task with mathematical programming as it may act to optimize logistic cost and with better planning, more collaborative environment between third party logistic firms and the company would be developed as it would give ability to quick response to customer's need. Especially, third party logistic firms can lead higher occupancy rate rather than half empty trucks as it becomes more profitable and provide the ability to serve more customers. This also affects overall supply chain and increase productivity through truckload and today LTL means 35$ billion worth business [5].

There is also another angle which is green logistics as less truck in traffic could lead to less CO2 and less consumption to fuel for a better environment. According to the United States Environmental Protection Agency (EPA), transportation effect on Green House Gas represented 27% which is second highest level as electricity was seen 29% as highest in 2015. Moreover, the same study pointed out that vehicle that used petroleum represented 90% against all options for fuel. Such waste could be earned back with suggested method [6].

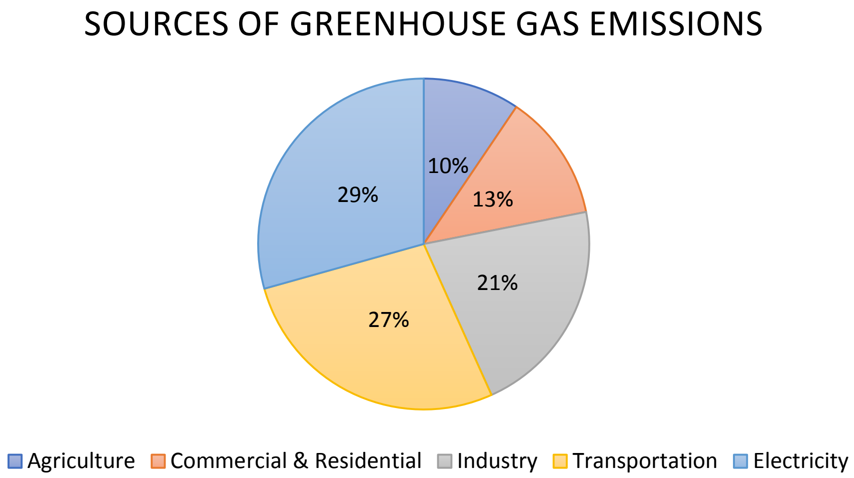

Figure 1. Sources of Greenhouse Gas Emission [6].

The following section introduces problem environment and example solution techniques as literature review, it follows with suggested solution method as mathematical model which follows with scenario analysis to calculate other options and finally this study completes with conclusion which shows importance of this kind of work and benefit of supply chain planning against Less Than Truckload (LTL).

LITERATURE REVIEW

This problem shows similarity to blending problems in operations research because volume distribution throughout the workdays for the best combination of given objective function which contains cost and workload. In the following sections, blending problems features are introduced and show similarity to our problem and how to use it. After that, network features and environment are represented with existing works and it follows with workload feature's importance and how that means goal programming for the problem.

Thus, blending feature was analyzed first as it plays a crucial part to model as it is the key to the supply chain's aim and it demands to combine with its network constraints and it increases the difficulty to solve without mathematical model solver. Especially, blending problems could be considered as complex as knapsack problem since both of them are about assignment [7]. There is only one difference between knapsack and blending problems which is blending problems are continuous as they are dealing with amount distribution but knapsack problems are binary such as the decision of "take it or leave it". This difference makes decision variable continuous.

Although blending problem is more about the combination of chemicals but in this problem, volume carried between two classes (low and high volume distribution points) represents chemicals and distribution of volume to days can be seen as products which result with LTL penalty costs and unbalanced workload. For example, Mendez and friends studied oil refinery to optimize its logistics expenses in order to determine best chemical combination according to their production capabilities [8]. Although this study seems different from our problem but most profitable way to distribute production or volume in our case shows the main logic in this problem.

Another study has shown to model short term balancing importance in refiners according to logistic costs, production capacity and expected the quality of the product. As it results in the final product of blending as well as efficient way to carry under refinery production capacities [9]. This example also supports the importance of logistics and similarity to using blending problem in modeling. However, this also showed a lack of study in blending problem applied in different areas as volume distribution to days does not have a connection with refinery production.

The second part of this study is to analyze the composition of logistic costs and importance of LTL in the supply chain as this study covers balancing the volume among the potential vehicles with the use of fuel efficiency. Therefore, according to one of the recent work of Naoto Katayama and Shigeru Yurimoto, minimizing total line haul cost was aimed and this goal leads them to design efficient design of the logistic network to carry aggregated demand of small points which causes minimizing the number of cross-dock points. However, some cases like covering larger areas might mean inefficient as fuel consumption may rise because of large clusters created [10]. There is also a problem with third party logistics firm as regional deals might prevent to change the larger covers which might contradict. This also shows the importance of partnership strength with third party logistics firms.

Another study of supply chain optimization has searched to optimize transportation network design through simulation as this technique leads to decide warehouse location problem [11]. This aims to decrease their transportation costs including LTL costs and more efficient way with steepest descent algorithm. One of the papers on freight distribution for the daily demand is similar to this study minimizing transportation costs with integral generalized transportation problem on a bipartite graph. In that freight distribution work, rounding and linear programming relaxation techniques are applied and in that problem, user can select their vehicles unlike our problem which basically is solved with GAMS and car selection was based on need rather than user determined selection [12]. This paper shows importance of our work as well as our modeling techniques simplify complicated system to solve the problem. Another study used the goal programming in transportation for different performance measurement techniques. However, this study optimized according to Pareto frontiers and NSGA II method techniques which are heuristic search algorithms [13]. Another goal programming in transportation developed heuristic techniques unlike current transportation model which found the best result for normalized values [14].

There is also another issue to address and it is as important as network features and blending problem. This is load balancing which changes the nature of the problem to goal programming as the problem now has logistic cost minimization as well as workload balancing. As it was a real world problem, this accounts to applicability. This feature is important as it plays balancing the cost of workers as well as it gives the ability to deal with sudden fluctuations of demand which is also another critical point in supply chain and this study. Also, workload balancing can be seen from any areas like distributed computing [15] or assembly line balancing [16]. However, few studies have combined with this feature and cost minimization to solve it as a goal programming which also supports our cases and importance of our work in the example of assembly line balancing with workload balancing and distance [17].

MATHEMATICAL MODEL

The following section is to describe the problem environment and introduce the mathematical model. This model is used for general case which ignores national and religious holiday planning. For holiday cases, this model can be re-run to adjust the distributions days and store planning. In this study, three-week shipments were considered to determine the effectiveness in short term planning (as well as adaptability against demand fluctuations) and comparison. 5 regions were considered in this problem and pre-selected day for low-level stores are assigned to 2 but other numbers were tested in scenario analysis.

Index:

$j = Workdays\ (1, \dots, 6)$.

$i = Regions\ (1, \dots, 5)$.

Constants:

$CW_{ij} = Volume\ level\ in\ region - i's\ high\ sale's\ class.$

$AW_i = Volume\ level\ in\ region - i's\ low\ sale's\ class.$

$assignDay = number\ of\ day\ to\ distribute.$

$Vcap1 = Vehicle - 1\ capacity.$

$level1 = Vehicle - 1\ volume\ LTL\ level.$

$Vcap2 = Vehicle - 2\ capacity.$

$level2 = Vehicle - 2\ volume\ LTL\ level.$

$per = Minimum\ level\ for\ ordering.$

$M \gg 0$

Decision Variables:

$x_{ij} = Assignment\ of\ low\ sale\ volume\ for\ region - i\ in\ day - j.$

$h_{ij} = If\ LTL\ is\ assigned\ to\ the\ vehicle - 2\ for\ region - i\ in\ day - j, 1. Otherwise, 0.$

$u_{ij}^{+} = amount\ over\ specified\ level\ for\ region - i\ in\ day - j.$

$u_{ij}^{-} = amount\ under\ specified\ level\ for\ region - i\ in\ day - j.$

$z_{ij} = If\ LTL\ occurs\ for\ region - i\ in\ day - j, 1. Otherwise, 0.$

$m_{ij} = number\ of\ vehicle\ type - 1\ for\ region - i\ in\ day - j\ (integer).$

$d_j^{-} = total\ shipment\ under\ balanced\ demand\ in\ day - j.$

$d_j^{+} = total\ shipment\ over\ balanced\ demand\ in\ day - j.$

$BCost = best\ cost\ for\ LTL\ only.$

$tt = objective\ function.$

Model:

$$Min.\ tt = \sum_{j=1}^{6} \sum_{i=1}^{n} u_{ij}^{-} \quad (1)$$

$$Vcap1 * m_{ij} + Vcap2 * h_{ij} * level2 + Vcap1 * level2 * (1 - h_{ij}) + u_{ij}^{+} - u_{ij}^{-} = CW_{ij} + x_{ij}\ \forall i, j \quad (2)$$

$$Vcap2 * (1 - level2) * h_{ij} + Vcap1 * (1 - level1) * (1 - h_{ij}) \geq u_{ij}^{+}\ \forall i, j \quad (3)$$

$$\sum_{j=1}^{6} x_{ij} = AW_i\ \forall i \quad (4)$$

$$z_{ij} * M \geq x_{ij}\ \forall i, j \quad (5.a)$$

$$z_{ij} \leq x_{ij}\ \forall i, j \quad (5.b)$$

$$\sum_{j=1}^{6} z_{ij} = assignDay\ \forall i \quad (6)$$

$$z_{ij} * AW_i * per \leq x_{ij}\ \forall i, j \quad (7)$$

$$x_{ij}, u_{ij}^{+}, u_{ij}^{-} \geq 0\ \forall i, j \quad (8)$$

$$h_{ij}, z_{ij} \in \{0,1\}\ \forall i, j \quad (9)$$

$$m_{ij} \geq 0\ \&\ integer. \quad (10)$$

The initial objective function and it minimizes the total amount of LTL is in (1). Decision variables in the objective function is limited with 6 days excluding Sunday and moreover, our initial objective only takes amount under the given limit. Daily LTL amount of assigned volume for regions are determined in (2) and (3). These two equations determine number of vehicle-1 which is used in a full capacity and last vehicle is vehicle-1 or vehicle-2 according to vehicle capacity and assignment to that day. Therefore, the last vehicle decides LTL amount under the given limit which is minimized in our objective. All volumes are forced to be sent with the help of the given equation (4). As this problem is based on finding the days which is determined by users, amount order and order day are need to be connected with constraints (5.a) and (5.b). The low class cannot exceed the number of the given limit for freight days. Therefore, number of freight day is controlled with the constraint in (6) (pre-selected assignment number). In case of low level shipments, a minimum level is determined to prevent unrealistic situation for order shipments which is seen in (7). Decision variables features are presented in (8), (9) and (10).

However, the initial model does not represent goal programming, so in order to use it with workload balancing, the following equations must be replaced with the given objective function with new constraints similar to [13]. The initial objective function is used to find *BCost* decision variable value which is best cost for minimum LTL amount to normalize the first goal as LTL. Thus, the model balances workload and cost at the same time in (11).

$$\text{Min. } tt = \sum_{j=1}^{6}\sum_{i=1}^{n} u_{ij}^{-} / \max(BCost, 1) + \sum_{j=1}^{6}(d_j^{+} + d_j^{-}) / (\sum_{j=1}^{6}\sum_{i=1}^{n} CW_{ij} + \sum_{i=1}^{n} AW_i)/6 \quad (11)$$

The following equation is used as the total fluctuation from balanced workload (12).

$$d_j^{+} - d_j^{-} = (\sum_{j=1}^{6}\sum_{i=1}^{n} CW_{ij} + \sum_{i=1}^{n} AW_i)/6 - (\sum_{i=1}^{n} CW_{ij} + x_{ij}) \quad (12)$$

The following equation is used in scenario analysis to give one day at least between two shipments in (13). This feature can be used as a time for a planner to see fluctuations in demand and prepare for it such as store plays a significant role in the planning phase of ZARA.

$$z_{ij} + z_{i,j+1} \leq 1 \ \forall i,j \quad (13)$$

SCENARIO ANALYSIS

In this phase, the developed model was tested against the different situation and how it reacts. Especially, some constants are re-evaluated against workload and LTL volumes in order to see expectations can be achieved or applicable. First of all, the model was tested only for LTL volume minimization. In the first test, different numbers of allowed shipment day are used with (13) (at least one day between two shipments). The existing situation is current condition and it means shipment in every day.

In table-1, scenario A and B can be seen. Scenario-A results are based on the model with (13) and Scenario-B results are based on the model with (13). In these scenarios, the objective function is only about LTL volume. Results show there is a significant effect of (13) as one day between two shipments mean important factor on LTL. However, there is a high fluctuation between workloads as Monday and Saturday have the highest difference in most of the cases in scenarios that used (13) (scenarios in A) even existing situation seems more balanced. However, scenarios in B which do not use (13) come more balanced and it has found a result that has not got any LTL amount and balanced workload. This supports our cases as our model can improve LTL costs.

Table 1. LTL minimization results

Scenario\Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	LTL Volume against Existing LTL Volume
Scenario-1.A							
pre-selected day=1	19%	17%	15%	15%	19%	14%	98%
pre-selected day=2	17%	18%	16%	15%	20%	14%	45%
pre-selected day=3	20%	16%	17%	16%	18%	14%	31%
Scenario-1.B							
pre-selected day=5	18%	15%	17%	17%	18%	15%	0%
pre-selected day=2	19%	16%	16%	15%	19%	15%	39%
pre-selected day=3	17%	15%	16%	19%	18%	14%	12%
Existing Situation	**18%**	**15%**	**17%**	**17%**	**18%**	**15%**	**Compared**

Scenario-2 is about goal programming which minimizing fluctuations of workload and LTL amount for their best values in (11). There is a significant change in scenarios in B which do not use (13). This means there are possible options for workload balancing for the model without one day between two shipments. However, Scenarios in A are not affected as scenarios in B (the only day=1 is affected). This also shows the effectiveness of goal programming in larger options. This means significant options can be found such as scenario-2.B of day=5. Scenario-2 results are seen in Table-2.

Table 2. Goal programming scenario results

Scenario\Day	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	LTL Volume against Existing LTL Volume
Scenario-2.A							
pre-selected day=1	18%	16%	15%	15%	18%	18%	114%
pre-selected day=2	17%	15%	16%	15%	17%	19%	57%
pre-selected day=3	20%	16%	17%	16%	18%	14%	31%
Scenario-2.B							
pre-selected day=5	17%	15%	17%	16%	18%	17%	0%
pre-selected day=2	18%	15%	16%	15%	17%	18%	47%
pre-selected day=3	17%	15%	17%	15%	18%	18%	17%
Existing Situation	**18%**	**15%**	**17%**	**17%**	**18%**	**15%**	**Compared**

CONCLUSION

This is a study to understand and exploit supply chain's weaknesses and create a more resilient environment for business. Now, the supply chain is about efficiency and in order to achieve this goal, this study sought an opportunity and decision support technique was offered. This requires known current state of the business which can be the frequency of need in the store, inventory level or production capacities. Thus, it designs need of product flow for LTL and at the same time, there is another issue to balance the workload for demand capacity which can also provide adaptability as one can consider ZARA's example. Results show opportunities and able to outperform the existing situation easily. Moreover, this model shows the importance of planning as unplanned results requires 6 days with highest LTL amount and at the same time, planned approach could have achieved zero LTL and balanced workload. These are the main reasons to have upper hand easily and there is also environment issue as transportation has been seen as the second highest reason for greenhouse gas emissions and LTL transportation is the unnecessary burden of transportation. These are reasons to need this kind of work and also simplicity and realistic calculations can provide better insight into the business and more importantly, it can protect the nature.

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CORRECT INTEGRATION OF MULTIPLE CHANNELS WITH OMNICHANNEL PERSPECTIVE

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Abstract *– Omni-channel provides better communication and coordination among transport activities which are disconnected in multi-channel strategies. Although omni-channel's best representative in our country is banking sector, the prevalence of e-commerce applications and logistics activities is rapidly increasing. For that reason end-to-end supply chains and communications have become compulsory. In this study, key differences of omni-channel vs multi-channel strategies have been identified, strategies for a properly implemented omni-channel were determined and requirements, constraints and contradictions of these strategies will be examined. Turkey's Sales data via internet and mail have been analyzed by compiling TurkStat's data with monthly and annual retail volume and endorsement. With this approach, omni-channel trend in our country has been analyzed.*

Keywords – Business Strategy, Innovation, Omnichannel

1. Introduction

Customer expectations and user habits change day by day, like all over the world, push companies to become more customer-focused in Turkey as well. This indicates that the one-channel period in which is the only physical store, as it used to be, is slowly coming to an end. In the new era that we are in the foreground, the necessity of offering services parallel to multiple channels with the foreground of e-commerce especially in order to ensure customer satisfaction comes out (Innova, 2015). Today the classical loyalty applications that attract and merely score points in the customer-brand cycle are not enough and for that reason a more comprehensive concept needs to be created (Accenture 2015).

The interaction between the consumer and the brand, which was once limited to getting the product or service, has spread to a much wider area with the growth of channels arriving to the customer, by the development of social media and smart mobile technologies. Many businesses have begun or is preparing to take steps to experience the omni-channel approach, which is a completely overlapping approach to the concept of customer engagement. Customer Engagement was conceptualized as a second order construct measured through customer experiences (Thakur 2016). The discourse that fully reflects this concept is the concept of "Customer Engagement" which means not only the customers who make money but also the relationship with the brand and see them as business partners.

Firms have discovered that maintaining the same experience in each channel increases the brand's commitment to reach more people. Hence, many brands have integrated the omni-channel approach to marketing strategies (Leeflang et al. 2014) .The number of firms that have successfully structured omni-channel applications and invested heavily in this issue has led other retailers to adopt this approach.

According to Forrester's "Customer Desires vs. Retailer Capabilities" report, which consumers have been looking for to anticipate and allow retailers to give away what they can afford, 55 percent of retailers who take an e-commerce initiative are doing this to meet omni-channel expectations. Forrester again says that online shoppers are looking for an option to go and buy products they buy from stores, but only a third of companies with the Omni-channel approach can offer this feature.

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2. Omni Channel Approach

The evolution of marketing strategies from channel focus to brand focus raises the necessity of being involved in every environment where the target is locked in order to create brand awareness and loyalty. Especially, the popularization of the concept of "Internet of things ", which paves the way for a rapid change of the user experience, plays a major role in the importance of conducting the same communication in all channels.

Firms have discovered that maintaining the same experience in each channel increases the brand's commitment to reach more people. Hence, many brands have integrated the omni-channel approach to marketing strategies. The number of firms that have successfully structured omni-channel applications and invested heavily in this issue has led other retailers to adopt this approach.

The concept of omni-channel can be explained as giving the user a common experience in all channels (Saghiri et al. 2017). Accordingly, it can be correlated with omni-channel logic to be able to offer a seamless shopping experience to all users, regardless of channel or device. In the omni-channel approach, it does not matter how well the customers come together with the company. The key point here is that the experience that customers will experience in any channel is the kind that can complement each other in the other channels.

Deloitte define as: "The ultimate goal of Omni-channel strategies is to direct customer attention to the brand instead of channel, providing continuity across all channels you communicate with or sell to customers." In other words, whichever channel you offer the product or service, you have to have certain coherence. The way to achieve this continuity is to follow the new technologies as well as to analyze the customer (Innova, 2015).

3. Differences between Multi-Channel and Omni Channel Retail

Priority customers were able to procure the products or services they needed mostly through physical stores. Later, direct sales practices by phone began to be developed. As the Internet began to widespread, new shopping alternatives emerged and consumers began to search for products and services on the internet, and to buy what they had decided to do online. Now, mobile devices are a practical way of shopping.

With the evolution of technology, customers now have many options to meet their shopping needs. Finding a lot of alternative shopping platforms leads to new opportunities for companies to interact with their target markets. This means that brands can be confronted both on television, on social media, and in the app store, and can follow a multi-channel marketing strategy.

Figure1. Belonging Diagram of the Channels

Omni-channel is often confused with the multi-channel concept because it is the subject of more than one channel. The omni-channel approach, however, is intended to create an uninterrupted customer experience so that the interaction between all channels can be tracked. The concept of multi-channel and omni-channel, which has a common point that basically takes the customer focus, creates two different strategies with the differences (URL2). The concepts are both very similar, but in the Omni channel strategy all of the retail channels that exist in multi–channel, work together simultaneously to create an engaging customer experience.

The multi–channel retailing strategy is that where each retail channel is isolated, acting as separate entities. This many times causes information to be disjointed across channels which degrades company branding. When information is shared and branded consistently across all channels, an omni-channel strategy appears. Consistent information sharing across channels make the shopping experience easier for consumers and can significantly increase brand loyalty in turn.

Multi-Channel retail came first and provides consumers with a variety of platforms or channels to facilitate the sale of products. Omni-Channel retail involves integrating the various retail channels to provide the customer with a consistent brand experience (URL1).

Omni-channel retailing is the more advanced, evolved version of multi-channel retailing. Multiple channels exist simultaneously. Intended to make consumer shopping experience easier and omni-channel contains same retail channels as multi-channel with some newer additions (URL1).

Table 1. Differences of Channels (Verhoef et al. 2009)

Multi-Channel "Multi"=Many	Omni-Channel "Omni"=All
Channels are isolated	Channels are fully integrated
Information across channels may be disjointed	Information across channels connects seamlessly
Typical Channels Available • Voice • Web • Mail • In Store	Typical Channels Available • Voice • Web • Mail • In Store • Social Media • Mobile

4. Strategic Key Points for Omni-channel

One of the first things that need to be done when determining the Omni-channel strategy is to introduce an approach that will set all processes in the background as services. Thus, any information that the customer may need and deemed relevant may be provided from all channels. Because it is not always possible to predict when a customer will demand what channel. Equipping the sales team with the technology that the customer uses is an approach that should not be overlooked (Fairchild, 2014). In summary, as in almost every other area today, in omni-channel applications, it is necessary not to ignore the human factor and make the workers as much as they are technologists (Fairchild, 2014).

Because if the customer arrives from any channel, whether it is a mobile phone application, web site or store, the biggest expectation in research, approach and purchasing processes will be consistency and continuity. Expectations must be determined correctly and employees should be involved in the process (Innova, 2015).
Next generation payment approaches should be adapted to the channels. The fact that omni-channel has become an emerging trend in the recent period, also paves the way for signing innovations in financial technologies that will complement user experience. Online payment systems, which have

emerged as a result of widespread online shopping, continue to facilitate the lives of interactive users. Companies that keep up with technology are increasingly using online payment methods to make their customers' lives even easier.

3D payment security, ease of payment on the web site, credit card and bank card information, various technologies such as technologies continue to speed up the online shopping experience. Innovations in online payment are beginning to offer convenience in the physical world by adopting the omni-channel approach (URL2).

For the shopping experience to be flawless and consistent, it is useful to empathize with the users (customers). Because only in the eyes of the customer it is easy to understand how the expectations are, and the user experience can be managed in the same way across all channels. In today's consumers' buying cycle, starting with a single channel and not ending with the same channel, it is important that the shopping experience is kept at the best possible level and that all channels respond in the same way as users.

5. Investigating the Trend of the Omni-Channel In Turkey

For analyzing omni-channel trend of Turkey, data of retail trade and orders via mail and internet were collected from Turkstat. According to Table 3 and Table 4, with calculation of average sales volume index and turnover index Table 2 was conducted. In regression analysis firstly time and sales volume of retail trade relationship was analyzed and high positive correlation with **0.96** was determined. It shows that next year an increase is expected with y = **1987.719 + 0.216x** regression function**.** Closeness of the correlation coefficient is to 1 indicating the continuity of the increase in years.

In regression analysis secondly, time and sales volume of orders via mail and internet relationship was analyzed and high positive correlation with **0.88** was determined. It shows that next year an increase is expected with **y = 2003.79 + 0.058x** regression function**.** Correlation coefficient of orders via mail and internet is smaller than correlation coefficient of retail sales.

In regression analysis lastly sales volume of retail orders and sales volume of orders via mail and internet relationship was analyzed and high positive correlation with **0.96** was determined. It shows that next year an increase is expected with **y = 71.977 + 0.284x** regression function**.** Closeness of the correlation coefficient is to 1 indicating the continuity of the increase in years. Regression of Turnover of retail trade and turnover of internet orders is supported to the Figure 2's increase.

In regression analysis sales volume of internet orders and turnover of internet orders have high positive correlation with **0.961**. Sales volume of retail trade and turnover of retail trade (out of Internet orders) orders have high positive correlation with **0.965**. It shows that non-internet sales have a stronger relationship with a very small difference. Cargo and investment costs in internet sales can be seen as the reason for the decrease in turnover sales relationship.

Table2: Average Volume and Turnover Index of Retail Trade and Orders via mail and internet

SALES VOLUME INDEX			TURNOVER INDEX	
Year	**AVG Retail trade**	**AVG Via mail orders and internet**	**AVG Retail trade**	**AVG Via mail orders and internet**
2010	99,91625178	100,5479988	99,85958281	100,3980982
2011	108,8954518	126,7127323	117,7012956	129,9387848
2012	114,2721627	154,7294706	133,2990941	165,322022
2013	119,2740217	175,5450973	146,3223652	189,1590088
2014	124,0995507	188,2970345	161,8393498	210,7268453

2015	128,4481081	210,7306494	172,6302561	250,7719373
2016	129,53245	184,6027724	186,6471852	236,4225905
2017	130,1784689	194,3334163	206,0330417	262,518492

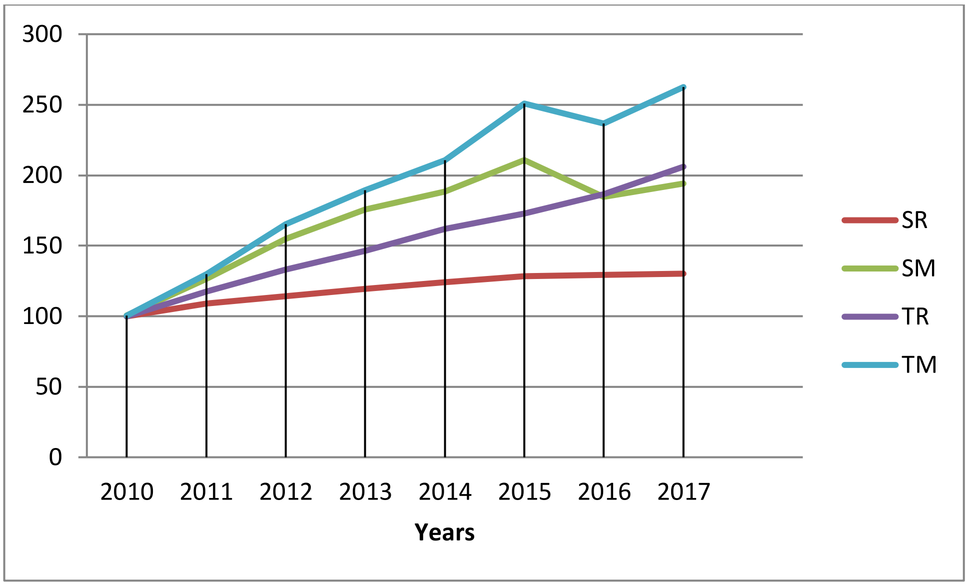

Figure2. Turnover and sales volume change over years

SR:Sales Volume Index of Retail
SM: Sales Volume Index of Mail Order and Internet
TR:Turnover Index of Retail
TM: Turnover Index of Mail Order and Internet

Table 3. Regression Analyses of Retail Trade and Internet and Mail Orders

Time and sales volume of retail trade
n=8, **Σx**=16108, **Σy**=954.6142, **(Σx)²**=259467664, **(Σy)²**=911288.27084164, **Σ(xy)**=1922296.877, **Σx²** =32433500, **Σy²**=114750.04632044 r = 0.965192875670466 **High positive correlation.** **Function** **y = -8566.783 + 4.314x**
Time and sales volume of internet orders
n=8, **Σx**=16108, **Σy**=1335.495, **(Σx)²**=259467664, **(Σy)²**=1783546.895025, **Σ(xy)**=2689582.536, **Σx²**= 32433500, **Σy²**=232628.847021 r = 0.88327443777802 **High positive correlation.** **Function** **y = -26840.498 + 13.413x**
Sales volume of retail trade and sales volume of internet orders
n=8, **Σx**=1335.2, **Σy**=954.6, **(Σx)²**=1782759.04, **(Σy)²**=911261.16, **Σ(xy)**=162070, **Σx²**=232528.86, **Σ y²**=114745.86 r = 0.964262121094505 **High positive correlation.** **Function**

y = 71.977 + 0.284x
Turnover of retail trade and turnover of internet orders
n=8, **Σx**=1224.2, **Σy**=1545.2, **(Σx)**^{2}=1498665.64, **(Σy)**^{2}=2387643.04, **Σ(xy)**=250600.22, **Σx**^{2}=196231.44, **Σy**^{2}=322161.24 r = 0.973987881885241 **High positive correlation.** **Function** **y = -50.122 + 1.59x**
Sales volume of retail trade and turnover of retail trade (non- Internet orders)
n=8, **Σx**=954.6142, **Σy**=1224.3305, **(Σx)**^{2}=911288.27084164, **(Σy)**^{2}=1498985.17323025, **Σ(xy)**=148735.1451039, **Σx**^{2}=114750.04632044, **Σy**^{2}=196283.87474525 r = 0.965427197051772 **High positive correlation.** **Function** **y = -222.389 + 3.146x**
Sales volume of internet orders and turnover of internet orders
n=8, **Σx**=1335.2, **Σy**=1544.9, **(Σx)**^{2}=1782759.04, **(Σy)**^{2}=2386716.01, **Σ(xy)**=272416.86, **Σx**^{2}=232528.86, **Σy**^{2}=322053.19 r = 0.961665321733269 **High positive correlation.** **Function** **y = -58.049 + 1.505x**
Formulations $r = \frac{\sum(xy) - (\sum x)(\sum y)/n}{\sqrt{(\sum x^2 - (\sum x)^2/n)(\sum y^2 - (\sum y)^2/n)}}$ $a = \frac{\sum y.\sum x^2 - \sum x.\sum xy}{n.\sum x^2 - (\sum x)^2}$ $b = \frac{n.\sum xy - \sum x \sum y}{n.\sum x^2 - (\sum x)^2}$ y = a + b . x

6. Conclusion

Omni-channel provides better communication and coordination among transport activities which are disconnected in multi-channel strategies. It has been seen that brands in the luxury category do not have internet sales channels while other retail companies allow this. This may be the reason for preventing damage while carrying by cargo of valuable product, or attracting the customer to the store.

When the literature is examined, it's seen that the most of the studies are done about "Omni Channel" and "Multi-Channel" issues, which they have placed together in same studies. Only Multi Channel studies follow with %1,52 decrease this publication. Only Omni Channel studies follow with about %50 decreases. The reason for this low number is that it's still a new area. And explaining this new area with comparing to the old one, increase the number of publications they have passed together.

In this paper, increase of "retail trade" and "orders via mail and internet" is shown under the influence of an incredibly fast-growing omni-channel strategy of companies. The month in which the most shopping is done in the channels is determined as "December". Monthly changes have not been studied intensively since seasonally adjusted and calendar adjusted data are analyzed. The causes and effects of the changes in the months can be examined in another study.

The regression analysis can be further developed than the one mentioned here, with the exception of the correct equation, which we have calculated and charted with operations such as significance test, confidence limits. Here, only linear function calculation has been done basically.

In the results of study it can be said clearly that; the companies, which perform the identified strategies, will increase sales volumes and turnover with the indicators of correlation.

Table 4. Seasonal and calendar adjusted retail sales volume index and monthly changes, 2010-2017

Constant prices VAT included]
[2010=100]

Economic activity **(NACE Rev.2)**	Year	January	February	March	April	May	June	July	August	September	October	November	December
		Endeks - Index											
Retail trade	2010	**94,2**	**95,6**	**98,4**	**99,3**	**99,0**	**98,4**	**100,9**	**100,5**	**100,0**	**101,8**	**104,9**	**106,0**
	2011	**108,9**	**107,9**	**107,8**	**105,4**	**106,1**	**108,1**	**109,3**	**107,9**	**111,7**	**112,3**	**111,0**	**110,3**
	2012	**110,6**	**112,6**	**111,7**	**115,9**	**115,8**	**118,8**	**114,1**	**113,2**	**114,1**	**113,0**	**114,6**	**116,7**
	2013	**113,3**	**116,2**	**118,8**	**116,6**	**118,1**	**116,3**	**118,1**	**124,1**	**123,4**	**123,6**	**121,7**	**121,0**
	2014 (r)	**124,1**	**122,6**	**121,9**	**122,7**	**122,9**	**123,0**	**121,9**	**124,2**	**127,0**	**125,3**	**126,7**	**127,0**
	2015 (r)	**129,2**	**125,3**	**126,3**	**127,2**	**128,5**	**127,5**	**129,6**	**128,6**	**127,4**	**129,0**	**131,1**	**131,9**
	2016 (r)	**129,5**	**134,5**	**131,8**	**131,4**	**130,4**	**129,9**	**125,9**	**128,7**	**129,1**	**127,7**	**128,1**	**127,4**
	2017 (r)	**126,5**	**128,4**	**131,0**	**131,2**	**131,6**	**132,3**						
Via mail orders and internet	2010	90,5	92,1	93,6	95,7	96,3	100,3	101,6	103,0	104,2	107,7	109,5	112,2
	2011	113,0	113,2	121,2	125,4	122,3	127,3	125,6	131,6	133,8	132,7	136,8	137,7
	2012	140,7	152,3	152,3	141,4	156,2	156,9	153,6	156,7	155,9	156,3	165,5	169,0
	2013	168,4	168,5	181,3	188,0	172,0	169,8	170,5	174,0	178,2	176,4	176,6	182,7
	2014 (r)	190,0	149,7	156,0	167,0	184,1	178,7	200,0	192,2	200,1	204,6	218,9	218,3
	2015 (r)	226,0	224,8	219,8	208,9	220,2	220,5	220,8	216,6	199,7	202,6	183,2	185,5
	2016 (r)	179,3	167,1	165,8	175,1	176,4	191,2	183,2	184,5	193,0	189,2	203,0	207,5
	2017 (r)	192,6	201,2	204,4	199,6	186,8	181,4						

Source:TurkStat, Retail Sales Indices
(r) Data are revised.

Table 5. Seasonal and calendar adjusted retail turnover index and monthly changes, 2010-2017

Current prices VAT excluded]
[2010=100]

Economic activity **(NACE Rev.2)**	Year	January	February	March	April	May	June	July	August	September	October	November	December
		Endeks - Index											
Retail trade	2010	**91,8**	**94,1**	**97,9**	**99,0**	**99,3**	**98,0**	**101,0**	**100,5**	**100,5**	**102,3**	**106,2**	**107,6**
	2011	**111,4**	**110,5**	**111,0**	**111,6**	**113,7**	**117,6**	**119,3**	**119,1**	**123,3**	**125,4**	**124,2**	**125,4**
	2012	**125,9**	**128,0**	**128,5**	**134,6**	**134,2**	**138,0**	**132,7**	**131,7**	**135,4**	**135,4**	**136,7**	**138,5**
	2013	**136,1**	**140,3**	**142,7**	**140,6**	**142,3**	**142,3**	**145,3**	**153,5**	**152,8**	**153,8**	**152,9**	**153,2**
	2014 (r)	**159,2**	**158,0**	**157,4**	**158,6**	**159,4**	**161,4**	**161,1**	**164,6**	**166,4**	**165,2**	**165,8**	**165,0**
	2015 (r)	**166,0**	**162,6**	**165,6**	**169,2**	**172,9**	**172,0**	**174,5**	**174,2**	**174,4**	**177,7**	**180,7**	**181,8**
	2016 (r)	**178,7**	**184,9**	**183,4**	**183,3**	**184,9**	**185,9**	**182,0**	**188,0**	**189,8**	**190,2**	**192,9**	**195,8**
	2017 (r)	**197,8**	**203,9**	**207,7**	**208,0**	**208,8**	**210,1**						
Via mail orders and internet	2010	90,7	92,2	91,9	94,5	96,0	100,1	102,6	103,0	104,9	110,0	110,2	108,9
	2011	111,8	113,0	122,4	127,1	124,0	129,9	127,8	136,6	139,1	138,8	144,0	144,8
	2012	149,7	157,7	158,0	152,7	165,8	165,3	166,7	168,0	171,0	171,9	176,9	180,2
	2013	180,2	179,9	193,1	201,1	184,4	182,8	184,0	188,4	193,5	191,9	191,5	199,2
	2014 (r)	209,0	165,9	173,9	185,7	205,4	198,2	225,3	215,4	224,4	229,9	247,3	248,3
	2015 (r)	257,1	256,6	252,3	243,9	259,2	261,9	263,9	260,9	244,0	250,9	227,6	230,9
	2016 (r)	225,1	210,2	208,4	219,5	223,3	243,5	235,9	238,6	248,8	244,5	265,1	274,1
	2017 (r)	255,2	269,5	275,9	271,4	254,1	249,0						

Source:TurkStat, Retail Sales Indices
(r) Data are revised.

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ELECTRIC VEHICLE CHARGING STATIONS AND CHARGER TYPE DECISIONS IN ISTANBUL

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Abstract *– As the number of vehicles increases gradually, the air pollution levels keep getting worse. The widespread usage of electric vehicles might be helpful in reducing the pollution however this reqires the establishment of charging stations and chargers to meet the demands of the customers. In this paper, a mixed integer mathematical model is developed to determine the locations of charging stations, and the number of different types of chargers that needs to be established in these stations. Constraints related to satisfying the demands of potential customers, capacity restrictions of potential electric vehicle charging stations and charger type restrictions in each charging station are taken into consideration, while minimizing the total cost of opening the charging stations. The mathematical model is applied in Istanbul and as a result optimal number of fast, normal and slow chargers are determined along with locations of potential charging stations.*

Keywords – Electric vehicles, charging station location selection, charger type selection, mixed integer mathematical model

INTRODUCTION

Due to increasing number of vehicles and the amount of carbon dioxide (CO2) and pollutant emissions in the atmosphere, nowadays many countries are taking precautions. As a result of these efforts, the number of vehicles using fossil fuels is expected to decrease day by day and eco-friendly electric vehicles are expected to take their places. However, special infrastructures such as charging stations and chargers are needed for this transformation.

In the literature there are several studies that determine the location of charging stations of electric vehicles. You and Hsieh [1] developed an origin-destination trip based mixed-integer programming model to determine the optimal locations and types of charging stations while maximizing the number of people who can complete round-trip itineraries and presented a hybrid heuristic approach to solve the problem. Sadeghi-Barzani, Rajabi-Ghahnavieh, and Kazemi-Karegar [2] presented a mixed-integer non-linear model to determine the location and size of fast charging stations, taking into consideration the station development cost, electric grid loss and electric vehicle energy loss, and developed a genetic algorithm to solve the problem. Shahraki *et al.* [3] developed a model in order to capture public demand based on vehicle travel patterns and to select the locations of public charging stations in Beijing, China while maximizing the amount of electrified travel miles. Guo and Zhao [4] implemented fuzzy TOPSIS to select the optimal site of electric vehicle charging station in Beijing. They used environment, economy and society criteria with related sub criteria. Hosseini and MirHassani [5] presented a two-stage stochastic refueling station location model. At the first stage, permanent stations were located and at the second stage, portable stations were located. They applied the model to the network of Arizona and presented an exact approach and a greedy heuristic to solve the problem. Arslan and Karaşan [6] studied the plug-in hybrid electric vehicles charging station location problem, taking into consideration different classes of vehicles with various ranges. They presented an arc-cover formulation and a Benders decomposition algorithm to solve the problem. Andrenacci, Ragona, and Valenti [7] first used fuzzy K-means clustering approach to find the optimal allocation of charging infrastructures into subareas in Rome based on data of private vehicle travels and then estimated the energy requirements of these subareas along with number of users. Guerra *et al.* [8] estimated the required infrastructure for refuelling alternative fuel vehicles with the help of profitability

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thresholds using discrete choice models. They used this to estimate Spain's hydrogen refuelling stations, electricity charging stations and the evolution of fuel cell vehicles over the years. Kim *et al.* [9] presented a stochastic model for an electric vehicle battery charging system taking into consideration time-varying behaviour of the electric vehicles, parking times, electricity demand, and number of charging stations. Hof, Schneider and Goeke [10] worked on the battery swap station location-routing problem with capacitated electric vehicles and presented the extended Adaptive Variable Neighborhood Search (AVNS) algorithm in order to solve it. In this problem, batters swap locations are determined along with vehicle routes to serve customers, while minimizing the total cost of battery swap stations and routing.

In the literature, the closest research to the presented one are by Zhu *et al.* [11] and Asamer *et al.* [12]. Zhu *et al.* [11] proposed a model to determine the location of charging stations along with the number of chargers to establish at these stations and presented a genetic algorithm based method to solve the problem. In their model, they minimized the total cost which includes the construction cost and travel cost of customers to the station. Asamer *et al.* [12] solved a version of maximal covering location problem in order to identify charging station places for electric taxi vehicles, and presented a case study in Vienna, Austria. At present, there does not appear to be a research paper in the literature that focuses on minimizing the total cost of opening charging stations, total cost of chargers and total budget for chargers while taking into consideration different types of chargers, demand coverage, and restrictions related to budget, capacity of charging stations and chargers. In the next sections, the developed mathematical model is presented in detail, along with a case study realized in Istanbul.

THE MATHEMATICAL MODEL

Indices:

i, j : Index for districts in Istanbul $(i, j = 1, 2, ..., m)$

k : Index for charger type (according to charging time) $(k = 1, .., n)$

Parameters:

c_k = Cost of charger type k

f_i = Fixed cost for opening charging station at district i

α_j = Electrical vehicle rate at district j

r = coverage range

d_{ij} = Distance between district i and district j

p = 18+ years old population of Istanbul

p_j =18+ years old population of district j

v = Number of vehicles in Istanbul

v_j =Amount of vehicles that may visit district j, ($v_j = v(p_j / p)$)

t_k =Charging time (per vehicle) for charger type k

t =Total available charging hours in a charging station (24 hours)

y_k =Maximum number of vehicles that can be charged in a day with charger type k, ($y_k = t / t_k$)

b_{ij} = Parameter which shows if district i covers j, $b_{ij} = \begin{cases} 1 & \text{if} \quad d_{ij} \le r \\ 0 & \text{otherwise} \end{cases}$

$q_{\max}$ =Maximum number of chargers in a station

$q_{\min}$ =Minimum number of chargers in a station

a_i = Traffic density at district i

$\bar{a}$ = Average traffic density for Istanbul, $\bar{a} = \sum_{i=1}^{m} a_i \Big/ m$

s_i = Parameter for traffic density comparison, $s_i = \begin{cases} 1 & if \quad a_i \ge \bar{a} \\ 0 & otherwise \end{cases}$

M = Very large positive number

RC = Total cost of opening charging station(s) and establishing charger(s) at these station(s)

Decision variables:

x_i = Binary variable for opening a charging station at district i,

$$x_i = \begin{cases} 1 & \text{if a charging station is opened at district i} \\ 0 & \text{otherwise} \end{cases}$$

q_{ik} = Number of type k chargers opened at district i

o_i = Number of station(s) opened at district i

h_i = Budget for chargers at each district i

The mathematical model is:

$$Min \quad z = \sum_{i=1}^{m} f_i n_i + \sum_{i=1}^{m}\sum_{k=1}^{n} q_{ik} c_{ik} + \sum_{i=1}^{m} h_i \tag{1}$$

$$RC = \sum_{i=1}^{m} f_i n_i + \sum_{i=1}^{m}\sum_{k=1}^{n} q_{ik} c_{ik} \tag{2}$$

$$\sum_{i=1}^{m} b_{ij} x_i \geq 1 \quad \forall j \tag{3}$$

$$\sum_{i=1}^{m} b_{ij} \sum_{k=1}^{n} q_{ik} y_k \geq v_j \alpha_j \quad \forall j \tag{4}$$

$$q_{ik} \geq s_i x_i \quad k = 1, \forall i \tag{5}$$

$$\sum_{k=1}^{n} q_{ik} \leq q_{\max} o_i \quad \forall i \tag{6}$$

$$\sum_{k=1}^{n} q_{ik} \geq q_{\min} o_i \quad \forall i \tag{7}$$

$$\sum_{k=1}^{n} c_{ik} q_{ik} \leq h_i \quad \forall i \tag{8}$$

$$o_i \leq x_i M \quad \forall i \tag{9}$$

$$x_i \leq o_i \quad \forall i \tag{10}$$

$$x_i = \{0,1\} \quad \forall i \tag{11}$$

$$q_{ik} \geq 0, q_{ik} \in Z \quad \forall i,k \tag{12}$$

$$o_i \geq 0, \quad o_i \in Z \quad \forall i \tag{13}$$

In this paper, a mixed integer mathematical model is developed to determine the locations of charging stations, and the number of different types of chargers that needs to be established in these stations. Objective function (1) is to minimize the total cost of opening charging station(s), total cost of chargers and total budget for chargers. First constraint (2) is the total cost of opening charging station(s) and establishing charger(s) at these station(s). Second constraint (3) is to make sure that all the districts are covered. Note that coverage is defined as "being in 10km range of the charging station". Third constraint (4) is to make sure that each district's demand is covered. Fourth constraint (5) ensures that if a district's traffic density is greater than or equal to the average traffic density and if a charging station is opened at the district, then the charging station has at least 1 fast charger. Fifth constraint (6) restricts the amount of chargers in a district to a maximum number. Sixth constraint (7) is to ensure that minimum number of chargers is available at a district (if the station(s) is/are opened.) Seventh constraint (8) is for budget restrictions that are related to chargers at each station. Eighth constraint (9) is to make sure that if there is no station opened at a district, number of stations that are opened at that district is zero. Ninth constraint (10) is to make sure that if a station is opened at a district, number of stations that are opened at that district is at least one. Tenth constraint (11) is for the binary restrictions. Eleventh (12) and twelfth (13) constraints are for the non-negativity restrictions and integer restrictions.

CASE STUDY

The mathematical model is applied in Istanbul, Turkey. 38 districts of Istanbul (except Adalar district since these are islands in Marmara Sea) are taken into consideration. Population of 18+ years old who may have a driving license at each district is taken from [13] and total number of vehicles in Istanbul from [14]. Based on these, amount of vehicles that may visit each district is calculated as seen in Table 1.

Table 1. Number of Vehicles that may Visit Each District

District	# of vehicles	District	# of vehicles	District	# of vehicles	District	# of vehicles
Arnavutköy	64,449	Beylikdüzü	75,516	Güngören	76,599	Sultanbeyli	43,661
Ataşehir	109,861	Beyoğlu	62,633	Kadıköy	96,984	Sultangazi	71,791
Avcılar	112,922	Büyükçekmece	58,770	Kâğıthane	119,802	Şile	86,223
Bağcılar	201,461	Çatalca	15,762	Kartal	115,941	Şişli	140,312
Bahçelievler	156,646	Çekmeköy	64,491	Küçükçekmece	203,109	Tuzla	66,085
Bakırköy	50,022	Esenler	123,372	Maltepe	123,761	Ümraniye	184,638
Başakşehir	96,274	Esenyurt	220,480	Pendik	182,353	Üsküdar	134,958
Bayrampaşa	69,361	Eyüp	98,234	Sancaktepe	103,014	Zeytinburnu	75,577
Beşiktaş	46,615	Fatih	105,565	Sarıyer	89,246		
Beykoz	62,681	Gaziosmanpaşa	128,988	Silivri	7,194		

Electric vehicle rate at each district (α_j) is taken as %5 based on [15]'s research. There are three types of chargers (n=3), k=1 is for vehicles with charging time of 1 hour (fast charger), k=2 is for 4 hours (medium, normal charger), and k=3 is for 8 hours (slow charger). While determining the maximum number of vehicles that can be charged in a day with a certain charger type, it is assumed that each electric vehicle will be fully charged. Maximum and minimum number of chargers in a station are taken as q_{max} =150 and q_{min} =25 based on [15]. Cost of fast, medium and slow chargers are taken as $75000, $4150 and $725 as in [16] and converted to TL with an exchange rate of 1$=3.5348 TL. [17]. Fixed cost of opening a charging station at each district is calculated taking into consideration average land costs at each district per m^2 which is taken from council of districts [18]. Here, it is assumed that on average, there are (q_{max} + q_{min})/2 chargers and $10m^2$ area is needed for each charger. The fixed cost for opening a charging station at each district is given in Table 2 in TL.

The traffic density of each district is analyzed based on the traffic density map published by Republic of Turkey General Directorate of Highways [19] to ensure that if a district's traffic density is greater than or equal to the average traffic density and if a charging station is opened at the district, then the charging station has at least 1 fast charger [20]. Based on these, in Başakşehir, Beşiktaş, Beykoz, Beyoğlu, Eyüp, Kağıthane, Sultanbeyli, Şişli, Ümraniye, Üsküdar, there should be at least 1 charger if a station is opened at those districts. Distances between districts are calculated with GoogleMaps [21] and a district is assumed to "cover" another district if the distance between is less than or equal to 10km, similar to [15]'s research.

Table 2. Fixed Cost of Opening Charging Station at Each District (TL)

District	Cost	District	Cost	District	Cost	District	Cost
Arnavutköy	99,507	Beylikdüzü	397,946	Güngören	1,373,493	Sultanbeyli	191,308
Ataşehir	102,520	Beyoğlu	4,742,056	Kadıköy	3,900,722	Sultangazi	422,472
Avcılar	383,313	Büyükçekmece	71,205	Kâğıthane	407,145	Şile	46,110
Bağcılar	957,388	Çatalca	10,992	Kartal	515,505	Şişli	1,0178,568
Bahçelievler	1064,198	Çekmeköy	112,821	Küçükçekmece	893,506	Tuzla	183,984
Bakırköy	2,034,950	Esenler	784,851	Maltepe	699,010	Ümraniye	207,253
Başakşehir	696,112	Esenyurt	2,845,09	Pendik	437,188	Üsküdar	2,186,039
Bayrampaşa	763,830	Eyüp	2,221,41	Sancaktepe	155,570	Zeytinburnu	369,231
Beşiktaş	3,534,073	Fatih	3,540,014	Sarıyer	854,929		
Beykoz	165,173	Gaziosmanpaşa	530,661	Silivri	65,146		

All the constraints are satisfied and the mathematical model is solved optimally with Lingo 16 solver. The optimal objective function is determined as 280,458,600TL, which includes the total cost of opening charging stations and establishing chargers at these stations (201,341,100 TL), and total budget for chargers (79,117,500 TL). Optimal solution is presented in Table 3, which includes the number of charger stations and different types of chargers that need to be established at each district.

Table 3. Optimal Number of Charger Stations and Types of Chargers

Districts	Number of charging stations	Num. Of Fast Charger	Num. Of Normal Charger	Num. of Slow Charger	Districts	Number of charging stations	Num. Of Fast Charger	Num. Of Normal Charger	Num. of Slow Charger
Arnavutköy	7	0	25	1,025	Gaziosmanpaşa	4	0	600	0
Ataşehir	21	0	0	3,078	Güngören	0	0	0	0
Avcılar	12	0	83	1,717	Kadıköy	0	0	0	0
Bağcılar	6	0	900	0	Kâğıthane	6	1	70	829
Bahçelievler	2	0	300	0	Kartal	0	0	0	0
Bakırköy	0	0	0	0	Küçükçekmece	4	0	386	214
Başakşehir	0	0	0	0	Maltepe	7	0	1,013	37
Bayrampaşa	3	0	330	120	Pendik	0	0	0	0
Beşiktaş	0	0	0	0	Sancaktepe	12	0	0	1,717
Beykoz	7	1	0	1,037	Sarıyer	5	0	738	12
Beylikdüzü	0	0	0	0	Silivri	1	0	0	120
Beyoğlu	1	114	32	4	Sultanbeyli	5	1	0	720
Büyükçekmece	9	0	0	1,259	Sultangazi	0	0	0	0
Çatalca	17	0	0	2,475	Şile	10	0	0	1,438
Çekmeköy	7	0	25	1,025	Şişli	0	0	0	0
Esenler	0	0	0	0	Tuzla	7	0	52	998
Esenyurt	0	0	0	0	Ümraniye	0	0	0	0
Eyüp	1	1	13	136	Üsküdar	8	1	1,043	156
Fatih	0	0	0	0	Zeytinburnu	0	0	0	0

CONCLUSIONS

With the increasing usage of electric vehicles in Istanbul, finding charging stations that are available are going to be a significant need in the future. In this paper, a mathematical model is developed for decisions related to the location of charging stations and establishment of different types of chargers. The model is implemented with the data of Istanbul and the optimal result is shared with the authorities. For future research, the application area of the study can be extended, and the model can be applied to all the cities in Turkey. In the mathematical model, the criterion considered is the minimization of total cost, however, for future research; the model can be extended to take into account the service levels and traffic. Also, in this research, it is assumed that an electric vehicle is fully charged once it is at a charging station. For future research, this assumption can be relaxed and the charging levels can be taken into consideration.

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A RESEARCH ON THE EXAMINATION OF NEW APPROACHES IN TRANSPORTATION SECTOR

İlknur YARDIMCI[1], Mehmet TANYAŞ[2]

Abstract *– Today transportation costs are rising due to increasing product options, rising fuel prices, small amount but frequent shipments, rising transport to whole country with e-commerce activities. For this reason, the sector is always open to new developments. As is the case in the world, as a result of the change and development of e-commerce especially in the field of e-commerce with the removal of the limits of the electronic communication in Turkey, cargo sector will also undertake the role of the consultant firm and offer its customers many different field values. As a result of changing climatic conditions, they will create environmentally friendly vehicles and business methods that will create more responsive operational processes around the environment. In this context logistics sector stakeholders have to create new strategies for sector sustainability. This study will examine the distribution strategies developed in the world and our country and analyze the new trends in the logistics sector.*

Keywords – Innovation, Transportation Management, Trends

1. Introduction

The demand for improving the quality and efficiency of transportation service has been growing, and new technologies have been entering the market at a rapid pace (Feng, 2014). Commercial transport companies have been hesitant about adopting more advanced technologies for a number of internal reasons including the lack of a digital culture, privacy concerns, and cost and widespread confusion about which hardware and software breakthroughs will have the biggest effect on profitability and overall organizational performance is a big handicap as well (PwC,2015). This situation can be overcome by adopting aspects of advanced vehicle-related IT systems, automated fleet management, cloud-based data analytics, robotics, location detection, and autonomous vehicle technologies, which will gained the flexibility and capabilities to shift gears and focus on the most profitable services based on customers' needs.

Although information systems have been disrupting carrier operations and logistics for years compelling companies to develop sophisticated data networks that respond ever more quickly to customer shipment demands, track shipments more transparently, and offer faster and more definitive delivery schedules only now are these technologies being implemented by a raft of new competitors with new business models.

2. Innovations in Transportation Sector

The modern consumer is the case with many industries, transportation and logistics will continue to be shaped by rising consumer expectations in today. Those have an inherent desire to receive goods and services instantly putting increased pressure on transportation and logistics companies to deliver goods exceptionally fast, and at the lowest price. Consumers now demand unprecedented visibility into order status, tracking and delivery, forcing the industry to invest in new technologies and partnerships.

Increase of consumer demands are fueled by the explosive growth of e-commerce. According to a

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survey by UPS, 51 percent of purchases were made online in year 2016. Moreover, the phone and mobile technology are becoming the primary shopping device of consumers, according to PwC, meaning that they can literally shop anytime and anywhere. To compete, retailers must employ an omni-channel logistics strategy to deliver a seamless shopping experience. This inevitably introduces new supply chain, fulfillment and shipping challenges.

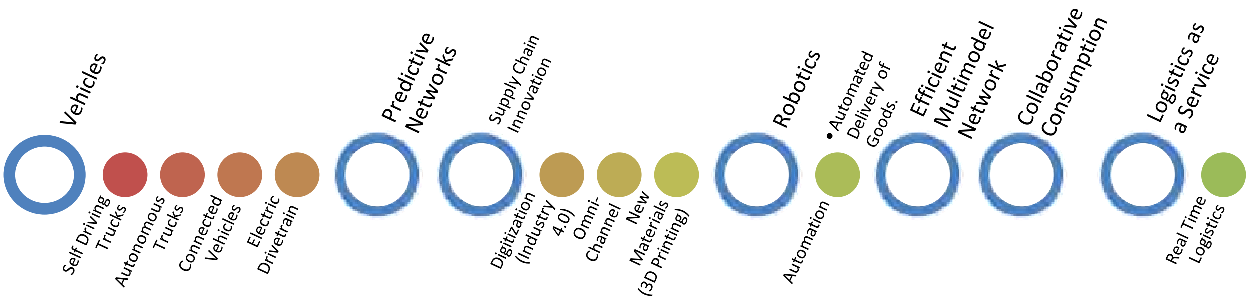

Figure1. Trends in Transportation Sector

From changes in the modern consumer's needs and the growth of ecommerce to digitalization of the supply chain, automation technology, and the overall economic shift to the cloud, 2015-2020 as being pivotal years for transportation and logistics companies. New generation mobile systems, use of drones in the logistics sector, intelligent urban logistics, new technologies in supply chain management, supply chain 4.0 (IOT, virtual reality-increased reality, big data), demand planning, optimization are the most mentioned topics in 2017. For collecting them under general categories the more intriguing and potentially high-impact technologies available now or on the horizon to consider sorted as:

2.1. Self-driving / Autonomous Trucks / Connected Vehicles: Even though today the technology exists for autonomous trucks, it must still overcome several obstacles, including perfecting driverless software. In this way it can operate in crowded urban environments, rather than only on wide-open highways where traffic flows freely and vehicle regulators are still working out rules for autonomous driving permits and safety requirements (Barker et al, 2013). In the interim, though, commercial transport companies should begin the process of revamping their trucking fleets with self-navigating equipment that can learn to drive from human truckers. Through the use of myriad sensors, an artificially intelligent vehicle can evaluate road conditions and observe how the human operator responds to various exceptions along the route. In the process, the soon to be autonomous truck would collect anecdotal data about instinctual human driver proclivities, such as not turning left into a busy side street even though the GPS suggests it is the fastest route. Moreover, communicating with one another over the cloud, these vehicles can share what they have learned and amass more sophisticated knowledge about driving than could ever be programmed in a lab. Ultimately, with this level of software and hardware development, these trucks should become better drivers than any individual human operator.

Considering the developments in this sector, AT&T added more car data subscribers than smartphone subscribers or tablet subscribers .These data plans deliver software updates to the vehicle, traffic data to the navigation system, and Internet connectivity to the passengers. Connections with other vehicles and with infrastructure reduce congestion and vehicle fatalities. They also enable automakers to develop new tools for predictive and preventative maintenance. Connectivity transform the auto insurance market by enabling insurance firms to differentiate between safe and unsafe drivers, and also help with shorter and safer commutes, plan fleet purchases and efficiently route, manage, and maintain vehicles.

2.2. Real-time logistics: Soon it will be possible to integrate the trucks in the entire supply chain into the logistics data. The advanced telematics has made it possible for the transportation companies to use the cloud-based analytics to locate the truck, the health and fatigue of the driver, the heat of the load and the barometric pressure. It will track and monitor the factors. At the same time, telematics will facilitate automatic freight matching. The truck trailer can determine the available space, weight, route and ETA based on the sensors and can transfer this information to software that produces the most efficient and cost-effective scenario for moving loads. Carriers can become more efficient using analytics to more efficiently distribute their fleet, optimize routes, and predict traffic.

2.3. Robotics: UPS, DHL and FedEx as the company is experimenting with robot loading and unloading of irregular parcels. The increased mobility provided by the gyroscope and mapping technologies further increases the robotic awareness of the specific sender size and recognition and can carry them to the appropriate places for collection and packaging. With this technology, labor costs can be greatly reduced while shipping and delivery times are accelerated (T. Niemueller et al 2017).

2.4. Predictive networks: Similar predictive networks can be used by carriers to improve their internal operations. Carriers can become more efficient by using past event-based analytics to deploy their fleet more effectively, increase capacity and load balancing throughout the logistics chain, optimize routes, and predict traffic and accidents. Giving better insights into a customer's shipping habits and marrying this knowledge with a new generation of telematics can ensure that a carrier will deliver the best possible delivery on time, even at peak periods and when driving conditions are challenging.

2.5. Supply Chain Innovation: Omni channel logistics owes more to an inclination that will spread itself as a "digital supply chain". IOT's power and data-driven insights offer tremendous potential to improve customer service and maximize productivity, leveraging various points throughout the supply chain. Big data and predictive analytics reinforce logistics that can explain external factors that can help mitigate risk significantly throughout the supply chain, such as natural disasters and war hazards.

2.6. Automated Delivery of Goods: Movement towards automation, efficiency is greatly increased. Amazon has begun to experiment with drones, a new form of express delivery, and the advances in sensor technology have transformed autonomous tools into reality for 2017 and beyond. These automated solutions have the potential to significantly increase safety, mitigate risk and improve productivity (Kunze, 2016).

2.7. Logistics as a Service: The cloud logistics movement in the broad sector enables business models of "logistics as a service". Finding innovations has allowed real-time information access to supply chain processes to be controlled, making them more agile in response to volatility or disruptive events. In the meantime, this same technology facilitates flexible integrations with other key business processes to optimize all operations (URL1).

2.8. Collaborative Consumption: Services like Uber and ZipCar allow one to get what they want (on-demand mobility) without having to buy what they do not need. This reduces car sales while redefining luxury in cars. The advantages of this system are that it does not need to be involved in traffic, to worry about ticket acceleration, to find parking, to charge or fuel the vehicle, or to pay insurance.

2.9. Electric Drivetrain: An electric drivetrain is more powerful, compact and efficient than the fossil-fuel alternative and produces zero local air emissions. While providing unparalleled combination of electric drive performance and efficiency, it produces maximum torque at any speed while achieving unmatched good wheel efficiency by internal combustion engines, and captures energy with regenerative braking. Investments in battery technology and disruptive innovations of emerging battery companies significantly reduce energy storage costs. Low-carbon electricity will continue to become more economical; Fossil fuels will become more expensive in the long run. As a result, more segments of the transportation sector will give up the electric drive market share. Segments of heavy-duty vehicles, such as transit buses and local delivery trucks, will be a pioneer in the electrification of transportation because electric drives are very attractive for heavy short-range vehicles.

2.10. Efficient Multimodal Network: Automobiles will be integrated into an efficient intermodal network. The BMW iSeries is the first attempt by an OEM to include public transport in the driving experience. Several companies, such as INRIX and Waze, have developed to improve the efficiency of our driver. Now, start-ups are working to increase transparency in public transport and add frustration to the community, sell tickets to smartphones, and reduce friction through price calculation for multiple travel options. Combining users' calendar, location, and travel preferences, mobile applications can now automatically plan the most effective trip possible using real-time data.

2.11. New Materials: (And mandatory 3D printing reference) In the short span, the light weight increase will intensify over the next decade. Fuel efficiency standards mean that producers are motivated to lose weight: now weight is a more important decision factor than cost of purchase. Electrification directs lightness to the extent that it increases the range and reduces the desired battery size. Lightening demand comes at a time when the cost of carbon fiber parts is falling dramatically. In the mid to long-term, new automotive manufacturing technologies, including 3d printing, will change the way cars are designed and installed to enable higher performance, lighter and newer design.

3. Literature Review

When the literature is examined, it's seen that the most of the studies are done about the Collaborative Consumption field, number of studies followed by Supply Chain Innovation, New Materials, Electric Drivetrain, Real-time logistics and Predictive networks. Robotics, Automated Delivery of Goods, Logistics as a Service, and Efficient Multimodal Network fields are specific areas, for that reason Because Robotics, Automated Delivery of Goods, Logistics as a Service, and Efficient Multimodal Network fields are specific areas for that reason minimum number of charts pie is in these areas. It is also noteworthy that publications are mainly based on USA.

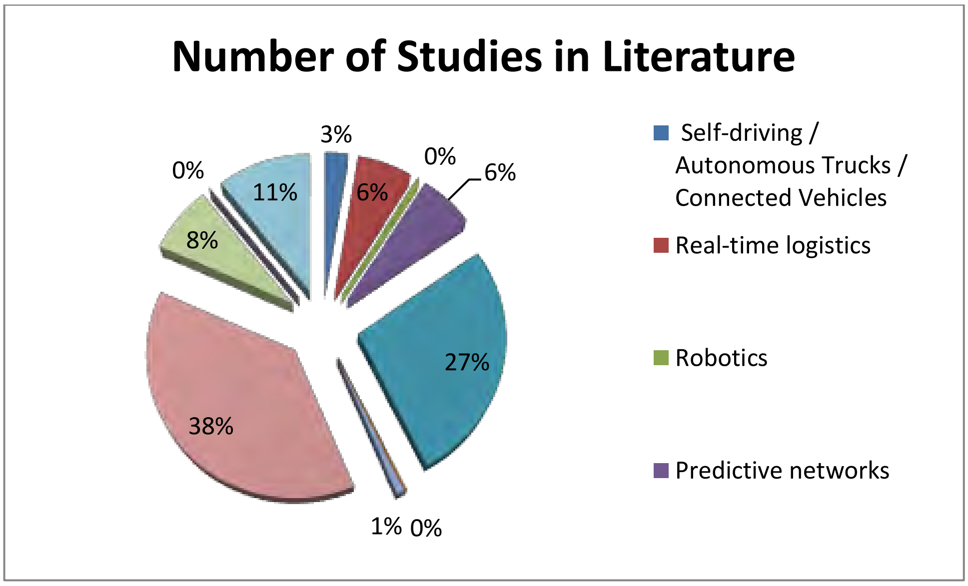

Figure 2. Number of Studies in Literature

4. Applications of New Approaches

The innovations that listed in Section 2 find applications areas such as listed in Table1.

Table1. Applications of New Approaches

Innovation	Country
Amazon announces Prime Air, which will deliver packages for 30 minutes without placing orders by Drone. The first Prime Minister's turn-off was completed by a UK customer at the beginning of December 2016.	England
Uber's autonomous trucking arm, Otto, made its maiden voyage in October, delivering 50,000 cans of beer via self-driving vehicle plying the Colorado highways from Fort Collins to Colorado Springs.	U.S.A
Arizona-based start-up Local Motors buried IBM's Watson Internet for Things Automotive in a bus-free shuttle bus produced by 3D printing. Designed as a bus, Olli put his first passengers in the streets of shopping areas just outside Washington, DC. Local Motors plans to produce commercial land vehicles based on this design.	U.S.A
Skuchain, a Silicon Valley company, created a transport chain application using block chains. The concept behind Bitcoin, the block chain, has been introduced as a potentially safe platform for direct business-to-business activities in financial services, as it creates a verifiable and auditable information package sequence for each transaction. This technology applied to commercial transport can create more seamless and transparent communication and interaction between carriers and transporters, possibly adding costs to customers by removing distributors and other intermediaries.	U.S.A
Skuchain's service and similar ones may reduce customer concerns about using smaller, less experienced carriers for part of their shipments because the safeguards built into block chain ostensibly create parity between new entrants and larger, established companies in safeguarding and tracking shipments step by step and from door to door. Also possible, though, is that established carriers will embrace block chain to reduce transaction complexity and enhance their brand with customers.	U.S.A
Convoy is a one-year company that matches software deliveries to a region with tractor trailers from small local suppliers to maximize planning efficiency and minimize shipping downtime. News came when Unilever signed a deal with a large part of the logistics of the consumer products conglomerate in North America.	U.S.A
This so-called sharing economy model, similar to what's happening in the taxi realm, is becoming a popular commercial transport option globally. UberCARGO in Hong Kong, Dolly in the U.S., and Nimber in Norway are other players hoping to make a splash in this arena. The sharing economy opens up possibilities in other areas of logistics as well. Seattle-based Flexe, for example, offers on-demand warehousing by matching available space in a location with requests for expedited warehouse facilities. Flexe bills itself as the "Airbnb for warehouse space."	U.S.A NORWAY HONG KONG
An even bigger disruptive force is on the horizon: the rise of free-floating, contractual services, the shipping versions of an e-marketplace. The "operators" will be cloud-based platforms that coordinate entire routes for shipments by choosing among carriers, hubs, depots, and warehouses to find the most efficient use of capacity. In this environment, the owner of a single truck can compete head-to-head with companies owning hundreds of vehicles.	-
Domino's inaugural pizza drone delivery test performed successfully.	-
Domino's DXP pizza-delivery vehicle that was crafted out of a small Chevy to include actual helpful aids such as an integrated warming oven and a permanent lighted logo sign on top of the car.	-
Zume Pizza, a startup in Mountain View, California, is known for using a fleet of	U.S.A

robots in the kitchen to speed up the pizza making process. But now, the company is outfitting its pizza delivery truck with 56 ovens programmed to make pies en route to customers. When the truck is four minutes away from its destination, an oven containing the order will turn on to fully bake the pie. It takes 3 minutes and 30 seconds to cook, and 30 seconds to cool down.	
The specialized LiDAR laser sensors that Google uses on its autonomous vehicles cost more than $70,000. This year, the manufacturer released a miniaturized version that costs one-tenth the price.	-

5. Innovative Enterprises in Transportation Industry in Turkey

According to analyze of TurkStat data, product and / or process innovative enterprises in transport, storage and communication, there is decrease in 2002-2004 and 2010-2012 periods. And transport technological innovations constitute a large part of the innovations provided in the service area on average %85.

Table 2. Innovative enterprises in industry by economic activity and size (%)

Economic activities **(NACE Rev.1.1)**		Product and/or process innovative enterprises / Enterprises with technological innovation					
		2002-2004	**2004-2006**	**2006-2008**	**2008-2010**	**2010-2012**	**2012-2014**
Total					**35,2**	**27,0**	**38,0**
Services		**25,9**	**24,6**	**23,2**	**33,8**	**23,9**	**33,5**
Transport, storage and communication (NACE 60-64)		**22,3**	**14,9**	**18,3**	26,8	21,0	28,7
60	Land transport; transport via pipelines	23,1	-	-			
61	Water transport	9,3	-	-			
62	Air transport	79,4	-	-			
63	Supporting and auxiliary transport activities; activities of travel agencies	22,0	-	-			
64	Post and telecommunications	32,2	-	-			

Source: TurkStat (2017)

However, when the table is examined, it is observed that the innovations made in total and are not very high percentages. The reason for this is that only successful projects are transferred to data.

6. Conclusion

It is seen in the result of the research that in transportation industry investments have been seen to increase as a result of innovations. Venture investors put $5.7 billion into transportation businesses last year, more than twice the level of investment in the previous two years combined. Uber was the big winner, raising $3B. But other startups also raised significant funds, like GrabTaxi ($334 million), Lyft ($250 million), BlaBlaCar ($100 million), and INRIX ($65 million).

Yet only 28 percent of the industry can claim a high level of digitization today, according to a recent survey by PwC in Figure 3, Figure 4, Figure 5, reflecting a troubling level of reluctance among carriers to fully embrace new technologies and business models. One common refrain from these players is that they don't need to invest in new systems because their traditional rivals don't. Another rationalization is that customers are not demanding sophisticated technology from their carriers.

According to Forbes analysis draws two different conclusions:

1. **Competitors.** As the industry morphs, traditional rivals will no longer be the sole or even the most threatening competition. Indeed, it will become more difficult to promptly recognize those vying for market share because they will emerge from outside the industry and target only portions of the commercial transportation value chain (Forbes, 2015).
2. **Customers.** The technological gap between some carriers and their customers is large and growing. Companies that rely on carriers' ability to ship their products around the world on tight schedules, or to deliver materials from their suppliers just as promptly, are increasingly cognizant of their carriers' technological capabilities and these companies' expectations for logistics transparency and advanced software tools used to monitor shipment activity are increasing rapidly (Forbes, 2015).

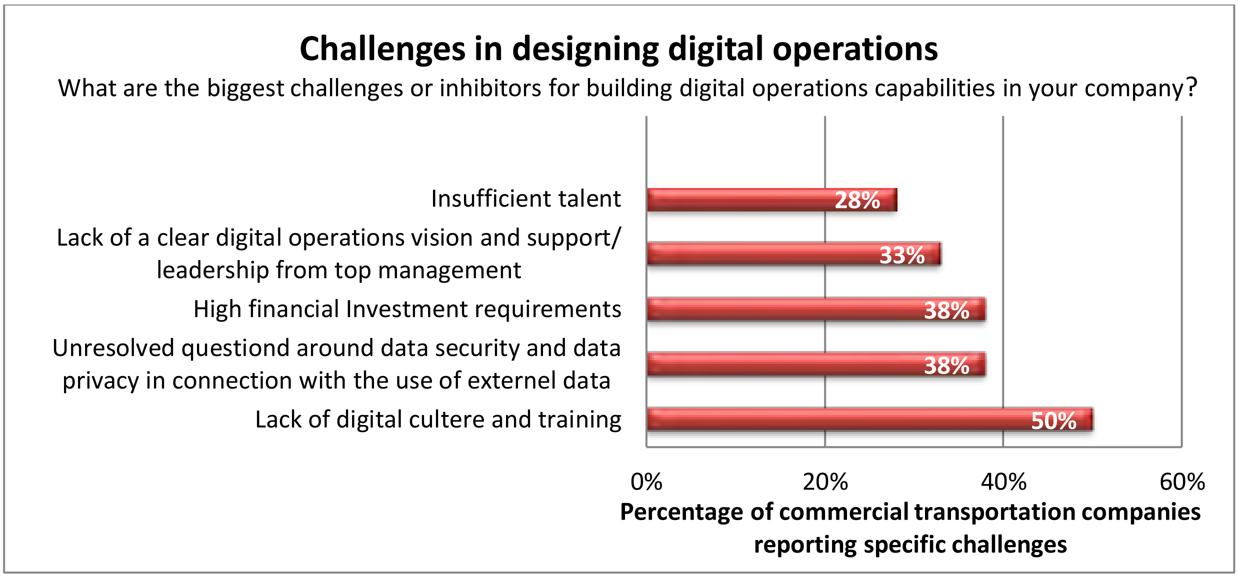

Figure 3. PwC Survey Question

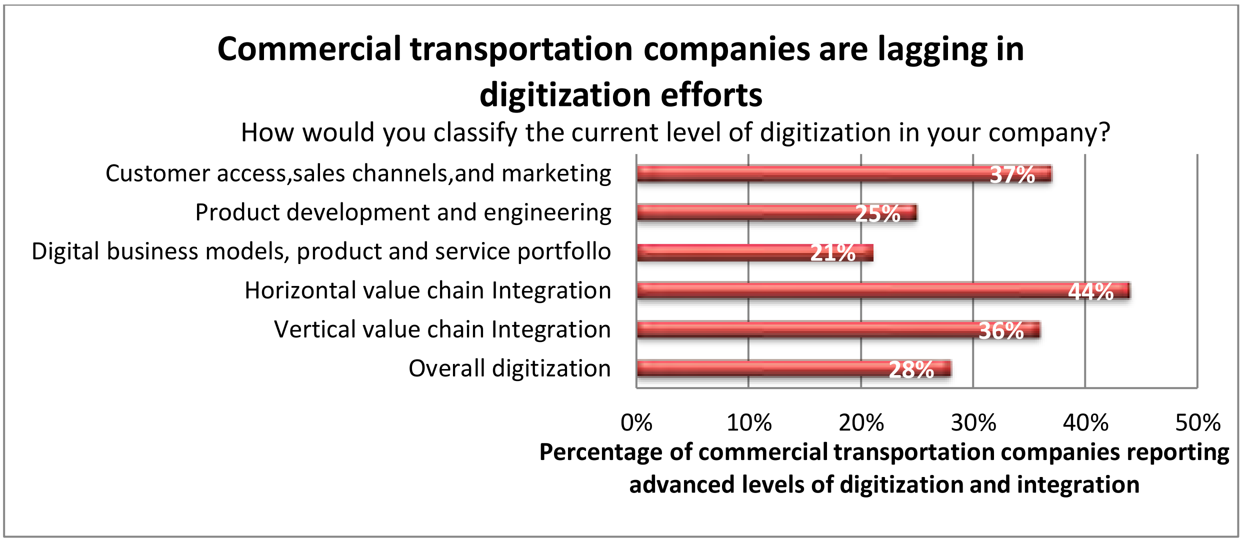

Figure 4. PwC Survey Question

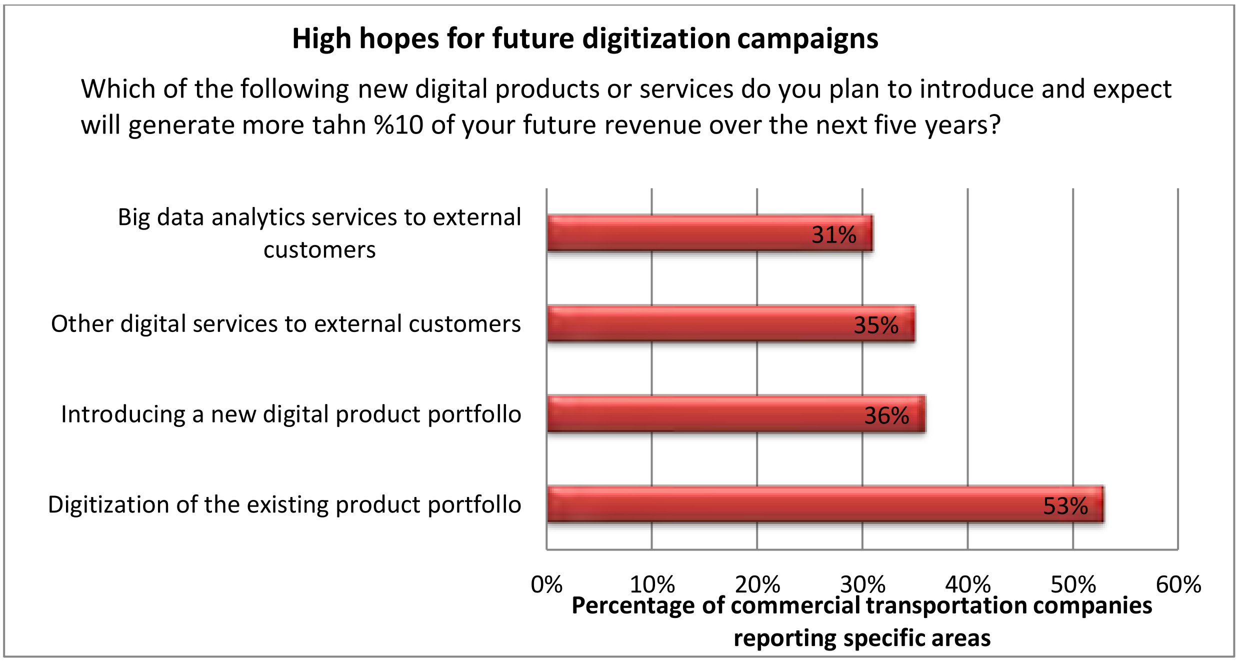

Figure 5. PwC Survey Question

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APPLICATION OF A SUPPLIER SELECTION AND EVALUATION IN SPARE PARTS SECTOR USING AN ANALYTIC HIERARCHY PROCESS METHOD

Buğra Bayender[1], Ahmet Balcıoğlu[2]

Abstract *– From the point of Supply Chain Management view, companies have to gain competitive advantage and increase their market share by managing their supply chain in the most effective way. It is not feasible for the companies to produce every kind of intermediate products in actual practice. Outsourcing for an effective supply chain management is an important scheme, and in this respect, the supplier selection of the companies becomes a strategic level decision which requires extensive evaluation. In this study, the problem of supplier selection and evaluation is discussed and Analytic Hierarchy Process (AHP) method is used as a multi-criteria decision making method. After the company's supplier selection criteria were determined, the importance and priority grade of these criteria are added. The AHP method was used to compare the criteria, and the obtained results were pointed and evaluated on a supplier basis. As a result of this evaluation, company categorizes its suppliers and all suppliers are ranked according to the highest valued supplier.*

Keywords – Supply Chain Management, Analytic Hierarchy Process, Supplier Selection and Evaluation

INTRODUCTION

The supplier selection problem is perhaps the most important component of the purchasing function. Supplier selection can be defined as a buyer managed process in which suppliers are identified, evaluated, and contracted in the end [1]. This process aims to reduce costs related to purchasing while increasing the overall value of purchasing [2]. Some of the common and influential criteria in the selection of a supplier include quality, price, delivery, financial stability, technical capability, supplier relationship, risk, agility, social responsibility, warranties and claim policies, reputation and position in industry, service and so on. These evaluation criteria often conflict each other, and it is frequently impossible to find a supplier that excels in all areas. It is also optimistic that a supplier can be perfect in meeting all supplier selection criteria. In addition, some of the criteria are quantitative and some are qualitative. Thus, a methodology is needed that can capture both subjective and objective evaluation measures.

Multi-criteria Decision Making (MCDM) is known to be a complex approach in dealing with both quantitative and qualitative aspects of problem at hand [3]. One of the most widely used methodologies in Multi-criteria DM is Analytic Hierarchy Process (AHP) and AHP has numerous applications in real life supplier selection problems. In this study, firstly main criteria and their relative weights have been identified with the help of the purchasing professionals. Secondly, according to these criteria, the suppliers have given their specific data, and following calculations, best supplier has been identified, and further recommendations have been made at the end.

LITERATURE REVIEW

Supplier selection is one of the most important decisions for organizations, and a challenge for every buyer as well [1]. The studies about supplier selection date back to research from 1960s. Dickson [4] identified 23 supplier selection criteria, which deeply influenced later researches in this area. In his study, he has sent a questionnaire survey to 273 commercial organizations, mainly purchasing managers who were working in manufacturing companies. The survey asked to purchasing managers to classify the important criteria for selecting suppliers. The results have differentiated into two categories: supplier selection experiences by

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organizations and supplier selection experiences by managers. At this first study, quality, delivery and performance history were the top three criteria that are picked up.

Dickson's seminal work was revisited by Weber et al. in 1991 [5], who have reviewed 74 articles which were published since 1966. They categorized these articles based on Dickson's 23 supplier selection criteria. Their study have specified that 23 criteria are not enough for taking supplier selection decisions. They have also developed new criteria such as maintainability and reliability, and have made major changes in order of criteria importance.

Narasimhan [6], and Nydick and Hill [7] highlight the use of AHP to mitigate the effect of imperfect information in supplier selection. Liu et al. [8] in 2000 proposes a simplified version of Data Envelopment Analysis, in which they evaluate the overall performances of suppliers according to three input and two output criteria, and their model tries to reduce the number of suppliers by favoring the one with higher supply variety. Verma and Pullman [9] lay out the difference between perceived importance of different supplier attributes and actual choice made by managers. Their experiments show that cost and delivery attributes are mostly chosen in real life cases event if the perceived importance of managers indicate quality attribute.

Akarte et al. [10] uses AHP where they use 18 criteria to assess suppliers on a web based system by allowing suppliers to login and provide their information for respective attributes. Then, buyers decide on criteria weights and assign the performance rating for each criterion using a pairwise comparison. Muralidharan et al. [11] proposes a five-step AHP-based model to rate and select suppliers with respect to nine criteria in supporting decision makers, where their approach involves staff from different functions of the company, e.g., purchasing, stores, and quality control, to increase the correctness of selection process.

Chan [12] develops an interactive selection AHP model, where he employs a method to prevent subjective human judgement, which is called as "chain of interaction", to specify relative importance of evaluating criteria. Then, they utilize AHP only to generate overall score for alternative suppliers. Chan and Chan [13], on another study, use AHP with six evaluating criteria and 20 sub-factors, of which the relative importance ratings were computed based on the customer requirements. Liu and Hai [14], following a similar approach to Chan [12] by not performing pairwise comparison to determine the relative importance, apply AHP to evaluate and select suppliers by incorporating Noguchi et al's voting and ranking method [15], in which managers can determine the order of criteria instead of the weights.

Chan et al. [15] studies an AHP-based decision making approach, in which 14 criteria is used to assess suppliers, then they conduct sensitivity analysis to examine the response of alternatives with respect to changes in relative importance rating of each criterion. Hou and Su [16] use AHP for the supplier selection in a mass customization environment, in which factors both externally and internally were taken into consideration to answer the needs of markets within the global changing environment.

PROBLEM DEFINITION

In this study, a company who works in spare part sector in Turkey for one of the biggest technology firms of Europe is examined from supplier selection perspective. We will simply call it "The Company" as we are not authorized to disclose any information to reveal the identity of the company due to privacy and confidential business information policy induced by the top level management.

The company in question procures and delivers spare parts on a wide range of products for the end consumer in Turkey, by using both local and global suppliers. The management of the company focuses mainly on the price and cost of the products in choosing suppliers. The company, in real life cases under competitive market conditions, is willing to make sure if they are working with the right and adequate suppliers with the right product category. Due to focus on the cost as the main criteria in selecting suppliers, the company is experiencing many problems about quality and rate of defective products, customer dissatisfaction, sales loss, instability in cash flow, and excess amount of stocks.

The company is about to select a new supplier for a new product. They got supplier's detailed information about the product in detail. Normally, the main criterion is cost for the supplier selection by the company but facing too many problems makes them very skeptical in selecting the right supplier.

In summary, the company wants to measure the correctness of its supplier selection criteria and to address the above mentioned problems as well. Thus, this study aims to assess and assist the company's decision making process by utilizing AHP.

According to literature, it is easily seen that AHP is the most widely used MCDM method for supplier selection problems. AHP offers a methodology to rank alternatives based on the decision maker's judgements taking into consideration both the importance of the criteria and the degree to which each criterion is satisfied by alternatives, making AHP ideally suited for the supplier selection problems.

SOLUTION METHODOLOGY AND THE APPLICATION

AHP is a scientific MCDM approach to capture priority scales based on the subject matter expert opinions via evaluating through pairwise comparisons [17]. AHP divides problem into hierarchical levels where attributes are analyzed and compared without difficulty [18]. This is favorable when a decision maker is to provide pairwise comparisons instead complete comparison of attributes, particularly in the presence of a large number of criteria. The comparisons are based on judgements which are represented on a scale to indicate the degree and level of dominance of each attribute with respect to another [17]. AHP provides a structured methodology where both quantitative and qualitative factors are incorporated into complex decision making process.

The process of applying AHP has four steps. First, establish a hierarchical structure by recursively decomposing the decision problem. Second, construct the pairwise comparison matrix to indicate the relative importance of alternatives. Third, calculate the priority weights of alternatives according to the pairwise comparison matrix. Fourth, measure the supplier performance.

You can find the below the numerical scale for paired comparison at Table 1.

Table 1 – Numerical Scale for Paired Comparison

Scale	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Demonstrated Importance
9	Extreme Importance
2,4,6,8	Intermediate Values

We should also focus on consistency index C.I., consistency ratio C.R. and random consistency index R.I. where C.R. can be found as the division of the C.I. over the R.I. On the other hand, If C.R. is <0.10 then the inconsistency degree of the comparison matrix is thought as acceptable [17].

Firstly, the company has identified five main criteria for supplier selection. These criteria have sent to three different purchasing professionals whose specifications and experience fit the spare part sector as a questionnaire to identify the weights of the five main criteria against each other.

The purchasing professionals have determined the criteria weights according to their experience at this sector. Then the criteria weights and the suppliers' real data for these five criteria have been incorporated into AHP for analysis and supporting the decision makers.

The five main criteria, which is selected by the company, for this supplier selection using AHP method is;

- Quality
- Delivery
- Production
- Cost
- Technical Capability

We will also evaluate the performance of the three suppliers which we call them as;

- Supplier A
- Supplier B
- Supplier C

Table 2 – Main Criteria Geometric Average

Main Criteria	Quality	Delivery	Production	Cost	Technical Capability
Quality	1,00	3,48	3,91	2,88	3,11
Delivery	0,78	1,00	3,30	2,71	4,72
Production	0,26	0,30	1,00	1,82	2,88
Cost	0,35	0,37	0,55	1,00	4,22
Technical Capability	0,32	0,21	0,35	0,24	1,00

In Table 2, you can find purchasing professionals comments on main criteria.

Table 3 – Main Criteria Priority Weights

Normalization	Quality	Delivery	Production	Cost	Technical Capability	Priority Weights
Quality	0,37	0,65	0,43	0,33	0,20	**39,53%**
Delivery	0,29	0,19	0,36	0,31	0,30	**28,95%**
Production	0,09	0,06	0,11	0,21	0,18	**13,04%**
Cost	0,13	0,07	0,06	0,12	0,26	**12,75%**
Technical Capability	0,12	0,04	0,04	0,03	0,06	**5,74%**

In Table 3, Quality and Delivery are the key indicators which is clearly seen.

Table 4 – The Quality Priority Weights

Quality	Supplier A	Supplier B	Supplier C	Normalization	Supplier A	Supplier B	Supplier C	Priority Weights
Supplier A	1,00	1,10	1,59	**Supplier A**	0,54	0,39	0,40	**44,42%**
Supplier B	0,21	1,00	1,41	**Supplier B**	0,12	0,36	0,35	**27,46%**
Supplier C	0,63	0,71	1,00	**Supplier C**	0,34	0,25	0,25	**28,11%**

In Table 4, Supplier A has advantage according to the Quality criteria.

Table 5 – The Delivery Priority Weights

Delivery	Supplier A	Supplier B	Supplier C	Normalization	Supplier A	Supplier B	Supplier C	Priority Weights
Supplier A	1,00	0,33	0,60	**Supplier A**	0,14	0,18	0,17	**16,39%**
Supplier B	4,48	1,00	1,85	**Supplier B**	0,63	0,53	0,54	**56,58%**
Supplier C	1,66	0,54	1,00	**Supplier C**	0,23	0,29	0,29	**27,04%**

In Table 5, Supplier B has advantage over other suppliers.

Table 6 – The Production Priority Weights

Production	Supplier A	Supplier B	Supplier C	Normalization	Supplier A	Supplier B	Supplier C	Priority Weights
Supplier A	1,00	1,30	4,22	**Supplier A**	0,50	0,50	0,51	**50,06%**
Supplier B	0,77	1,00	3,11	**Supplier B**	0,38	0,38	0,37	**37,91%**
Supplier C	0,24	0,32	1,00	**Supplier C**	0,12	0,12	0,12	**12,03%**

In Table 6, Supplier A has advantage over other suppliers.

Table 7 – The Cost Priority Weights

Cost	Supplier A	Supplier B	Supplier C
Supplier A	1,00	1,40	3,41
Supplier B	0,71	1,00	0,60
Supplier C	0,29	1,67	1,00

Normalization	Supplier A	Supplier B	Supplier C	Priority Weights
Supplier A	0,50	0,34	0,68	**50,77%**
Supplier B	0,36	0,25	0,12	**24,03%**
Supplier C	0,15	0,41	0,20	**25,21%**

In Table 7, Supplier A again outperforms other suppliers for given cost priorities.

Table 8 – The Technical Capability Weights

Technical Capability	Supplier A	Supplier B	Supplier C
Supplier A	1,00	0,92	3,21
Supplier B	1,09	1,00	3,91
Supplier C	0,31	0,26	1,00

Normalization	Supplier A	Supplier B	Supplier C	Priority Weights
Supplier A	0,42	0,42	0,39	**41,10%**
Supplier B	0,45	0,46	0,48	**46,55%**
Supplier C	0,13	0,12	0,12	**12,35%**

In Table 8, Supplier A and B have similar results.

Table 9 – The Results

Options / Criteria	Quality	Delivery	Production	Cost	Technical Capability	Total
Supplier A	0,4442	0,1639	0,5006	0,5077	0,4110	**0,3766**
Supplier B	0,2746	0,5658	0,3791	0,2403	0,4655	**0,3791**
Supplier C	0,2811	0,2704	0,1203	0,2521	0,1235	**0,2443**

CONCLUSION AND RECOMMENDATIONS

Firstly, the company is surprised to find out that the cost is not a single decision criterion by itself in selecting the right supplier to the benefit of the company. Top management of the company, however, considers that the results may not be satisfactory at all in maintaining a long run relationship with the suppliers. Therefore, they seek further analysis with more criteria to obtain more comprehensive solution in supplier selection process.

There is a slight difference between the evaluations of supplier A and Supplier B. According to this study, spare part company may divide its orders and risk between supplier A and Supplier B since company has identified two suppliers almost equal in given criteria.

According to common practice, it is always a good idea to push both of the suppliers to improve their quality and lead time investments which can create difference between their selection criteria. Alternatively, it is also a good opportunity to work simultaneously with both of the suppliers.

In contrary to the abovementioned idea, we may also think that 5 criteria are not enough to decide to select the right supplier. The number of main criteria should be increased, and we may also add sub criteria to look for more precise solution. It might also worth to ask purchasing professionals to think more on priority weights so as to obtain more accuracy. On the other hand, we might make a wrong decision based on the inadequate current data, and might not choose purchasing from the right supplier. Therefore, it should be considered to put extra work for identifying and evaluating additional main and sub criteria.

This AHP solution should also be benchmarked with studies of supplier selection in other markets to obtain better insights on how these criteria fit. We also recommend using AHP method with more than 3 suppliers, the more suppliers you analyze, the more accurate results in selection of suppliers may be obtained. One of the major drawbacks of using AHP in selecting a supplier is the number of objective functions and their relevant evaluation factors. It requires a considerable time for purchasing manager to collect necessary data. Then they need to make a comparison among the available suppliers and put weighted values against them. Sometimes, it differs from one manager to another and hence the overall scores will be affected by that significantly.

This study helps us in affecting the company's attitude in supplier selection, as they have come to understand that there might be numerous criteria which are important for supplier selection in their market. This work is an initial solution to the for the company's urgent needs. If the company wants to decrease level of customer dissatisfaction, they should focus on the quality, cost and the delivery criteria. Company should also decide if they want to have better performance for new product development, and therefore to focus on the production and technical capability criteria as well as increasing their respective weights.

Finally, it is always a good practice to get consultancy support from academic environment so as to keep up with the latest improvements and new approaches in tackling with this kind of supplier selection problems. We also suggest that this study should be performed with the involvement of academic personnel in identification of priorities and weights of relevant criteria. The results should also be benchmarked with other multi criteria decision making methods (e.g., ANP, CBR, DEA, fuzzy set theory, etc.) to check the results thoroughly.

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THE IMPACT OF CARBON EMISSIONS POLICIES ON REVERSE SUPPLY CHAIN NETWORK DESIGN

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Abstract *– Reverse Supply Chain is described as an initiative that plays an important role in the global supply chain for those who seek environmentally responsible solutions for their end-of-life products. The relative economic and environmental benefits of reverse supply chain are influenced by costs and emissions during collection, transportation, recovery facilities, disassembly, recycling, remanufacturing, and disposal of unrecoverable components. The design of reverse supply chain network takes into account social, economic and environmental objectives. This research addresses the design of reverse supply chain that is also sensitive to the carbon policies under the three common regulatory policies, strict carbon caps, carbon tax, and carbon cap-and-trade.* CO_2 *emissions and total profit are integrated using a multi-criteria decision making model. In this research, a mixed integer linear programming model of reverse supply chain with full valuation of emissions is considered to determine the optimal flow of parts among multiple remanufacturing centers that will maximize the total profit with less* CO_2 *emissions, based on actual sites in the Boston area. Numerical example illustrates different policies and their impact on the costs and the effectiveness of emission reduction.*

Keywords – Greenhouse gas (GHG) emissions, low carbon logistics, reverse supply chain, sustainably supply chain

INTRODUCTION AND RELATED WORK

The number of products discarded by consumers has been gradually growing, which has led to legislations in various countries that hold the original equipment manufacturers (OEM) responsible for the end-of-life processing of products. In addition, the field of supply chain has also been influenced by consumer awareness of environmental issues [1, 2].

Climate change, disposal capacities, finite resources, growing population, improving quality of life, increasing emissions, and rising energy prices have motivated both corporations and academics to develop strategies based on corporate social responsibilities and sustainable supply chains [3-5]. While the concept of integrating sustainability into supply chain is relatively new, its implementation is however increasing continuously [6].

Nowadays, although the products are still moving in the direction of the end customer the reverse flow of products is also taking place. This movement is obviously pronounced in most of the industrial sectors, especially in automobiles, beverages, electronic products, and pharmaceuticals. The automobile industry, for example, has included the changes in the supply chain to smooth the end-of-life vehicles recovery and the US vehicle recycling infrastructure [7, 8].

Reverse Supply Chain (RSC) is an initiative that plays an important role in the global supply chain for those who seek environmentally responsible solutions for their end-of-life (EOL) products. The relative economic and environmental benefits of RSC are influenced by costs and emissions during collection, transportation, recovery facilities, disassembly, recycling, remanufacturing, and disposal of unrecoverable components [2, 9, and 10].

Seuring and Muller [11] defined the sustainable supply chain management as "the management of materials, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, viz., economic, environmental and social, into account which are derived from customer and stakeholder requirements". In this paper, the supply chain economics is taken into account by maximizing the total profit and minimizing the CO_2 emissions, energy use, transportation, rent, labor, and product recovery costs, by investigating the cost factors by facility type, on-

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site, inter-facility, and total tCO2e from on-site electricity use by unit. Greenhouse Gas (GHG) emissions regulations and environmental sustainability are preventing extreme environmental damages from happening. The social dimension includes, but not limited to, the reduction in negative consequences of coastal destruction, noise, stress, traffic congestion, spread of disease, and the improvement in the quality of life.

A literature review is conducted by Mexiell and Gargeya [12] on economic considerations of supply chain design. A comprehensive review of the published literature on sustainable supply chain is presented by Seuring and Muller [11], and Srivastava [13].

Recent available literature reviews considering different aspects of supply chain sustainability include: energy use [14], GHG emissions reduction [15], green design [16], production planning and control for remanufacturing [17], product recovery [18], reverse logistics [19], and waste management [15].

Gungor and Gupta [20] addressed the issues of environmentally conscious manufacturing and product recovery with an extensive review of the literature. The study looked at the product recovery process from environmentally conscious manufacturing point of view, and included the common issues in both environmentally conscious manufacturing and product recovery (viz. environmentally conscious design, environmentally conscious production, recycling and remanufacturing, and production planning and inventory control). Ilgin and Gupta [2] further extended this literature review through 2010. There are several other authors who reported on product recovery designs under certain legislation and regulations [21-27].

Reducing the emissions generated due to a supply chain has become an important goal. Thus, the "trade-offs in the supply chain are no longer just about cost, service and quality, but also about cost, service, quality and carbon," [28]. A Closed-loop supply chain (CLSC) network considered by Paksoy et al. [29], focused on the transportation logistics cost and their GHG emissions, to exam the trade-off between operational and environmental performance measures. Abdallah et al. [30] investigated the carbon emissions as a consequence of the supply chain network design and supplier selection using life-cycle assessment (LCA) approach.

A mixed-integer programming model was formulated to find an optimal strategy for companies to meet their carbon cap, while minimizing costs by Diabat and Simichi-Levi [31]. Chaabane et al. [28] formulated a model of an aluminium firm and examined the carbon emissions impact on designing a sustainable CLSC network based on LCA principles. They also evaluated the tradeoffs between economic and environmental dimensions under various cost and strategies. The issues of facility location problem in CLSC with a trading price of carbon emissions and a cost of procurement were considered in Diabat et al.'s [32] work. Fahimnia et al. [33] evaluated the forward and reverse supply chain influences on the carbon footprint using mixed integer linear programming (MILP) model, where carbon emissions are demonstrated in terms of dollar carbon cost.

Benjaafar et al. [34] illustrated the impact of carbon emission and introduced a series of lot sizing models to be integrated into operations decisions and showed how significant emissions reductions without increases in costs can be achieved by operational adjustments alone. Supply chain and transportation mode selection decisions study for a major retailer based on the carbon policies was reported by Jin et al. [35].

In this research, a mixed integer linear programming model of reverse supply chain with full valuation of emissions is considered to determine the optimal flow of parts among multiple remanufacturing centers that will maximize the total profit with less CO_2 emissions, based on actual sites in the Boston area. The proposed model considers a mid-sized LG A/C unit with a refurbished market price of $288 [40]. Valuation of emissions is done using a direct carbon tax, with the value varied according to ranges proposed at the current COP21 climate talks in Paris, and with the other two different regulatory policies, strict carbon cap where firms are subject to mandatory caps on the amount of carbon they emit, and carbon cap-and-trade where firms are subjected to carbon caps but are rewarded (penalized) for emitting less (more) than their caps. To that end, we determine how the proposed policies will influence profit margins for remanufactured goods.

The model proposed can be used for designing and analyzing a reverse supply chain in a carbon trading environment, and optimize not only costs but also emissions in the supply chain operations. It captures the trade-offs between costs and emissions in the supply chain operations. It shows that carbon tax emissions, particularly at higher taxes, mostly affects transportation operations which results in reduced transportation costs and emissions; on the other hand, the higher the carbon tax is, the greener would be the supply chain design, not necessarily following a linear relationship. Applying an emissions cap combined with a carbon tax slightly increases total supply chain costs, but yields a greener design. Numerical example illustrates different policies and their impact on the costs and the effectiveness of emission reduction.

NOTATION AND ASSUMPTIONS

Notation

The notations used in this paper are given below:

Notation	**Definition**
$C1v$	Storage capacity at remanufacturing facility v per remanufactured unit;
$C2v$	Storage capacity at remanufacturing facility v per used unit;
Cu	Storage capacity at collection center u per unit;
Cw	Storage capacity at reselling center w per unit;
CAP	Carbon strict cap;
Du	Demand of products at collection center u;
Dw	Demand of products at reselling center w;
duu	Distance from collection center u to remanufacturing facility v, per mile;
dwv	Distance from remanufacturing facility v to reselling center w, per mile;
EXu	Energy cost at collection center u per unit;
EXv	Energy cost at remanufacturing facility v per unit;
EXw	Energy cost at reselling center w per unit;
GH	GHG emissions per ton-mile;
GHu	GHG emissions in collection center u, per unit;
GHv	GHG emissions in remanufacturing facility v, per unit;
GHw	GHG emissions in reselling center w, per unit;
$GHGt$	GHG emissions total;
Hu	Holding cost per unit at collection center u;
Lu	Labor cost at collection center u per unit;
Lv	Labor cost at remanufacturing facility v per unit;
Lw	Labor cost at reselling center w per unit;
O_1	Occupied space by remanufacturing unit;
O_2	Occupied space by used-product unit;
Kg	Weight of each unit;
P	Reprocessing cost per unit;
R	Retrival cost per unit;
$RCAPv$	Remanufacturing facility v capacity;
RCu	Rent cost at collection center u per unit;
RCv	Rent cost at remanufacturing facility v per unit;
RCw	Rent cost at reselling center w per unit;
SHu	Shortage cost per unit at collection center u;
$SUPu$	Supply at collection center u;
Tuv	Transportation cost from collection center u to remanufacturing facility v, per unit;
Tvw	Transportation cost from remanufacturing facility v to reselling facility w, per unit;
u	Collection center;
v	Remanufacturing facility;
w	Reselling center;
Xuv	Decision variable for the number of units transferring from collection center u to remanufacturing facility v;
Yvw	Decision variable for the number of units transferring from remanufacturing facility v to reselling center w;
Zv	Binary variable (0/1) for selection of remanufacturing facility v;
Zw	Binary variable (0/1) for selection of reselling center w.

Assumptions

We assume that GHG emissions come from four sources:

1. from the collection centers: the amount of emissions is proportional to the power consumption of these centers;
2. from the remanufacturing facilities: the amount of emissions is proportional to the volume of these remanufacturing facilities;
3. from the reselling centers: the amount of emissions is proportional to the power consumption of these centers; and
4. from the distribution of the products: the emissions level is based on the traveled distance between facilities, and the weight of each unit (40 Kg).

The model also assumes that inventory cost of a used product at the remanufacturing facility is 25% of its retrieval cost (*R*), and for a remanufactured product it is 25% of its reprocessing cost (*P*).

PROBLEM FORMULATION

The model is formulated as a single period mixed integer linear programming model of reverse supply chain where full valuation of emissions is considered to determine the optimal flow of parts among multiple remanufacturing facilities that will maximize the total profit which includes the CO_2 emissions, energy use, transportation, rent, labor, and product recovery costs.

Objective Functions

Minimize

Retrieval cost $\sum_u \sum_v R \quad X_{uv} +$

Transportation cost $\sum_u \sum_v T_{uv} X_{uv} + \sum_v \sum_w T_{vw} Y_{vw} +$

Remanufacturing cost $\sum_v \sum_w P \quad Y_{vw} +$

Inventory cost $\sum_u \sum_v (R_u / 4) X_{uv} + \sum_v \sum_w (Pv / 4) Y_{vw} +$

Rent cost $\sum_u RCu * Du + \sum_v RCv * Xuv + \sum_w RCw * Yvw +$

Labor cost $\sum_u Lu * Du + \sum_v Lv * Xuv + \sum_w Lw * Yvw +$

Energy cost $\sum_u Eu * Du + \sum_v Ev * Xuv + \sum_w Ew * Yvw +$

Greenhouse Gas (GHG) Emissions

$$\sum_u GHu * Du + \sum_u \sum_v GHvXuv + \sum_v \sum_w GHwYvw +$$
$$\sum_u \sum_v GH * duv * Kg * Xuv + \sum_v \sum_w GH * dwv * Kg * Yvw$$

Shortage cost $\{(Dw - SUPu) * (1 - Z)\} * SHu$ (1)

Constraints

Demand constraint must be met while minimizing the total cost of production and inventory.

$$\sum_{v} Yvw = D_w \; ; \; \forall \, w \tag{2}$$

Remanufacturing facility total output is at most its total input

$$\sum_{u} Xuv \geq \sum_{v} Yvw \; ; \; \forall \, v \tag{3}$$

Remanufacturing items occupied space at each remanufacturing facility is at most its capacity, and total space occupied at each collection center by returned items at most its capacity

$$\sum_{w} O_1 * Yvw \leq C_{1v} * Yv; \forall v \tag{4}$$

$$\sum_{v} O_2 * Xuv \leq C_u; \forall u \tag{5}$$

Total space occupied at each remanufacturing facility by returned items at most its capacity

$$\sum_{u} O_2 * Xuv \leq C_{2v} * Zv; \forall v \tag{6}$$

Total space occupied at reselling center by returned items at most its capacity

$$\sum_{v} O_1 * Yvw \leq C_w * Zw; \forall w \tag{7}$$

Carbon strict cap limit

$$GHGt \leq CAP \tag{8}$$

Non-negativity constraint

$$X_{uv} \geq 0 \; ; \; \forall \, u, v \tag{9}$$

$$Y_{uv} \geq 0 \; ; \; \forall \, v, w \tag{10}$$

Total number of returned items supplied to remanufacturing facilities by collection centers is at most the supply

$$\sum_{w} Yvw \leq RCAPv; \forall v \tag{11}$$

$$\sum_{v} Xuv \leq SUPu; \forall u \tag{12}$$

CASE STUDY

The numerical example is based on actual sites in the Boston (Massachusetts) area and considers three collection centers (located in Melrose, Canton, and Natick), two remanufacturing facilities (located in Taunton and Hingham), and three reselling centers (located in Revere, Boston, and Somerville). The actual distances in miles between the locations were considered, to calculate mile per gallon costs and emissions of CO2 kg per gallon, assuming the gasoline price per gallon of October 2015. The number of laborers, their annual salaries, and the size of the space were also considered. In short, the example reflects a breakdown of the cost factors: rent, labor, energy, CO_2 emissions, and transportation, by facility type, on-site, inter-facility, and total tCO_2e from on-site electricity use by unit. The U.S. Energy Information Administration at the U.S. Department of Energy data reports [38] were used to calculate the energy usage for each facility. This example considers a mid-size LG A/C unit, model LW1213ER, with dimensions of 23 5/8" x 15" x 22 1/6", and a refurbished market price of $288 [40]. Two 12-foot trucks with a capacity of 58 A/C units each and a load volume of 475 cubic feet were used for transportation [41]. Valuation of emissions is done using the suggested direct carbon tax, strict cap, and cap-and trade values according to ranges proposed at the 21st Conference of the Parties under the UNFCCC in Paris [42], the U.S. Interagency Working Group [36] and, the U.S. Environmental Protection Agency [37], to determine how proposed ranges will influence profit margins for remanufactured goods.

DATA

In this section two different survey databases were used, Commercial Buildings Energy Consumption Survey (CBECS) which was used for collection centers and reselling centers energy data. Manufacturing Energy Consumption Survey (MECS) was used for remanufacturing facilities energy data in subsection. Tables 1 to 4 have the labor cost, rent cost, and distances between locations per mile respectively.

Table 1: Labor Actual Cost

Cities	Number of laborers	Labor cost per year
Canton	5	$93,600
Natick	3	$56,160
Melrose	4	$74,880
Taunton	15	$280,800
Hingham	17	$318,240
Revere	4	$74,880
Boston	3	$56,160
Somerville	6	$112,320

Table 2: Rent Actual Cost

Cities	Space (Sq ft)	Rent per Sq ft/year	Total rent per year
Canton	1000	$14.4	$4,220
Natick	3000	$10.5	$10,575
Melrose	1500	$15.0	$7,460
Taunton	10000	$11.0	$110,000
Hingham	9801	$8.0	$78,408
Revere	2700	$10.0	$27,000
Boston	5100	$25.0	$127,500
Somerville	4000	$17.0	$68,000

Table 1: Actual Distances between Collection Center and Remanufacturing Facilities per Mile

From/To City	Taunton	Hingham
Melrose	52.8	28.1
Canton	17.2	19.3
Natick	37.0	30.5

Table 2: Actual Distances Between and Remanufacturing Facilities and Reselling Centers per Mile

From/To City	Revere	Boston	Somerville
Taunton	45.0	40.0	43.0
Hingham	24.0	19.0	22.0

RESULTS AND DISCUSSION

The absence of a carbon tax for the A/C unit priced at $218 results in a profit margin estimated to be 24.3% for a $288 selling price according to current refurbished market price [40], whereas a USEPA-recommended $40/ton CO_2 equivalent (tCO2e) tax reduced the profit margin to 19.1% assuming a price for remanufactured item of $233 per unit [37]. However, strict carbon cap reduces the profit margin to 13%, and cap-and-trade policy reduces the profit margin to 9%. LINGO 13.0 was used to solve the problem. The optimal results obtained from the direct carbon tax are shown in Tables 5 and 6.

Table 5: Optimal Number of Units Transported From Collection Center to Remanufacturing Facility

City	Taunton	Hingham
Melrose	0	50
Canton	0	0
Natick	0	450

Table 6: Optimal Number of Units Transported From Remanufacturing Facility to Reselling Center

City	Revere	Boston	Somerville

Taunton	0	0	0
Hingham	150	200	150

The optimal remanufacturing cost is $218 per unit, which shows that this model is $70 per unit less than the current refurbished market price. The emission quantity is 0.018 tCO2e per unit. Comparing this result to the deflated refurbished market price using a consumer price index expressed in 2002 dollars and analyzing that result using the economic input-output life cycle assessment (EIO-LCA) model (a technique for estimating the materials and energy resources required for environmental emissions resulting from economic activities [39]. The EIO-LCA sector chosen was the U.S. 2002 Benchmark for air conditioning, refrigeration, and warm air heating equipment manufacturing. This shows that the emission quantities are 0.109 tCO2e per unit less than refurbished manufacturing. The valuation of emissions for the optimal result was done by using the values according to ranges proposed at the 21st Climate Change Conference (COP21) in Paris, therefore existing approaches used different carbon policies and applications. Using the carbon price of $40/ton CO2 equivalent (tCO2e), our model gives a profit margin of 19.1%.

CONCLUSION

This paper has presented a reverse supply chain optimization model designed to take into account the influence of both strategic and operational activities of the supply chain on the environment. A case study based on actual sites was considered to illustrate performance of the model and to determine how the proposed policies would influence profit margins on remanufactured goods. The results indicated that the carbon price ranges that were used in this study will control the amount of GHG emissions generated in reverse supply chain operations. The results also indicated that the carbon tax policy forces a strict constraint on the amount of carbon emissions generated in supply chain operations. It shows that the RSC is sensitive to the carbon price. The work herein advances the theoretical modeling of optimal RSC systems while presenting an empirical case study of remanufactured appliances, an understudied facet of current industrial literature.

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ANALYSIS OF TRAVELING SALESMAN PROBLEM WITH DRONES UNDER VARYING DRONE SPEED

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Abstract –*In this study, traveling salesman problem with drone (TSP-D), in which a truck and a drone visit customers in coordination, is studied. Since some commercial firms announced that they have already begun to test using drones in delivery, the cases which simulate real-life applications must be investigated. One of them is the relation between the drone speed and its load state, full or empty. In TSP-D, the drone is allowed to carry exactly one parcel at a time because of its load capacity. Therefore, it has to return to the truck after each customer visit to load next customer's package. It is explicit that the load affects drone's speed. In this study, we incorporate the case with load state dependent drone speed into TSP-D. We analyze the changes in assignment and routing decisions in details for sample instances.*

Keywords – *drone delivery, varying drone speed, traveling salesman problem*

INTRODUCTION

Due to the recent developments in drone technologies, drones have been considered to be deployed in many civil areas as well as the military purposes. Especially, logistics and e-commerce companies, seeking for new technologies with the aim of operational efficiency, consider to use drones in their operations. Because the drones are faster than the traditional delivery trucks and also are not affected from the land conditions [1]. Firstly, Amazon has announced to deploy a fleet consisting of drones in last mile delivery [2]. However, drones are able to carry exactly one package at a time and the flight ranges are limited due to the battery life [4]. As a consequence, a new delivery approach proposing to take the advantages of both vehicles has emerged [11]. This new delivery approach is mostly referred as traveling salesman problem with drones (TSP-D).

In the simplest form of TSP-D, one vehicle of each type visit customers cooperatively. The truck is equipped to carry a drone on its roof and the drone is able to launch from and be picked up by the truck. The drone is allowed to make customer visits separately from the truck and also allowed to travel on the truck during the customer visits. Each customer is served exactly once by either the truck or the drone. Some of the customers have to be served by the truck owing to the drone's flight range limit while some of the customers have to be visited by the drone because the land conditions don't allow the truck to visit. The load capacity and the battery life of the drone oblige the drone to return to the truck in order to load the next customer's package and to have a full battery after each customer visit. Therefore, the drone may launch from and return to the truck for many times. Figure 1 illustrates a TSP-D solution. Suppose that the delivery network consists of 8 customers. The truck route is denoted by the straight line while the drone tours are distinguished by the dashed line. The truck leaves the depot carrying the drone on its roof and serves customer node 1. At customer node 1, the drone launches from the truck in order to visit customer node 6. After serving customer node 6, the drone returns to the truck at customer node 3. Meanwhile, the truck visits customer node 2 alone before meeting with the drone at customer node 3. While the truck goes from node 3 to customer node 4, the drone visits customer node 7 and meets with truck at customer node 4. The vehicles travel together (the drone is on the truck's roof) from customer node 4 to customer node 5. At customer node 5, the drone launces from the truck for the last time to serve customer node 8. The vehicles meet at the depot.

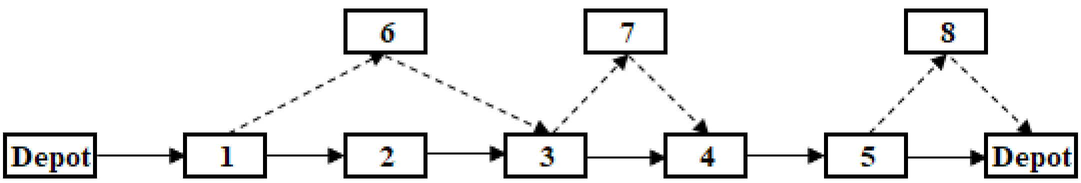

Figure 1. Illustration of Traveling Salesman Problem with Drone

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TSP-D is introduced by [7]. A mixed-integer linear programming model and a heuristic approach are proposed for this problem. Beginning with the TSP solution, they partition the truck route into drone tours considering cost savings. Drone delivery has received a growing attention however there are a limited number of studies investigating the problem introduced by [7]. One of them belongs to Agatz, Bouman and Schmidt [1]. Unlike the assumption in [7], they allow the drone to return to the truck at the customer node where it launches from. They present two heuristics based on local search and dynamic programing. Reference [5] developed a two stage heuristic: In the first stage, they assign customers to the drone such that the drone route is maximized as much as possible. In the second stage, they construct a truck route. In another study, the authors investigate the delivery cost of TSP-D for the first time [6]. Reference [10] provides bounds for various cases from a theoretical perspective and extend the study in [8]. A metaheuristic, simulated annealing, is applied in [9].

The studies above demonstrate the efficiency of deploying drones in last-mile delivery. However, there are many cases which simulate a real-life application. Since some commercial firms announced that they have already begun to test using drones in delivery, also these cases require to be investigated. One of them is the relation between the drone speed and its load state, full or empty. In TSP-D, drone is allowed to carry exactly one parcel at a time because of its load capacity. Therefore, it has to return to the truck after each customer visit to load next customer's package. It is explicit that the load affects drone's speed. In other words, drone's traveling time to the truck is expected to be shorter than its traveling time to the customer node. In this study, unlike the previous studies, we investigate the effect of load state dependent drone speed and analyze the traveling salesman problem with drones under varying drone speed.

METHODOLOGY

In this study, we incorporate varying drone speed into the model presented in [1]. The combinations of the truck and the drone routes between each possible launch (the node where the drone leaves the truck) and pickup (the node at which the truck and the drone meet) nodes are generated in [1] and referred as "operation". Then, an operation based formulation is proposed. In the example given in Figure 1, the operations are *0-1, 1-2-3-6, 3-4-7, 4-5 and 5-0-8*. The set of feasible operations are denoted by O and the operation time by c_o. O_v, $O^-(v)$ and $O^+(v)$ denote the set of operations that contain node *v*, the set of operations starting at node *v* and the set of operations ending at node *v*, respectively. x_o is the decision variable indicating whether operation *o* is traveled or not, the other variable y_v takes value 1 if node *v* is chosen as the start node in at least one operation and 0 otherwise. The mathematical model in [1] is provided below:

$$min \sum_{o \in O} c_o x_o \tag{1}$$

$$st. \sum_{o \in O_v} x_o \geq 1, \qquad \forall v \in V \tag{2}$$

$$\sum_{o \in O^+(v)} x_o \leq n y_v, \qquad \forall v \in V \tag{3}$$

$$\sum_{o \in O^+(v)} x_o = \sum_{o \in O^-(v)} x_o, \qquad \forall v \in V \tag{4}$$

$$\sum_{o \in O^+(S)} x_o \geq y_v, \qquad \forall S \subset V\{v_o\}, v \in S \tag{5}$$

$$\sum_{o \in O^+(v_o)} x_o \geq 1 \tag{6}$$

$$y_{v_0} = 1 \tag{7}$$

$$x_o \in \{0,1\} \qquad \forall o \in O \tag{8}$$

$$y_v \in \{0,1\} \qquad \forall v \in V \tag{9}$$

Equation (1) minimizes the total delivery completion time as the other equations ensure a feasible delivery. Equation (2) ensures that all customers defined in set V are visited. If an operation ending at node *v* is chosen then at least one operation starting at node v must be chosen (3). The balance constraint is provided in (4) and the sub tour elimination constraints are presented in (5) and (6). The depot is ensured to be the starting node by (7).

The reason for using the above formulation in this study is that the definition of operation enables us to incorporate the load dependent drone speed without much effort. Varying drone speed just affects the drone's traveling time and so the operation time. As it can be seen in the model above, the operation time doesn't affect the feasibility constraints. Therefore, any adjustment is not required in the model in order to investigate the effect of varying drone speed. It is sufficient to take the speed change into account while generating the operations.

NUMERICAL STUDY

This section presents a numerical study to analyze the assignment and routing decisions of the problem under the drone speed varying with the load state. To achieve this, we used a part of the data provided in [3]. The sets of operations are generated using C++ and the model is solved via ILOG CPLEX Concert Technology 12.6.3. All the experiments are run on a desktop PC with Intel Core i5-6500 CPU with 8 GB of RAM.

In our numerical study, we use Euclidean metric for the distance traveled by the drone and Manhattan metric for the distance traveled by the truck to simulate the city roads as [7] did. Reference [5] specifies the truck speed as 40 km/h and drone speed as 56 km/h. To ensure that the average drone speed is 56 km/h, we specify the drone speed as 50 km/h when it is loaded and 62 km/h when it is empty. Also the truck speed is assumed to be 40 km/h to be consistent with the studies in literature. We assume no limitation on the flight range of the drone and the launch and the pickup times are neglected for the sake of simplicity.

First of all, we present the results when the load dependent drone speed case is neglected. In other words, the results in Table 1 are obtained under the constant drone speed which is 56 km/h.

Table 1. Summary of Results Under Constant Drone Speed

		Traveling Time		Waiting Time	
Instance	Delivery Time	Truck	Drone	Truck	Drone
uniform-51-n10	389,752	381,507	379,264	8,245	10,488
uniform-52-n10	317,862	308,726	314,918	9,136	2,944
uniform-53-n10	319,522	298,552	319,522	20,970	0,000
uniform-54-n10	357,648	346,043	335,015	11,605	22,634
uniform-55-n10	407,100	407,100	389,434	0,000	17,666
uniform-56-n10	357,915	352,401	348,401	5,514	9,514
uniform-57-n10	309,283	309,283	272,342	0,000	36,941
uniform-58-n10	366,122	366,122	320,719	0,000	45,403
uniform-59-n10	368,196	328,013	368,196	40,184	0,000
Avg.	354,822	344,194	338,646	10,628	16,177

Figure 2 represents the results under varying drone speed and the comparison of the two scenarios is provided in Table 3. As it can be explicitly seen in Table 3, the delivery completion time significantly increases in the first instance. In four of the nine instances (instances 52, 55, 56 and 58), there are almost no changes. There are slight decreases in three instances (instances 53, 54 and 59) and a slight increase in the remaining instance. Significant increases are observed in the truck's traveling time of two instances (instances 52 and 59) and in the drone's traveling time of just one instance (instance 56). We observe slight decreases in the average waiting times of both vehicles.

Table 2. Summary of Results Under Varying Drone Speed

Instance	Delivery Time	Traveling Time		Waiting Time	
		Truck	Drone	Truck	Drone
uniform-51-n10	398,291	381,507	380,922	16,784	17,369
uniform-52-n10	317,808	317,432	312,772	0,376	5,036
uniform-53-n10	316,615	298,552	316,615	18,063	0,000
uniform-54-n10	353,298	346,042	337,398	7,256	15,900
uniform-55-n10	407,099	407,099	386,225	0,000	20,874
uniform-56-n10	357,867	352,164	356,663	5,703	1,204
uniform-57-n10	311,069	309,283	271,608	1,786	39,461
uniform-58-n10	366,122	366,122	323,847	0,000	42,275
uniform-59-n10	364,543	338,038	364,543	26,505	0,000
Avg.	354,746	346,249	338,955	8,497	15,791

Table 3. Comparison of Results Obtained Under Constant and Varying Drone Speed

Instance	Increase in Delivery Time	Increase in Traveling Time		Increase in Waiting Time	
		Truck	Drone	Truck	Drone
uniform-51-n10	8,539	0,001	1,658	8,538	6,881
uniform-52-n10	-0,054	8,706	-2,145	-8,760	2,091
uniform-53-n10	-2,907	0,000	-2,907	-2,907	0,000
uniform-54-n10	-4,350	0,000	2,384	-4,350	-6,734
uniform-55-n10	-0,001	-0,001	-3,209	0,000	3,208
uniform-56-n10	-0,048	-0,237	8,262	0,189	-8,310
uniform-57-n10	1,786	0,000	-0,735	1,786	2,521
uniform-58-n10	0,000	0,000	3,128	0,000	-3,128
uniform-59-n10	-3,653	10,026	-3,653	-13,679	0,000
Avg.	-0,076	2,055	0,309	-2,131	-0,385

Although there are slight differences in delivery, traveling and waiting times, we observe that the routing decisions remains unchanged in six and vary in three of the instances. The changes in routing decisions of those three instances are demonstrated in Figure 2, Figure 3 and Figure 4. The truck and the drone routes under constant drone speed are illustrated on the left side and the routes under varying drone speed are illustrated on the right side of the figures. It can be easily observed that there are slight changes in the truck routes. However, the drone routes change such that the distances traveled when the drone is loaded are shorter and the distances traveled when it is empty are longer in three of the instances. In order to achieve this, the directions of the drone routes are reversed in the instances represented in Figure 3 and Figure 4.

CONCLUSIONS

In this paper, a new variant of TSP, which is referred as traveling salesman problem with drones, is studied. We propose to incorporate load dependent drone speed into TSP-D and present a numerical study to investigate the effect of varying drone speed. The numerical results indicate that the average difference in the delivery completion time is trivial. It is observed that this is accomplished by assigning longer distances in the case where the drone is empty and faster, and shorter distances in the case where it is loaded and slow.

Owing to the commercial firms' rising interest in this new delivery concept, an extensive study is required in this field of study. In future studies, various cases that simulate real-life applications can be investigated.

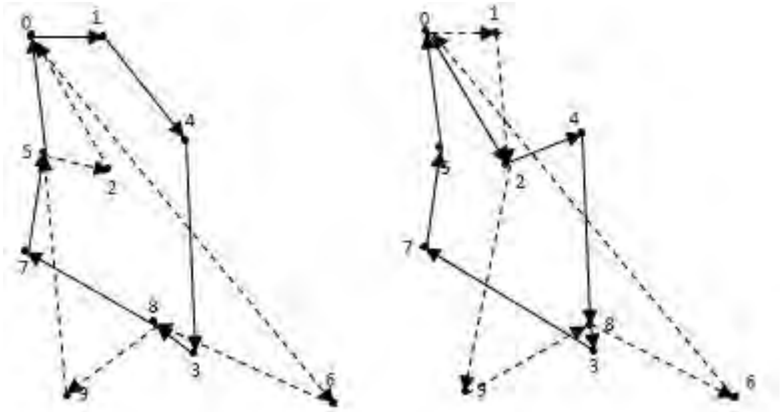

Figure 2. The Truck and The Drone Routes Under Constant and Varying Drone Speed for Instance Uniform-52-n10

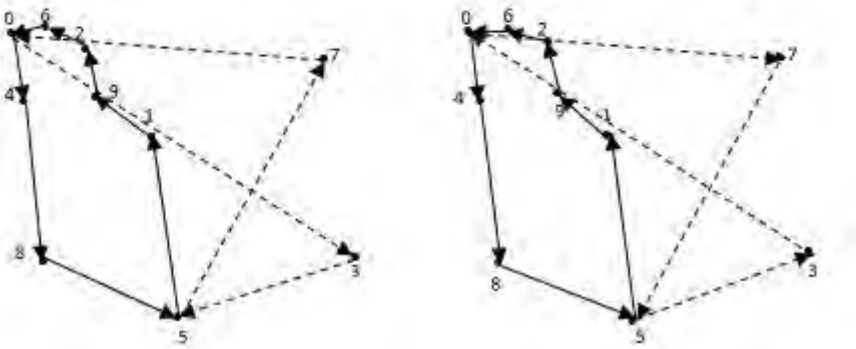

Figure 3. The Truck and The Drone Routes Under Constant and Varying Drone Speed for Instance Uniform-53-n10

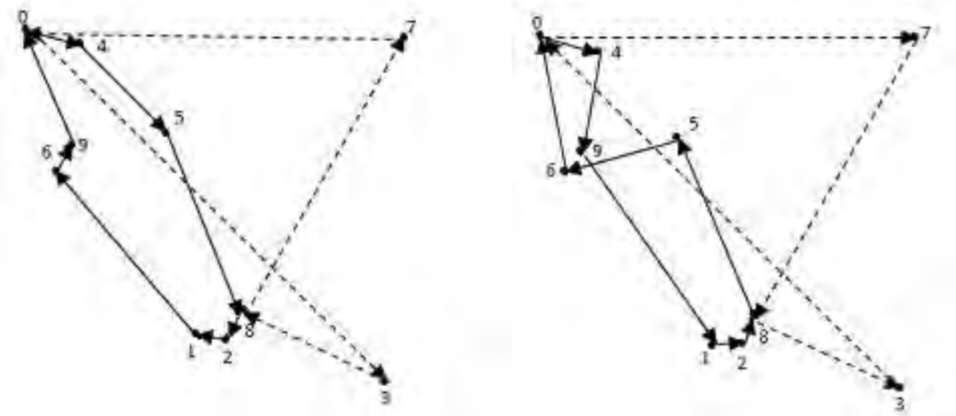

Figure 4. The Truck and The Drone Routes Under Constant and Varying Drone Speed for Instance Uniform-59-n10

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Technology Related Logistic Trends and Technology Usage in Humanitarian Logistics

Kıvanç Onan

Abstract - *Humanitarian logistics (HL) is an emerging field of research since the frequency and severity of disasters and the number of people in need is continuously increasing. And because of this fact proper planning is getting more crucial. Efficiency is another important issue when it comes to disaster relief operations. Keeping these operations efficient is the key to successful implementation and therefore technology usage is essential. In this study, a framework is proposed to benefit from the technology and volunteers for HL. This study emphasizes the role of technology and people for more efficient humanitarian logistics.*

Introduction

Humanitarian crisis caused by natural disasters appear to be becoming more severe and frequent (Pelling, 2003). This growing severity and frequency increases the need for better planning and according to researches it is very difficult to solve the HL problems without a proper information system (Özdamar & Ertem, 2015). Especially the improvement in mobile and web technologies, along with satellite systems, lets us to improve the infrastructures of information systems and so lets the researchers to build better frameworks (Sangiamkul & Hillegersberg, 2011).

Technological improvements not only enhance the information systems such as geographical information systems (GIS) but also change the people's reactions during and after disasters. The role of internet in our daily lives and increasing possibilities that combines individuals to the world changes the way of individual responses during hard times. But these improvements not only affect individuals but also began to change the overall operations including the involving organizations. But still technology may have a better role in solving the problems of people in need such as; victims of disasters, refugees etc.

There are similarities and differences between commercial logistics and HL. These similarities and differences also include the technology related issues. Since HL is a non-profit type of an operation, the point of view should be different. This research conducts a discussion about technological trends in commercial logistics and technology – HL relationship. The aim is building a framework to help HL people to manage the relation between technology and HL. Briefly, this research includes a survey on the recent technology related trends in logistics and a discussion about the gap between technology and HL which is needed for offering a framework for proper technological planning and implementation in all phases of humanitarian operations.

Literature Survey

The literature on the relation between technology and humanitarian logistics is a narrow field for research. So there is a need for more detailed researches. The most related and recent papers are listed and summarized in this section.

In the book of Meier (2015), Enzo Bollettino, the executive director of the Harvard humanitarian initiative of Harvard University, defines the new era which is shaped by technology as;

"This is a world where dedicated people work closely with and in increasingly elegant and synchronous ways with the technologies and applications they have created to better the lives of those most affected by disasters."

This was written after the Haiti 2010 earthquake when people voluntarily analyzed SMS and other social media messages to locate and help the victims of the disaster. This case highlights the importance of technology usage in humanitarian operations. He also mentions this disaster as a start of a new era, in which the humanitarian operations are totally changed by the presence of "digital humanitarians". Another issue that should be highlighted is the importance of volunteers in HL. The spread of internet and mobile devices eventually increased the coordination and support of volunteers in HL systems. Supporting the ideas of Bollettino, Read et al. (2016) suggests that the use of SMS and other social media data is increasing. Also, he suggests that, visual technology, crisis mapping and big data technologies improve the data gathering and use of data. Shortly, it can be concluded that these advances revolutionize humanitarian operations.

Another study which highlights the importance of social media in humanitarian operations is Crumbly and Carter's paper (2015). In their work Crumbly and Carted proposed a conceptual model which integrates social media and supply chain management. Their study mostly focuses on food charities.

Agostinho (2013) also mentions the lack of resources and tools which is necessary for efficient humanitarian supply chains. The author emphasizes the importance of focusing on information to sustain efficacy. Agostinho (2013) presents the lack of investments and weakness of information systems as one of the important reasons for low efficiency. And concludes that we should utilize people and information in a better way for the ultimate goal of better aiding.

Abushaikha & Schumann-Bölsche (2016) focuses on use of mobile phones in humanitarian logistcis in their study. They also mention the limited discussion in literature on technology usage in humanitarian logistics. They used mobile technology in order to improve the performance of disaster relief operations. They offered the usage of mobile phones for better replenishments of aids. Their offer also bears the wide spread usage of mobile phones and messaging technologies and the users of these tools and applications; shortly people and information as mentioned in Agostinho's (2013) study.

Without considering the interaction between people and technology, Özdamar & Ertem (2015) classified the technology usage in HL as;

- maps and geographical information systems,
- integrated systems,
- coordination networks and
- other technologies such as remote sensing technologies (e.g. image processing and RFID etc.).

Özdamar & Ertem (2015) also listed the challenges in implementation as;

- lack of real-time data,
- fragmented nature of humanitarian organizations,
- lack of commonly accepted interoperability standards among different humanitarian organizations, and

- not realizing the importance to balance good bookkeeping practices and to act fast in emergency relief operations.

Usage of the technologies in the first list above is essentially important to overcome most of these challenges mentioned in the second list. Especially integration and coordination can better be sustained by adopting the proper technology.

Table 1: The summary of the use of information systems in HL (Özdamar & Ertem, 2015)

Citation	Maps and/or GIS	Coordination network	Smart phone apps	Other technologies
GDACS (2014)	GIS data, map	Mass and social media	iGDACS	Satellite, geo-pictures
Chang et al. (2007)	GIS	N/A	N/A	N/A
Saadatseresht et al. (2009)	GIS	N/A	N/A	Spatial multi-objective optimization
Mete and Zabinsky (2010)	N/A	N/A	N/A	RimSim (a simulation and visualization environment)
Widener and Horner (2011)	GIS	N/A	N/A	Spatial optimization
Benini et al. (2009)	GIS algorithms	UN joint logistics cluster	N/A	NASA satellite imagery
ACAPS (2014)	Heat maps	Community of practice	NOMAD	N/A
MapAction (2014)	GIS, GMES satellite imagery, QGIS	UN assessment and coordination team	N/A	GoogleEarth, portable satellite data modem, hand held GPS units
SandyCoworking (2013)	GoogleMaps	List of available spaces	N/A	Ushahidi platform
Humanitarian OpenStreetMap (2014)	GIS	Web portal	Available	Aerial imagery
Chen et al. (2011)	ArcGIS	Collaborative GIS	Mobile resource requesting ability	Resource tracking and management
Zografos and Androutsopoulos (2008)	GIS	N/A	N/A	Database, human machine interface
Jotshi et al. (2009)	ArcGIS	N/A	N/A	Data fusion, Tele-Atlas, and HAZUS
Demir and Özdamar (2013)	ArcGIS	N/A	Android app	On-line user interface
Huang et al. (2013)	OpenStreetMap	Urban search and rescue	SMS	Matlab, ArcGIS, Python
Pasupathy and Madina-Borja (2008)	N/A	American Red Cross	N/A	Excel, Access, VBA, SQL
Vitoriano et al. (2009)	Logistics maps	Web based tool	N/A	Java, Access, GAMS
Tomaszewski et al. (2006)	Open source GIS	Geo-collaborative web portal	PDA or tablet	MapBuilder API and JetSpeed Portal
Özgüven and Özbay (2013)	N/A	N/A	N/A	RFID
Yang et al. (2011)	N/A	N/A	N/A	RFID

The above table from the research of Özdamar & Ertem (2015) summarizes the literature on the use of technology in HL (Table 1). It can also be seen from this table that, information technologies (IT) are used in almost all the disaster related studies, but mostly the usage is limited to geographical information systems and in most of the cases, mobile applications are not used. Also, from the same table, it can be derived that there is a lack of technology usage in terms of coordination in some of the cases. These two findings of the authors express the need of technology usage especially in terms of coordination.

Next, the following figure is about the upcoming trends in logistics (Figure1; DHL, 2016). According to the figure of DHL, one of the greatest companies of logistics sector, the technology trends with high relevance to logistics are;

- big data,
- cloud logistics,
- internet of things,
- robotics and automation,
- self-driving machines and
- 3D printing (Figure 1).

DHL (2016) expects the first upcoming trend to shape the sector is big data followed by cloud logistics etc. These trends along with the technologies listed before, should be considered by the researchers in the field of HL.

- Hence these, technology related, trends in logistics, according to Özdamar and Ertem (2015) commercial solution does not satisfy HL and there is a need for methods that can deal with large scale disasters.

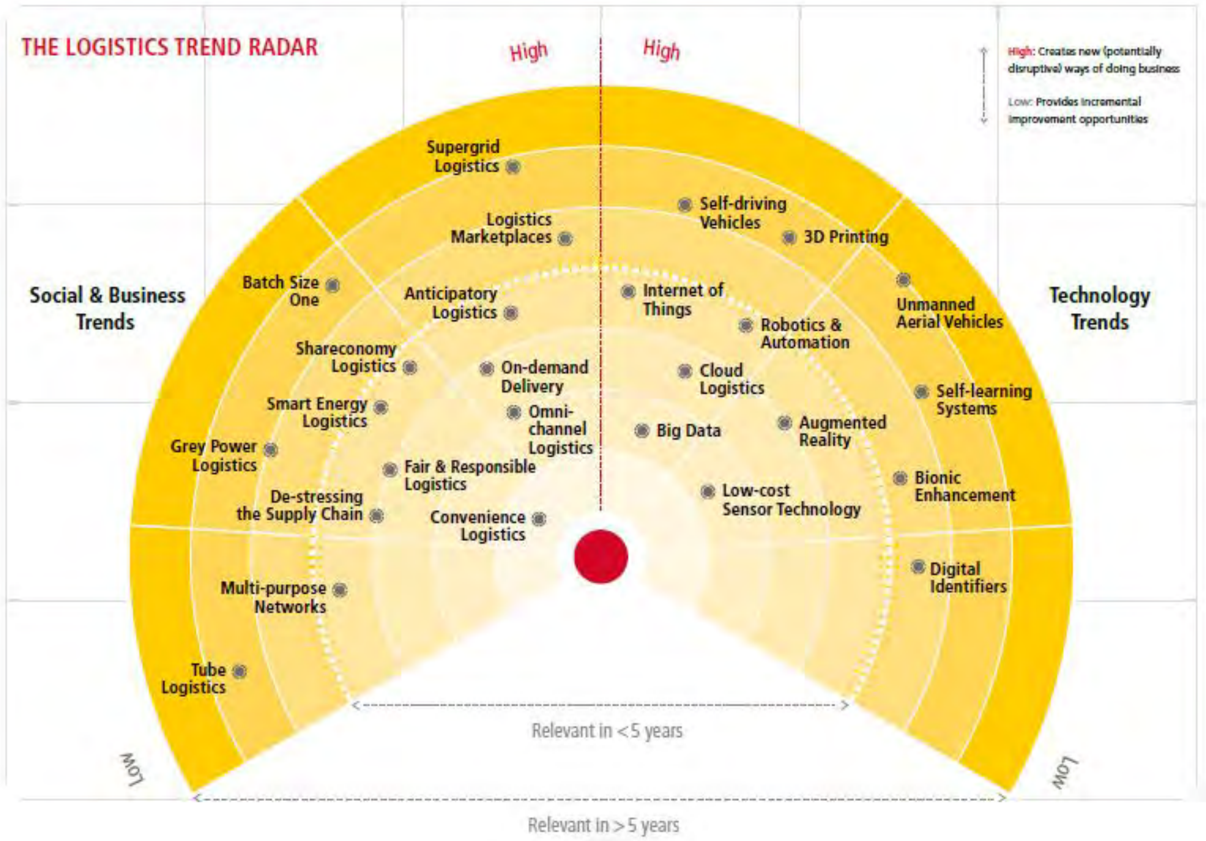

Figure 1: The Logistics Trend Radar (DHL, 2016)

Proposed Framework

The key points summarized from the literature survey part are as follows;

- technology usage is very crucial in terms of overcoming the challenges in HL
- people's relation with social media and mobile devices played a critical role in recent disasters
- data is very important for HL; both in terms of collection and analysis
- fast response is very crucial in the times of life and death situations
- probably the best adopted technology in HL is GIS
- real-time streaming of data and its immediate usage is vital
- hence the organizations are fragmented, coordination and integration is a big problem in HL
- commercial solutions one by one utilize technological advancements such as cloud computing and big data etc. but these methods do not satisfy HL needs because of its different nature
- probably one of the least used technologies is mobile applications in HL except the ones with messaging features

These points listed above highlights the importance of mobile technology and collection/analysis of data along with volunteers in terms of humanitarian operations. So, it is essential to develop a guide for these parties, in order to better benefit from technology and at the same time increase the efficiency of humanitarian logistics.

Table 2: Proposed framework to benefit from technology in data collection and analysis phases of HL (BD: before disaster, DD: during disaster, AD: after disaster)

	Training	Data collection	Data analysis
Voluntary individuals	Attend trainings, distribute knowledge (BD)	Use non-commercial technology (DD-AD)	Support analysis of data and use results (DD-AD)
Solution providers	Develop trainings for individuals (BD)	Develop non-commercial technology (BD)	Develop and run real–time online analysis tools (DD-AD)
Social media	Announce trainings and distribute notes (BD)	Adapt to developed technologies (BD)	Perform analysis and report results (DD-AD)

Other actors of HL are national and international NGOs, governmental agencies, suppliers etc. These actors should be involved in all stages of this plan in terms of regulating, coordinating, and incorporating the process. This revolution was started by individuals with the help of internet and mobile technology, now this knowledge learned from previous disasters can be used to drive all actors for the better of people in need, with the help of all kinds of technologies.

Conclusions

Reviewing the key points, it is obvious that there is a need to find a way for utilizing technological advancements in HL operations. So, the question is which technologies should be invested in terms of humanitarian logistics. It was clearly seen from the literature survey that involvement of volunteers with the help of technology revolutionized the way we look at HL. So, it can be suggested that the technologies that can increase the capabilities and effectiveness of voluntary individuals should be considered. Also, commercial solution providers in logistics sector may be encouraged to develop methods which can be used during the times of disasters. Here the governmental agencies may play an important role by providing incentives such as tax reductions. Briefly people and information matters and best way to gather information is through people and their mobile devices.

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AN ANALYSIS FOR PROJECT LOGISTICS OPPORTUNITIES AND CHALLENGES IN RENEWABLE ENERGY PROJECTS IN TURKEY

Tümay YAVUZ[1]

Abstract - *This study focuses on and deals with the renewable energy portion of the power plant investments in accordance with Turkey's energy policies and aims to identify the project logistics requirements for renewable energy power plant installations. Projection and calculations were based on up-to-date sector data for capacity installations, technical assumptions and previous project experiences and data provided by an investor company in the energy sector. Collaterally, a separate analysis is carried out for transportation and logistics challenges that affect the deployment of larger wind turbines given that wind farm projects shall constitute the utmost business volume amongst the renewable projects.*

Kewords - *Project Logistics, Energy Investments, Data Analysis*

1. INTRODUCTION

Turkey, being an attractive investment destination in the world, aims to put more renewable resources in the production of electricity by putting more new projects into the market, including but not limited to installing power plants that will provide 1.000 MW of geothermal and 5.000 MW of solar energy and increasing the installed capacity based on wind power to 20.000 MW, to satisfy the increasing demand in the country with further investments to be commissioned by the private sector. Investments in this area are also preparing a hard working environment presenting both opportunities and challenges for the project logistics companies.

This study aims to identify the project logistics requirements for renewable energy power plant installations. Projection and calculations were based on up-to-date sector data for capacity installations, technical assumptions and previous project experiences and data provided by an investor company in the energy sector. Collaterally, a separate analysis is carried out for transportation and logistics challenges that affect the deployment of larger wind turbines given that wind farm projects shall constitute the utmost business volume amongst the renewable projects.

Instead of relying on rough figures based on targets set by several strategies which seems to have some inconsistencies, this study provides a more clear view of the renewable energy projects in accordance with these targets free from uncertainties as much as possible. Introducing the status of the projects as planned, licenced, under evaluation etc. provides a timeframe for the projects as well which is important considering schedule issues.

A brief overview of the project logistics sector is presented in the second section of this study. Turkish energy market outlook together with strategies, policies and targets and assessment of them are discussed in third section. The status of renewable (geothermal, wind and solar) power plants, whether they are in operation, under construction, licensed, pre-licensed or at project evaluation stage, are indicated in section three as well.

Logistics requirements and operations such as vehicle planning and transportation organization for geothermal, wind and solar power plant installations based on Zorlu Enerji's, which is one of the leading investors in the energy sector, previous project experiences are treated in section four of this study. Fifth section treats the projections and calculations for logistics requirements for future power plant projects based on data obtained from Zorlu Enerji's previous operations, the assumptions based on technical conditions and limitations, the previous project experinces in the sector and project realization rates.

Opportunities and challenges for the project logistics sector are discussed in sixth section with a special emphasis on challenges and barriers in wind power logistics together with recommendations for further studies and equipment solutions to overcome such challenges and barriers. Finally in seventh section, findings of this study are concluded pointing out further study areas in this subject as well.

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2. PROJECT LOGISTICS

Rather than defining project logistics as transportation of bulk loads which are considered to be out-of-gauge, it may better be defined as logistics activities for projects such as complete facility relocations, facility installations and construction projects carried out either locally or internationally and the organization of all needs from A to Z within a plan, program, transport, storage and distribution processes. Naturally, a company with the ability to operate in the field of project logistics will also be able to manage the out-of-gauge transport activities at the same time [1].

The critical factors for a successful application of a road map that reveals the process for project logistics can be identified as below [2].

- Planning Studies: Beginning of operations by determining the route.
- Cost Analysis and Research: Creating an optimal budget with cost and related benefit analysis.
- Operational Eligibility: Checking the availability and applicability of the necessary team and equipment.
- Regulatory Compliance: Obtaining authorization from local authorities for the required operations.
- Operation Phase: Execution in accordance with the plan.
- Supervision and Supervision: Control of the suitability of operations for the environment and human health.
- Informing: Providing up-to-date information flow between the client, the project manager, the operator and the field.

According to the "Sector Analysis General Report of International Goods Transportation By Road" conducted by the International Transporters Association in 2011-2012, project transportation has risen to the top with 17% market share in the Turkish logistics sector. Approximately 23% of logistics companies also specialize in the field of “out-of-gauge transportation services” which are carried out with special vehicles and which require special permits [2].

Turkish logistics sector has become a leading player in the field of project logistics especially in the Turkic Republics, Middle East and Arabian Peninsula with its current infrastructure capacity, service quality, price policy and experience. The sector needs more investment and experience to be competitive in other regions and to be capable of meeting the anticipated growth. Currently, the number of companies with this capability and experience is limited. Additional experience and investment requirements affect the number of players in the sector [1]. To carry out the works within the scope of project logistics, special experience, communication, professional business style, planning is required together with a special equipment park for transportation of heavy and large goods. As the projects are often different from each other, the experience must be supported by creativity, technical and academic knowledge [3].

3. ENERGY INVESTMENTS IN TURKEY

3.1. Turkish Energy Market Outlook

Figures in the last 15 years reveal that Turkey is one of the few countries with sustained economic growth supported by increasing population, industrialization and urbanization. Turkey’s energy demand will double during the next decade, which calls for an investment requirement of minimum 100 billion USD. This economic growth and increase in energy demand will be supported with secure and sustainable sources utilizing local and renewable sources and providing security of supply in a competitive and transparent way. It is worthwhile to underline once more that making best use of renewable energy resources, with a focus on solar and wind, is crucial [4].

The model that has been introduced recently on development of large scale renewable energy areas, namely YEKA, should be very closely pursued by the investors. New Investment Model for Renewables, YEKA

(Renewable Energy Resource Area) Mechanism, has been introduced in order to further support renewable energy investments and incentivize local manufacturing of renewable generation assets [4].

3.2. Energy Strategies, Policies and Targets

The objective of Turkey's energy policies is to ensure secure, sustainable and affordable energy by diversifying energy supply routes and source countries, promoting indigenous energy production and energy efficiency to moderate growth of total final consumption. In this regard, as part of the 2009 Electricity Market and Security of Supply Strategy, and the Vision 2023, the government adopted energy targets for 2023, followed up in a number of strategies and action plans on energy efficiency, renewable energy (RE) and climate change.

In one decade, installed RE capacity has almost doubled, from 15.6 gigawatts (GW) to 28 GW, thanks to the support scheme which offers generators the choice between direct marketing on the day-ahead market and a feed-in tariff with local content support [5].

In December 2014, on the basis of the results of a co-operation project between the European Bank for Reconstruction and Development (EBRD), Deloitte and MENR, the government presented the National Renewable Energy Action Plan (NREAP) for the period 2013-23 (MENR, 2014), in line with the methodology and requirements of the EU of Turkey and contains a number of indicative targets for the different renewable energy technologies to reach a total capacity of 61 gigawatts (GW) as of 2023 [5];

- use all economically feasible hydropower potential for generating electricity to reach 34 GW
- increase installed power generation capacity to 20 GW of wind
- expand the use of solar power in electricity generation to utilise Turkey's potential and reach 5 GW
- use all of 1 GW of geothermal electricity potential in Turkey
- support biomass use of 1 GW
- achieve a 10% share of renewable energy use in the transport sector.

Turkey has set out various indicative targets but has no legally binding renewable energy target fixed in legislation. The government has set out a plethora of technology-specific RE targets in different strategies and plans for 2023 and 2030 which are not consistent. Overlaps and inconsistencies between the different strategies and action plans hinder the assessment of progress and the identification of gaps in the progress towards the targets and priorities. Moreover, Turkey does not have a long term outlook for its renewable energy sector, which would go beyond 2023 [5].

In the second phase of renewable energy development, the government will need to ensure that clear and long term targets (consistent with the longer-term 2030 goals) are established for all renewable energy technologies. Longer term targets provide for the continuity of policies and support a stable investment environment. The Turkish economy is set to grow continuously in the coming decade and new capacity is needed to meet demand as illustrated in Figure 1 [5].

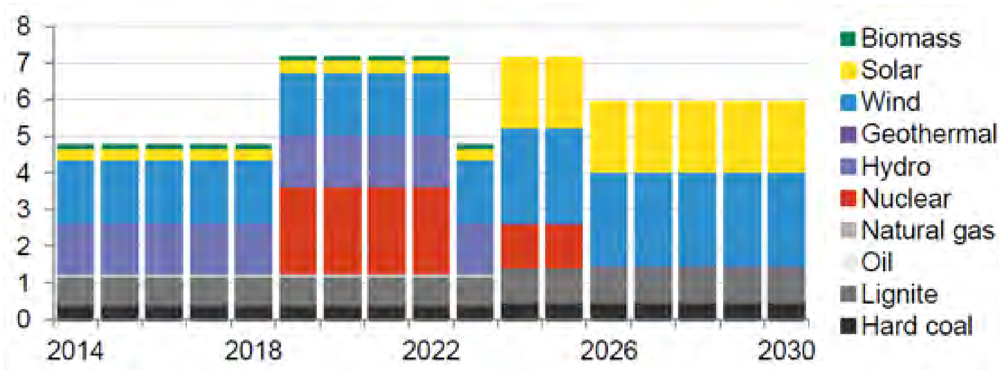

Figure 1. Official Plan Capacity Additions in Gigawatts [6]

3.3. Renewable Energy Investments: In operation, Ongoing and Planned Projects

Representing a far smaller portion of Turkey's energy matrix than wind or even solar, geothermal energy played a greater role in power generation than previously anticipated. Possessing by some estimates as much as much as 4.5 GW of theoretical potential, geothermal in Turkey, and interest in it, is on the rise [7].

Currently there are 33 geothermal power plants (GPPs) in operation with a total installed capacity of 861 MW producing 4.600 GWh/year approximately. The current status in detail is summarized in Table 1 below.

Table 1. Installed and Project Capacities of Geothermal Power Plants

Status	Number	Capacity (MWe)
In operation	35	983,6
Under construction	4	109
Production licence granted	5	131,4
Pre-licence granted	20	432
Project phase	5	144
Total		1.801

Turkey has a significant potential in wind energy, where we need to contribute not only to the wind investments but also to the development of the wind industry. Currently, Turkey is the most important wind market in Europe with a project portfolio in stock more than 10 GW and a target installed capacity of 20 GW in 2023. Electricity production from wind power not only contributes positively to the energy sector but also to the preservation of ecological equilibrium. The current status of the wind power plants and the project portfolio are summarized in Table 2 and Table 3.

Table 2. Installed and project capacities of Wind Power Plants

Status	Number	Capacity (MW)
In operation	158	6.483,9
Under construction	32	808,9
Production licence granted	78	2.901,5
Total	268	10.194,3

Table 3. YEKA and Capacity Auctions for Wind Power Plants

	Capacity (MW)	remarks
Year 2013 applications received by EMRA in April 2015	3000	
	710	Granted in July 2017 for 19 projects
	2290	To be granted in October 2017
Year 2015 applications to be received by EMRA in April 2018	2000	Applications to be received by EMRA on 2-6 April, 2018
YEKA	1000	

Turkey had reached 1.503 MW of installed PV capacity as of the end of June 2017, according to statistics released by the International Solar Energy Society – ISES, Turkey Branch, GÜNDER, which are based on the country's Energy Market Regulatory Board's monthly Electrical Statistics Report. Furthermore, it is expected that Turkey's installed PV capacity may cross the 2 GW threshold by the end of this year, thus enabling deployment of more than 1 GW of solar power. If the current trend is confirmed, Turkey may become Europe's third largest PV market in 2017, after Germany and the UK, which are both expected to surpass 2 GW of new solar capacity [8].

Of the cumulative installed capacity, 1.491,7 MW is represented by unlicensed PV plants. The remaining 12,9 MW is represented by licensed PV capacity. The growth that has taken place in the sector up until now is mainly due to unlicensed solar energy investments and that the remaining licensed projects will come into operation soon. Market for the roof-top solar power installations is expected to spread following the completion of legal regulations [9].

On 20 March 2017, Karapınar Renewable Energy Resource Area (YEKA-1) tender was held in the Ministry of Energy and Natural Resources with the participation of 4 consortiums. South Korea's Hanwha Q Cells and local Turkish firm Kalyon Enerji won the tender and the companies acquired the right to construct a solar power plant with a capacity of 1.000 MW in Konya's Karapınar district. According to the specification, the consortium is expected to establish a solar panel manufacturing facility with a capacity of at least 500 MW per year, covering all the components of solar modules in Turkey, and establish an R&D center as well.

4. LOGISTICS OPERATIONS FOR RENEWABLE ENERGY PROJECTS

Data for the logistics requirements and operations for geothermal, wind and solar power plant installations listed in the below subsections have been provided by Zorlu Enerji which are derived from their previous project experiences.

Table 4. Zorlu Enerji Kızıldere-3 Unit-1 GPP Equipment Procurement and Logistics Summary

Items	Weight (tons)	Import operation	Inland operation	Description& Remarks
Binary Equipment (turbo expander, heat exchanger, generator, refrigerant, piping system and accessories)	950	Breakbulk underdeck (in 9 trips)	14x low-bed trailers 2x flatbed trailers	Imported from Israel
Steam Turbine & generator equipment and accessories	360	Breakbulk underdeck (in 1 trip) 1x low-bed trailer 9x flatbed trailer	4x low-bed trailers 9x flatbed trailers - -	Imported from Japan
Brine injection pumps, cooling tower equipment & misc. Equipment	190	Container ship. 6x flatrack 2x 40'DC 11x 20'DC 5x partial container	6x flatbed trailers 18x FTL	Imported from USA/Japan
Pipes, valves & fittings and misc.	325	2x full charter 88x partial airfreight	12x FTL 88x LTL	2/3 from USA, 1/3 from Europe
Pipes&Fittings	160	7x FTL 14x LTL	- -	From several European countries
Casing Pipes required for drilling works, seamless steel pipes at various diameters and wall thicknesses.	7000	Breakbulk underdeck	Equivalent to 96.000 mt with 1.500x FTL (multi-trips)	Imported from China.
Pipes for production and reinjection lines *Steel pipes at various diameters*	-	-	41.000 mt with 400x FTL (multiple-trips)	Local

Table 5. Zorlu Energy Sarıtepe WF – Vehicle Planning for 20 sets of GE 2.85-103 Wind Turbines

Item	Unit	Set	Dimensions (mt)	Weight (kg)	Vehicle Type
Nacelle	pcs	20	9,66 x 4,25 x 3,95	83.600	8-axle trailer
Hub	pcs	20	3,50 x 3,82 x 3,40	25.200	4-axle trailer
Nose Cone	pcs	20	2,92 x 2,92 x 1,80	800	
DTA Transformer	pcs	20	2,60 x 2,40 x 3,00	12.500	Standard trailer
DTA Controller	pcs	20	3,20 x 3,21 x 3,15	5.000	Standard trailer
DTA Converter	pcs	20	2,80 x 1,10 x 2,90	3.800	Standard trailer
DTA Converter Box	pcs	20	1,95 x 1,30 x 2,20	600	Standard trailer
Blade 1-2-3	pcs	60	51,00 x 3,60 x 2,90	12.700	Extendible blade trailer
Tower Door Section	pcs	20	23,00 x 4,30 x 4,30	46.800	6-axle trailer
Tower Mid Section	pcs	20	28,00 x 4,36 x 4,36	65.000	8-axle trailer
Tower Top Section	pcs	20	30,00 x 4,38 x 4,38	36.800	6-axle trailer
Tower					
Platform (Field Mount.)	case	20	0,90 X 0.70 X 0,29	400	Standard trailer
Connection Bolts	case	20	1,57 X 0,90 X 0,29	750	Standard trailer
Connection Bolts Set (M36x235)	case	20	1,20 X 0,80 X 0,34	650	Standard trailer
Connection Bolts Set (M48x310)	case	20	1,20 X 0,80 X 0,54	1.000	Standard trailer
Connection Bolts Set (M48x310)	case	20	1,20 X 0,80 X 0,54	1.000	Standard trailer

In summary, transportation of a 2,85 MW wind turbine is carried out with 5 multi-axle trailers for heavy components such as nacelle and tower sections, 3 extendible trailers for blades and 9 standard trailers for the rest of the equipment.

Solar power plant installations do not require so many equipment transportation and challenging logistics operations contrary to the other renewable power plant installations investigated in this study. However, its contribution to the business volume of projects logistics sector is noteworthy.

5. PROJECTIONS FOR FUTURE PROJECT LOGISTICS REQUIREMENTS

Projection for project logistics requirements has been based on data for logistics requirements obtained from Zorlu Enerji's previous operations and for future power plant installation data till 2023 taking into account the assumptions based on technical conditions and limitations, the previous project experinces in the sector and project realization rates.

5.1. Geothermal Projects

The assumptions listed herewith for geothermal projects shall enable us in making reasonable calculations for identifying the logistic requirements for such future project installations. These assumptions can be enhanced with a further study in order to make more accurate calculations.

i. Capacity subject to projection can be obtained by summing up the capacity datas 432, 144 and 131.4 MW which gives a total of 707,4 MW under 30 projects.
ii. Only five of the GPPs in operation are flash and binary combined cycle installations corresponding to 15% of the plants in operation. Excluding two installations ongoing, all of the future installations are expected to be limited to binary type power plants taking into account the site and the project characteristics.
iii. Regardless of the plant size, most of the major equipment will require the same logistics operation just as it is in the base case, Kızıldere-3 Unit-1 GPP. In such cases, the number of the vehicles are calculated as multiplying the base case vehicle number with 30, which is the number future projects.

iv. Quantity of some of the equipment will depend on the plant size. Projection for such equipment has been made by multiplying the vehicle requirement both with 30, the number of projects number and 0,6 which is a coefficient based on past project experiences.
v. Given that a production well is able to provide at least 5 MW capacity, 142 wells for production and same number of wells are to be drilled for reinjection.
vi. Total 284 wells at an average depth of 2500 mt yield a total of 700.000 mt drilling length, which consequently yields approximately 900.000 meters casing pipe at various diameters. This is 63.000 tons to be transported with multiple breakbulk underdeck operation and then to be transported to the project sites with 13.500 FTL. (the values are projected over Zorlu Enerji's Kızıldere-3 Unit-1 GPP data, 100 MW, 96.000 mt, 7.000 tons, 1.500 FTL)
vii. Calculations are based on assumption of 5 MW per production well and a production & reinjection well couple to be drilled concurrently for successful operation. Of course this will strictly depend on the site and reservoir characteristics.
viii. The quantity of the pipes required for production and reinjection shall vary to a great extent as per the site and reservoir characteristics and the project capacity requirements. Therefore, it's not possible to make precise calculation per MW to be installed in order to estimate the required pipe length to feed the power plant. However, for ease of calculation, a reasonable assumption based on Zorlu Enerji's several project experiences, the total 284 wells (both production and reinjection) will yield an approximate 400.000 mt of steel pipe lenght considering a coefficient of 1.500 mt/well. This means a 4.000 FTL inland operation.

Table 6. Logistics Requirements Projection for Future Geothermal Power Projects.

Items	Projection for the future installations	Total logistics requirement	
		Import	Inland
Binary Equipment (turbo expander, heat exchanger, generator, refrigerant, piping system and accessories)	x30	30 breakbulk underdeck operation (28.500 tons)	420 low-bed trailers 60 flatbed trailers
Steam Turbine & generator equipment and accessories	-	-	-
Brine injection pumps, cooling tower equipment & misc. Equipment	x30	Container shipments 180x flatrack 60x 40'DC 330x 20'DC 150x partial container	180 flatbed trailers 540x FTL
Pipes, valves & fittings and misc.	x30 x0.6	36x full charter airfreight 1.584x partial airfreight	216x FTL 1.584x LTL
Pipes&Fittings	x30 x0.6	126x FTL 252x LTL	- -
Casing Pipes required for drilling works, seamless steel pipes at various diameters and wall thicknesses.	as per assumptions, item vi	Brealbulk underdeck operation (63.000 tons)	13.500 flatbed trailers
Pipes for production and reinjection lines (Steel pipes at various diameters)	as per assumptions, item viii	-	4.000 flatbed trailers

5.2. Wind Power Projects

In order to determine the logistic requirements for future wind power plant installations, a capacity projection shall be more useful regarding the realization rates and the regional distribution. A much more realistic scenario than the objective stated in NREAP for capacity calculation is as follows. Summing up 2.901,5 MW (licenced), 3.000 MW (capacity auctions, 1st round), 2.000 MW (capacity applications), 2nd round and 1.000 MW (YEKA) shall yield a total capacity of approximately 9.000 MW to be installed and together with the capacities, 6.483,9 MW in operation and 808,9 MW under construction, total installed capacity by 2023 is expected to reach 16.194,3 MW.

Considering the previous project data comparing the planned and installed capacities, [10] points out to the fact that it is not possible to reach the projected targets 100% due to failure in execution of some of the project stock because of managerial and financial problems. Despite targets being an important driving force for the realization of renewable energy projects, all the players in the sector should take such realization rates into account and analyze the sector data in detail while making their future plans. In this study, a realization rate of 0.8 shall be taken into consideration when projecting the capacity which will be subject to logistics requirement calculations. Another finding in [10] is that wind turbines from several companies world wide have been installed and are in operation in Turkey, where turbine power rates chosen for the projects centre on the 2-3 MW range.

Table 7. Turbine Power Rates in Wind Power Plants in Operation

Turbine Power (MW)	$P \leq 1$	$1 < P \leq 2$	$2 < P \leq 2.5$	$2.5 < P \leq 3$	$3 < P$
Number of projects	12	39	50	32	19
Installed capacity	248,9	1.628,7	2.001	1.396,2	831,2
Installation period	1998-2007	2008-2016	2008-2016	2011-2016	2015-2016
Total installed capacity ratio	4%	27%	33%	23%	14%

The above data in Table 7. has been derived out of TWEA 2017 July Report [11] which provides a list of the wind power plants under operation in Turkey. According to that table, we can say that majority of the turbines (totaling 56% of the installed capacity) have power rates between 2 and 3 MW as suggested in [10]. On the other hand, it's seen from the report [11] that 12 of the 15 projects which have been completed in the first half 2017 utilises turbines with power rates greater than 3 MW reaching up to 3,45 MW. In addition, 21 of the 32 projects which are under construction are utilising turbines with power rates greater than 3 MW reaching up to 3,9 MW. This shows us that current technological trend is to deploy wind turbines with power rates greater than 3 MW unless deployment of larger turbines encounter application drawbacks and challenges.

In order to calculate the logistics requirements for wind power plant projects, rather than relying on the 2023 target capacity, we shall proceed with the realistic approach and apply the following steps. Multiplying the 9.000 MW capacity to be installed with the realization rate of 0,8 as indicated above gives us a 7.200 MW capacity which will be subject to our calculations. Average turbine power rate shall be taken as 3 MW considering the current technological trend. Consequently we get 2.400 turbines to be deployed during the future installations.

In conclusion, taking into account the above number of turbines and the summarized vehicle planning data stated in section 4, we can project a 12.000 multi-axle trailer, 7.200 extendible trailers and 21.600 standard trailer logistic operation which will be required for the future wind power plant installations until 2023. We should also keep in mind that average turbine power rate might be more than 3 MW resulting in a less number of vehicles need for future installations. In this case, logistic operations may require vehicles capable of transporting heavier nacelles, larger and taller tower sections and wider turbine blades. Moreover, project logistics companies might need extra solutions to overcome the barriers encountered in such larger turbine logistic operations.

5.3. Solar Power Projects

Given the fact that solar market is booming and the investments have a tendency to increase, Turkey is expected to reach its 2023 target in solar power projects. When we deduct the current installed capacity of 1.503 MW from the 5 GW target, the remaining capacity of 3.500 MW to be installed shall be subject to transportation projections. The major transportation requirement shall be for the solar panels and the steel construction. Assuming 7 FTL for solar panels and 4 FTL for steel construction for major equipment transportation operation for a 1 MW solar power plant, projection for the target capacity to be installed yields us a 24.500 FTL operation for the transportation requirements of solar power plant projects.

6. OPPORTUNITIES, CHALLENGES AND BARRIERS IN PROJECT LOGISTICS

6.1. Opportunities

In line with the 2023 vision, as discussed in detail in the third section of this study, Turkish government is expected to invest more than a total of 100 billion dollars in the energy sector by year 2023, which covers investments for refineries, petrochemical and energy storage facilities, nuclear power plants, mining and renewable energy power plants. Estimated expenditure distribution by years is illustrated in Figure 2. This is a pretty appetizing figure for all the sectors and these investments will create significant opportunities for the logistics sector as well. Companies in the project logistics sector should carry out the necessary investments to be able to undertake tasks for the energy projects including but not limited to renewable energy power plants.

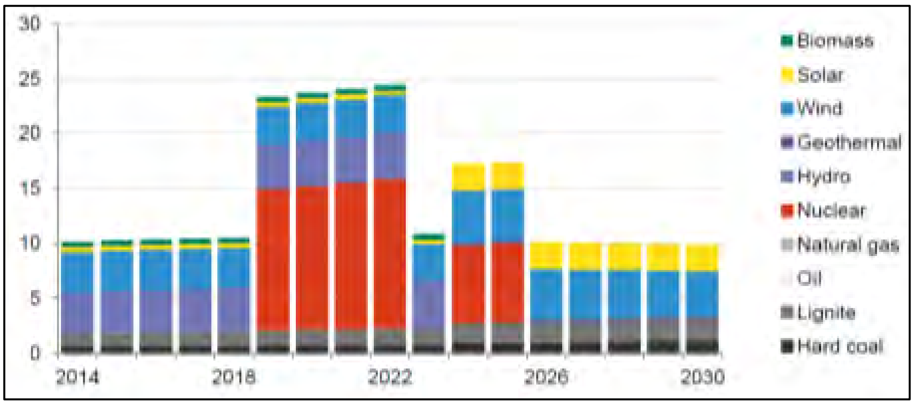

Figure 2. Estimated Capital Expenditure In Official Plan in Billion $ [6]

6.2. Challenges in Power Projects

Top priority of investors in the energy sector when choosing a logistics partner can be defined as its capability of transporting the equipment free of damage in a timely manner and when demanded and required at site, encountering the least problems at the borders and customs, so that they shall not bear any consequent loss of turnover or interest due to delay in the start-up of the power plants. In the energy sector, especially the major equipment comprise important technological components which are very expensive and remanufacturing of such components will cause all plans to delay for a long time. A possible damage which might occure during transportation is one of the greatest threats to the success of project execution [12].

Concerning the wind power projects, the projects within the 9.000 MW scope including the YEKA projects to be realized in 5 major districts, shall be carried out in a wider area across Turkey as illustrated in Figure 3 and Figure 4, when compared to the previous projects (existing installations up to now) which are mostly located in the Agean (39,8%) and Marmara (34,5%) regions.

Figure 3. Wind Power Plant Capacities, 2nd Round, 3000 MW, 2013 & 3rd Round, 2000 MW, 2015 [13]

Project logistics sector providing services for wind power projects should carry out the necessary investments taking into consideration that wind turbine power rates in the current projects show an increasing trend above 3 MW. Higher power rates meaning that larger turbine towers and wider blades and heavier nacelles as well. They should also take into account the regional distribution of the projects as indicated in Figure 3 where some new areas may require making detailed road studies.

A technical report issued by National Renewable Energy Laboratory (NREL) in US [14] studies comprehensively all the aspects of deploying larger wind turbines. The levelized cost of energy (LCOE) from wind turbines has declined in part as a result of the increased economies of scale associated with larger wind turbines on taller towers. However, transportation and logistics challenges limit the size and tower height of land-based turbines that can be deployed. Addressing these transportation and logistics challenges will allow for deployment of larger state-of-the-art turbines. The authors of the study [14] primarily relied on interviews with wind industry project developers, original equipment manufacturers, and transportation and logistics companies to obtain the information and industry perspectives needed for this study in order to identify the mass, cost, and size breakpoints for the wind turbine blades, tower and nacelle. Addressing these transportation and logistics challenges is expected to enable the deployment of larger wind turbines on taller towers and enable LCOE reduction pathways for all land-based wind turbines.

A technological solution to overcome the difficulties in the transportation of wider turbine blades is the Blade Adaptor by Scheuerle, which has been used in several projects in the world and has been used by Borusan Logistics in Borusan EnBW Enerji's Fuat RES project first time in Turkey. This blade adapter technology which allows the huge 60 meter blades to be loaded on 15 meter long trailers also enables lifting of the blades into the air up to 50 degrees and rotating it at ±110 degrees. Thanks to this technology, the company was able to reduce their road construction costs while at the same time proceeding with an environmentally sensitive system for new road construction. Also, this technology prevented about 10.000 truck excavation and more than 100.000 meters of soil loss and ensured that ecological balance was not spoiled and the damage to the environment was minimized [15].

Figure 4. Scheuerle Blade Adapter for Turbine Blade Transportation

7. CONCLUSION

Based on data from previous project experiences, realistic capacities to be installed for geothermal wind and solar power plants in accordance with 2023 targets, assumptions reagrding technical conditions and limitations and the realization rates, projections in this study yield project logistics requirements as summarized below.

Table 8. Project Logistics Requirements for Renewable Energy Projects

Geothermal	30 breakbulk underdeck operations for 38,500 tons (for equipiment), Multi breakbulk underdeck operation for 63,000 tons (for casing pipe), 180 flatrack, 60 40'DC, 330 20'DC and 150 partial container shipments, 36 full charter, 1584 partial airfreight, 420 low-bed trailers, 240 flatbed trailers, 17,500 flatbed trailers (for plant pipes), 882 FTL & 1836 LTL
Wind	12,000 multi-axle trailer, 7,200 extendible trailer, 21,600 FTL
Solar	38,500 FTL

Some of the technical assumptions for geothermal projects, which are the basis for calculations, can be subject to further revisions following discussion with technical expert and relevant authorities. Similarly, operational requirements and vehicle planning for the wind power logistics as provided in this study may vary depending on the realization rate of the projects and average power rates of the turbines to be deployed in-line with the technological trend of deploying larger turbines.

The scope of this study was limited to identify and quantify the logistics requirements of renewable energy projects. With further studies using the same approach, a realistic view of logistics needs other segments of energy investments may be identified. In any case, project logistics companies should make the necessary investments to be able to undertake tasks for energy projects including but not limited to renewable energy power plants. The companies should also take into consideration the export logistics operations thanks to YEKA investments which will boost the local manufacturing of solar and wind power equipment.

Concerning the wind power logistics, sector should carry out necessary preparations taking into consideration the deployment of larger turbine towers, wider blades and heavier nacelles. They should also take into account the regional distribution of the projects as indicated in Figure 3 and 4 where some new areas may require making detailed road studies. Investing in innovative solutions like the blade adaptor technology to overcome the challenges and barriers in blade transportation is also subject to further consideration.

A similiar study to [18] tailored according to Turkey’s conditions and needs should be carried out to identify the challenges and barriers in transportation of larger wind turbines.

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BUS STOP SELECTION FOR EMPLOYEES WITH BI-OBJECTIVE PARTICLE SWARM OPTIMIZATION APPROACH: CASE STUDY

Derya Deliktas[1], Ozden Ustun[2]

Abstract – *In this paper, bus stop selection problem is studied to determine a set of bus stops and assign employees to these ones by considering the total walking distance of employees and the number of bus stops. These objectives are crucial to minimizing total pick-up/delivery time of buses and total walking distance of employees. The total walking distance affects the satisfaction of each employee. On the other hand, fewer bus stops provide both fuel savings and a reduction in the total running time from first bus stop to last stop, and vice versa. Particle Swarm Optimization (PSO) approach is proposed to determine bus stops by clustering locations of employees. The proposed PSO approach is also applied to employees of a university.*

Keywords – *Bus stop selection, Clustering, Fuzzy C-means, K-means, Particle swarm optimization.*

1. Introduction

Many large-scale production or service organizations have a transportation problem for employees who live far distances from their workplaces. Employees can arrive to workplaces with different ways such as public transportation and private vehicle. In addition, managers should consider effectively transportation service systems in order to facilitate the travel of remote employees. Effective transportation service systems consist of determining appropriate bus stops and optimal bus routings. Selecting bus stop locations within employees' acceptable distances is an important task to provide employees' satisfaction. Although each employee prefers to be taken from their home, it can increase the expenditure of transportation system. On the other hand, the clustering of employees' locations is a proper method to reduce organization cost by taking into account employees' acceptable distances. There are two conflict objectives in real life problems such as the total walking distance of employees and the number of bus stops. The total walking distances of employees is critical to reach easily to bus stop location. However, the less the number of bus stops is, the less the cost for organizations is.

In this study, we interested in bus stop selection problem for Dumlupınar University employees in Turkey. It deals with 387 employee locations in Kütahya. The coordinates of locations are determined by using both of employees' addresses and Google Maps. Firstly the available system is analyzed and then we proposed an alternative system to optimize the conflict objectives. Clustering is a useful technique to determine groups. Employees are grouped into clusters by using K-means, Fuzzy C-means and Particle Swarm Optimization (PSO). The center of each cluster is calculated and assigned to nearest bus stop. The total walking distance is minimized due to the number of bus stops by using these artificial intelligence methods. The obtained results are compared by considering objective functions and CPU times. The obtained efficient solutions are compared with an additive utility function.

2. Bus Stop Selection

Our bus stop selection problem in employee transportation service system can be considered as a part of school bus routing problem (SBRP) in the literature. The SBRP has been studied since the first publication on it by Newton and Thomas [1]. Desrosiers et al. [2] indicate that SBRP consists of five sub-problems or phases such as data preparation, bus stop selection (student assignment to stops), bus route generation, school bell time adjustment, and route scheduling. In the data preparation phase, the road network consisting of home, school, bus depot, and the origin-destination (OD) matrix among them are calculated. The bus stop selection step determines the location of stops, and the employees/students are assigned to them. The bus routes for a single university/school are generated in the bus route generation phase. The university/school bell time adjustment and route scheduling phases are necessary for the multi-school configuration. Although these phases are not independent but are highly interrelated, they are treated separately due to the complexity and

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size of the problem. Moreover, in most literature, only some parts of SBRP are considered. A detailed review of SBRP is given by Park and Kim [3].

In our work, we focus on the bus stop selection phase. Bus stop selection tries to find locations of a set of bus stops and assign employees/students to these stops. For universities, the employees are assumed to walk to a bus stop from their homes and take a bus at the stop. As indicated by Park and Kim [3], bus stop selection is often omitted in the literature. Many studies assume that the locations of bus stops are given. Only a few papers considered bus stop selection. These studies use heuristic algorithms based on the location-allocation-routing (LAR) strategy or the allocation-routing-location (ARL) strategy [4-5]. Bodin and Berman [6], Dulac et al. [7] and Desrosiers et al. [8] proposed a heuristic approach based on the LAR strategy. Chapleau et al. [9] and Bowerman et al. [10] used an algorithm based on the ARL strategy. Schittekat et al. [11] developed a simple mathematical model for bus stop selection from potential stops and bus route generation for a single-school problem. Leksakul et al. [12] compares different methods for solving a location-routing problem (LRP), using real-world data from the bus transport service for employees of a large-scale industrial factory in Thailand. They tested four artificial intelligence techniques Maximin, K-means, Fuzzy C-means, and Competitive Learning and two hybrids of these four K-means with Competitive Learning and K-means with Maximin to allocate the bus stops.

In this study, Particle Swarm Optimization (PSO), K-Means, Fuzzy C-Means is proposed to determine bus stops by clustering locations of employees.

The K-means algorithm is a clustering method in statistical and machine learning [13]. The objective of the K-means algorithm is to select the number and the position of center points while minimizing the sum of the distances between the data and the center points. The main idea of this algorithm is to define K centers, one for each cluster. These centers should be placed in a skillful way because different locations create different results.
The Fuzzy C-means algorithm is a data clustering technique that allows each data point to be assigned to more than one cluster, which is specified by a membership grade. This algorithm was created by Dunn [14] and developed by Bezdec [15]. The objective of the Fuzzy C-means algorithm is to minimize J_m as follows:

$$J_m = \sum_{i=1}^{N}\sum_{j=1}^{C} u_{ij}^{m}\left\|x_i - c_j\right\|^2 \quad 1 \leq \mathrm{m} \leq \infty \tag{1}$$

where $m > 1$, where u_{ij} is the degree of the data x_i in the cluster j, and x_i is the ith of the data, and c_j is the center of the cluster. In this study, we have used a fuzziness coefficient m=2.

The Fuzzy C-means procedure minimizes J_m and updates u_{ij} and c_j, which are given in (2), until $\max_{ij}\left\{\left\|u_{ij}^{(k+1)} - u_{ij}^{k}\right\|\right\} < \varepsilon$. For this equation, ε is the terminating variable valued from 0 to 1 and k is the iteration step.

$$u_{ij} = \frac{1}{\sum_{k=1}^{c}\left(\frac{\left\|x_i - c_j\right\|}{\left\|x_i - c_k\right\|}\right)^{\frac{2}{m-1}}}, c_j = \frac{\sum_{i=1}^{N} u_{ij}^{m} x_i}{\sum_{i=1}^{N} u_{ij}^{m}} \tag{2}$$

PSO is a heuristic technique introduced by Kennedy and Eberhart [16]. It is one of the latest evolutionary and population- based optimization algorithms, which can simulate bird flocking or fish schooling behavior. PSO applies the concept of social interaction to problem solving. In the PSO algorithm, each individual in the population is called a particle and is subject to move in the search space. In PSO, a swarm of n particles communicate either directly or indirectly with one another search directions. In addition, each particle is a candidate solution. Particles have memory, and thus, they retain part of their previous state. There is no restriction that particles share the same point in the search space, but their individuality is preserved. Each particle's movement is the composition of a velocity and two randomly-weighted influences. The two randomly-weight influences are individuality, or the tendency to return to its best previous position, and sociality, or the tendency to move towards its neighborhood's best previous position [17]. The position x of particle i moves at iteration k as follows:

$$x_i^{k+1} = x_i^k + wv_i^{k+1} \tag{3}$$

where v_i^{k+1} is the velocity of the particle at iteration k+1. The velocity of each particle is calculated as:

$$v_i^{k+1} = wv_i^k + c_1r_1\left(p_i^k - x_i^k\right) + c_2r_2(p_g^k - x_i^k) \tag{4}$$

where v_i^k is the velocity of the particle at iteration k, r_1 and r_2 are random numbers between 0 and 1, p_i^k shows the best position of particle i obtained so far (personal best), and p_g^k expresses the global best position in the swarm at iteration k (global best). The remaining three constants are problem-dependent parameters. The selecting of the appropriate parameters for PSO improves the performance of the algorithm [18]. The remaining three parameters are that w is the inertia weight factor, c_1 is a cognitive parameter, and c_2 is a social parameter. In this study, we have used as w=0.1, c_1=1.47, and c_2=1.47. In PSO, sometimes a particle tends to leave the search space. Although several methods all induce a bias, they can be used to prevent this [19, 20].

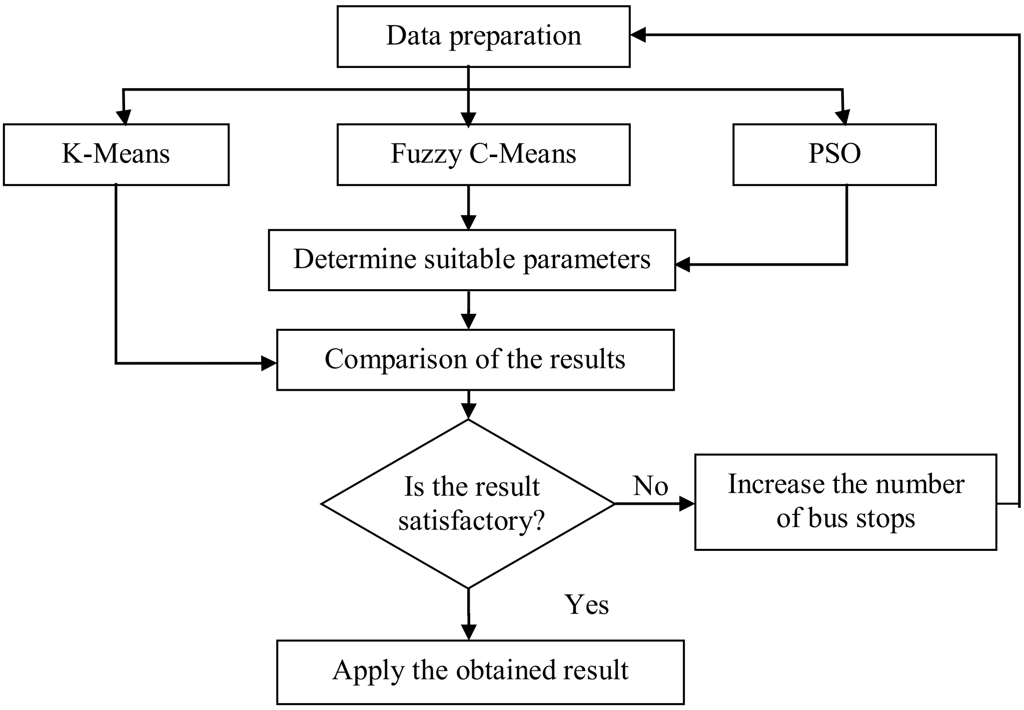

Figure 1. The flowchart of the proposed approach

In this study, we interested in bus stop selection problem for Dumlupınar University employees in Turkey. It deals with 387 employee locations in Kütahya. The coordinates of locations are determined by using both of employees' addresses and Google Maps. However, this map does not contain enough traffic and address information. In addition, there is no information about one way streets, divided roads and buildings on this map. It is quite difficult to complete this information. After reaching the solution without using this information, Dumlupınar University administration was consulted about the suitability of the bus stop locations. If these locations aren't suitable, the solution has been corrected. Kütahya's place on the map of Turkey and the employee addresses in the GPS system can be shown in Figure 2.

Dumlupınar University has 1501 employees including both academic staff and administrative staff. However, most of these employees does not use the vehicles provided for these employees because some of them have their own private cars, or live in houses around the campus and in the campus. So, the remaining 387 employees need a vehicle from university to their home, and vice versa. A questionnaire was applied to these employees to obtain their location information. The university provides service to the personnel with 11 vehicles and 51 bus stops. These vehicles bring the staff to the campus around 8:30 am and leave the campus at 17:30 pm. The capacity of each vehicle is 45 employees.

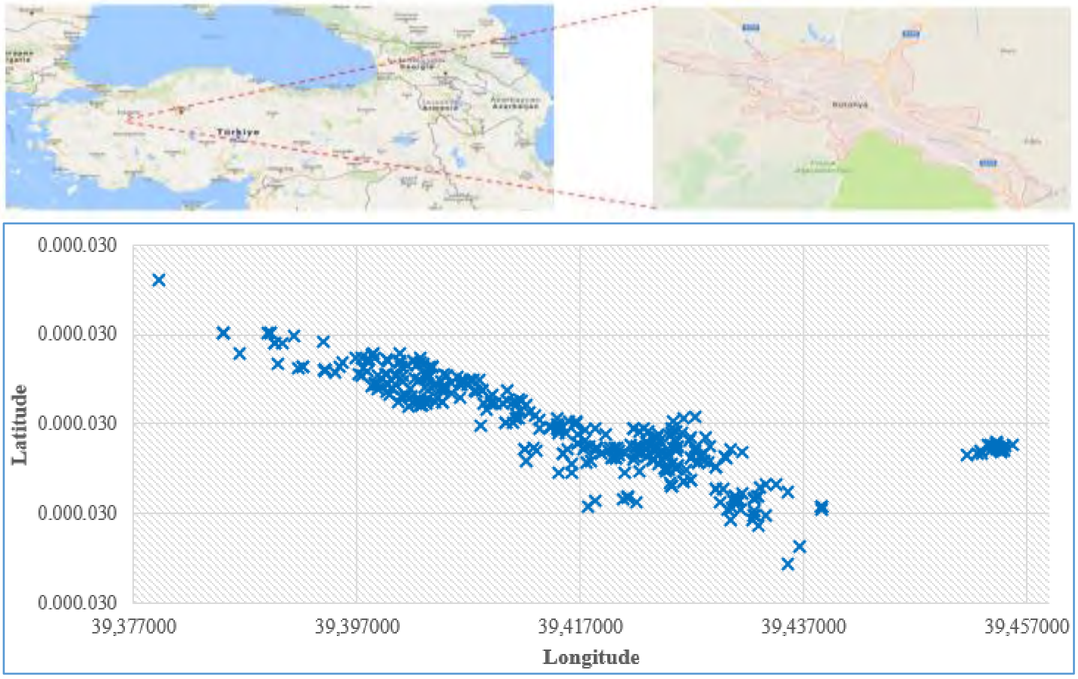

Figure 2. Kütahya's place on the map of Turkey and the employee addresses in the GPS system

3. Experimental Results

In this section, it is presented the results obtained k-means, fuzzy c-means, and particle swarm optimization. At the current situation, total walking distance of all employees is 1658.7365 meters and maximum walking distances for an employee is 68.1159 meters. To evaluate these heuristics, it was evaluated the different number of bus stops between 5 and 50. To compare the performance of these heuristics with each other, algorithms were each run 10 times for each bus stop.

Table 1. Comparison of total walking distances for the three algorithms

No of bus stop	Criteria	K-Means	Fuzzy C-Means	PSO	No of bus stop	Criteria	K-Means	Fuzzy C-Means	PSO
	Average	2840.72305	2724.702495	3289.66815		Average	925.5531	905.9086190	1094.948
5	Best	2743.58311	2724.702495	2924.60143	30	Best	859.0888	905.9086190	1079.256
	Worst	3706.77490	2724.702495	3510.39163		Worst	1009.488	905.9086190	1128.235
	Average	1766.41158	1763.051478	2011.36377		Average	820.3104	821.2501167	995.6840
10	Best	1708.79022	1763.051478	1932.53565	35	Best	780.3863	821.2501167	969.6083
	Worst	1881.85096	1763.051478	2114.7006		Worst	862.5691	821.2501167	1031.662
	Average	1438.15860	1349.365743	1591.05751		Average	751.2716	735.0642958	933.3274
15	Best	1411.62865	1349.365743	1526.62882	40	Best	719.7401	735.0642958	903.3464
	Worst	1490.85751	1349.365743	1698.53278		Worst	794.5464	735.0642958	975.8829
	Average	1187.52483	1117.217064	1334.39264		Average	701.3092	758.3829765	866.4000
20	Best	1128.91671	1117.217064	1286.77373	45	Best	670.0672	758.3829765	831.5011
	Worst	1275.15766	1117.217064	1415.42387		Worst	735.1231	758.3829765	906.6188
	Average	1037.09417	972.9496196	1199.62481		Average	669.3530	649.3507741	818.7078
25	Best	994.582373	972.9496196	1162.92726	50	Best	628.3322	649.3507741	783.6583
	Worst	1070.81749	972.9496196	1255.03302		Worst	741.9176	649.3507741	833.6444

* All distances are given in meters and the case study is solved by using Intel® Core™ i5-4460 CPU @ 3.20 GHz and 8.00 GB Ram.

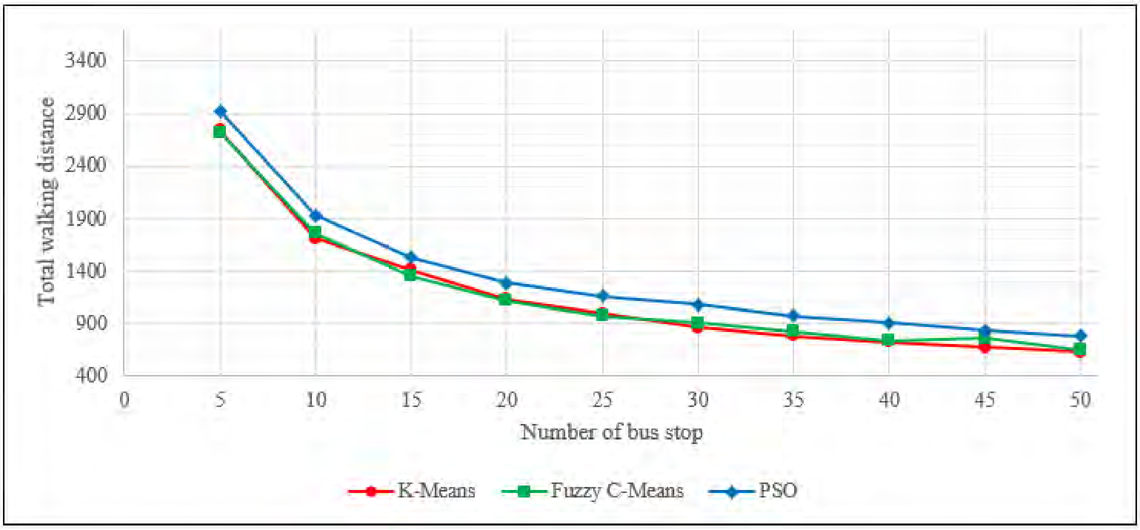

Figure 2. Sensitivity analysis based on the different number of bus stop

As shown in Table 1, it has reported the average of 10 total walking distances and the best (i.e. minimum) and the worst (i.e. maximum) total walking distance of 10 experiments because each algorithm was run 10 times. Total walking distance is the summation of all of the employees' travel distance from their addresses to the corresponding centroid while maximum distance is the maximum radius measure from the centroid to the farthest employees' address in cluster. From the results given in Figure 2, the number of bus stop affects total walking distance. Total walking distance decreases with the increasing number of stop. Therefore, management can decide the appropriate number of bus stop both to provide satisfaction of employee and to reduce fuel cost. According to these results, in general, the performance of fuzzy c-means is better than the remaining algorithms in Figure 2. In addition, it is also seen in Table 1 that the results of all of algorithms are better than the result of current situation with 50 bus stops. So, total walking distance can decrease form 1658.7365 meters to 628.3322 meters.

Table 2. Comparison of computation times for the three algorithms

No of bus stop	Criteria	K-Means	Fuzzy C-Means	PSO	No of bus stop	Criteria	K-Means	Fuzzy C-Means	PSO
	Average	4.8	6.2	13.5		Average	4.8	18.1	22.1
5	Best	4	5	11	30	Best	4	18	21
	Worst	8	8	17		Worst	5	19	23
	Average	4.7	6.8	14.5		Average	5.4	22.7	33.9
10	Best	4	6	13	35	Best	5	22	32
	Worst	5	7	16		Worst	6	23	38
	Average	5.3	9.2	18.7		Average	5.4	26.9	28
15	Best	5	9	17	40	Best	5	26	26
	Worst	7	10	20		Worst	6	28	30
	Average	5.2	11.2	16.8		Average	5.8	32.9	40
20	Best	4	11	15	45	Best	5	32	39
	Worst	7	12	18		Worst	7	34	42
	Average	5.1	14.8	25.3		Average	6.1	37.3	44.5
25	Best	5	14	24	50	Best	5	37	43
	Worst	6	15	26		Worst	7	38	47

* All times are given in CPU seconds and the case study is solved by using Intel® Core™ i5-4460 CPU @ 3.20 GHz and 8.00 GB Ram.

Table 2 gives the computation time in seconds for the three algorithms applied to the different number of bus stop. In addition, Table 3 shows the maximum distance for the three algorithms applied to the different number of bus stop. Maximum distance also reduces with the increasing number of bus stop. This value drops to 7.130201 meters from 68.1159 meters for 50 stops.

Table 3. Comparison of maximum distances for the three algorithms

No of bus stop	Criteria	K-Means	Fuzzy C-Means	PSO	No of bus stop	Criteria	K-Means	Fuzzy C-Means	PSO
	Average	47.8873898	49.77985759	57.0366253		Average	26.55023	32.19811061	35.43638
5	Best	47.5014747	49.77985759	52.3893022	30	Best	8.838872	32.19811061	30.12907
	Worst	50.2928413	49.77985759	61.9875689		Worst	30.19587	32.19811061	45.52239
	Average	32.3585745	33.52491609	48.6211995		Average	24.74755	30.41894398	32.71587
10	Best	31.1219833	33.52491609	46.7707713	35	Best	6.998094	30.41894398	23.05056
	Worst	33.8564685	33.52491609	50.1038932		Worst	30.19587	30.41894398	47.46125
	Average	31.5683742	32.97903696	38.0025621		Average	26.14516	30.44924739	32.34331
15	Best	31.1219833	32.97903696	30.9796836	40	Best	8.838872	30.44924739	17.41168
	Worst	33.3539378	32.97903696	48.8637532		Worst	30.19587	30.44924739	44.73106
	Average	30.8441502	32.33025642	35.5735620		Average	26.57091	31.57320905	33.26625
20	Best	30.1958729	32.33025642	31.5201984	45	Best	8.838872	31.57320905	28.60078
	Worst	31.1219833	32.33025642	39.9768071		Worst	30.19587	31.57320905	39.37630
	Average	27.8919157	32.48186654	36.2688170		Average	18.66109	31.55793560	27.85476
25	Best	20.0606826	32.48186654	30.5976919	50	Best	7.130201	31.55793560	16.78047
	Worst	31.1219833	32.48186654	47.6299961		Worst	30.19587	31.55793560	35.04738

* All distances are given in meters and the case study is solved by using Intel® Core™ i5-4460 CPU @ 3.20 GHz and 8.00 GB Ram.

The importance coefficient of each objective is obtained using Saaty's [21] 1–9 scale. Alternatives consist of the objectives. The objectives are compared by taking into account employees' satisfaction criterion. The summarizing of the importance coefficients' calculation is shown in Table 4.

Table 4. Calculation of each objective's importance coefficient

Hierarchy of objectives' priority		Pairwise matrix of the employee satisfaction			The importance coefficients of each objective
Criterion	Alternatives		Objective 1	Objective 2	
Employee satisfaction	No of bus stop (Objective 1)	Objective 1	1	1/5	0.17
	Total walking distance (Objective 2)	Objective 2	5	1	0.83

The weighted sum method is used to evaluate the total walking distance with the number of bus stop. The total walking distances are determined by selecting minimum value among the three algorithms for each bus stop. Normalization is required to make the values more normal or regular. The number of bus stop value is divided by the maximum one as 50 while the total walking distance value is divided by the maximum one as 2724.7 in shown Table 5. The minimum weighted sum value is obtained by 40 bus stops.

Table 5. Normalized objective values and the results

No of bus stop (NoBS)	Total walking distance (TWD)	Normalized NoBS value	Normalized TWD value	Weighted Sum Method
5	2724.70	0.1	1.0000	0.8500
10	1708.79	0.2	0.6272	0.5560
15	1349.37	0.3	0.4952	0.4627
20	1117.22	0.4	0.4100	0.4084
25	972.95	0.5	0.3571	0.3809
30	859.09	0.6	0.3153	0.3627
35	780.37	0.7	0.2864	0.3553
40	**719.74**	**0.8**	**0.2642**	**0.3535**
45	670.07	0.9	0.2459	0.3549
50	628.33	1.0	0.2306	0.3588

4. Conclusion

In this study, bus stop selection problem is studied to determine a set of bus stops and assign employees to these ones by considering the total walking distance of employees and the number of bus stops. It is applied to this problem a clustering approach by using three artificial intelligence techniques such as k-means, fuzzy c-means and particle swarm optimization. The results analyzed is compared both the current situation and each other. When compared with the current situation, the better results could be achieved by using these three algorithms. The performance of fuzzy c-means is better than the remaining two algorithms. The results are evaluated by using the weighted sum method and the satisfactory walking distance is obtained by 40 bus stops.

Initial population affects the result of the algorithm. Initial populations of these algorithms can be improved by using hybrid approaches and local search algorithms. After clustering, the optimal bus routing can be determined by using with the meta-heuristics approach such as ant colony optimization, genetic algorithm, simulated annealing, tabu search, etc.

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COMBINING GREY-AHP AND GREY-TOPSIS METHODS FOR GREEN SUPPLIER SELECTION

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Abstract *- Increasing awareness of environmental protection and sustainability has made the selection of environmentally conscious suppliers a more crucial task for manufacturing companies. Although several researchers focused on supplier evaluation and selection, studies with a green focus are relatively limited. Traditionally, organizations have considered cost, quality, and service levels as the primary criteria to evaluate the performance of their suppliers. In order to introduce green considerations into the evaluation process, this paper proposes a green supplier evaluation and selection (GSES) method that takes green competencies and environmental performances into account. In order to capture the complexity and the uncertainty of the problem environment, the grey system theory has been utilized. The proposed model employs Grey-AHP method to obtain the weights of the criteria and evaluates the alternatives using Grey-TOPSIS. To demonstrate the functionality of the approach, a case study is conducted on a U.S. based company that manufactures and distributes plastic closures and dispensing systems internationally. The results of the algorithm and a discussion on the findings are provided.*

Keywords*- Green Supplier Selection and Evaluation, Grey System Theory, Grey Analytical Hierarchy Process (AHP), Grey Technique for Order Preference by Similarity (TOPSIS), Multi-Criteria Decision Making.*

1. INTRODUCTION

Increasing awareness regarding environmental pollution and prevention and accompanying governmental legislations resulted in businesses measure and analyze the environmental impacts of their operations. Therefore, Green Supply Chain Management (GSCM) has drawn a growing attention from both researchers and industry professionals. Green supplier selection and evaluation has become one of the major topics that gained attention in GSCM.

Maintaining long term relationships with reliable suppliers is the primary focus of current supply chain management [1, 2]. Lower cost, higher quality and shorter lead times have been the three main criteria in traditional supplier selection and evaluation activities. In recent practices, an additional factor, environmental responsibility [3] has been added to this list, since suppliers today are being prioritized with a stronger emphasis on environmental sustainability.

Green supplier selection and evaluation has been well studied in the literature. In their extensive literature survey, Tozanli et al. [4] reviewed recent studies with the multi-criteria decision making approaches for green supplier selection and evaluation in fuzzy environment. According to Tozanli et al. [4], studies with grey system, a theory derived from grey sets, which copes with both known and unknown information are relatively limited.

Li et al. [5], applied a grey-based decision-making approach to the supplier selection problem. Golmohammadi et al. [6], developed a two-phased grey decision making approach to the supplier selection. Bai and Sarkis [7] utilized grey system and rough set theory for sustainable supplier selection. Bali et al. [8] studied a green supplier selection problem for an automobile company integrating Intuitionistic Fuzzy Set (IFS) and Grey Relational Analysis (GRA). Hashemi et al. [9] developed a grey-based carbon management model for green supplier selection. Furthermore, Hashemi et al. [1] utilized and combined Analytic Network Process (ANP) and GRA for green supplier selection. Dou et al. [10] applied a Grey ANP based methodology to evaluate green supplier development programs selection. Sahu et al. [11] developed a green supplier appraisement platform using grey concepts.

Analytical Hierarchy Process (AHP) and Technique for Order Preference by Similarity (TOPSIS) are two frequently used methods in supplier selection problems. Several studies have been published with different variations and combinations of these two methods [4]. However, to the best of our knowledge, there is no other study that aims at combining Grey Systems, AHP and TOPSIS for green supplier evaluation and selection. With this motivation, this paper proposes a hybrid multi-criteria decision making framework utilizing Grey-AHP and Grey-TOPSIS methods. Theoretical background, problem statement and the proposed methodology are detailed in the following sections. A case study in a U.S. based manufacturing company is provided along with the conclusions and discussion regarding the future research.

2. METHODOLOGY

This study proposes a combined hierarchical approach that combines Grey-AHP and Grey-TOPSIS methods forming a holistic solution methodology for the green supplier selection problem. Grey-AHP is utilized to determine the importance weights of the Customer Requirements (CRs). Following this, Grey-TOPSIS is applied to rank the provided suppliers. Detailed steps of the proposed method is provided in Figure 1.

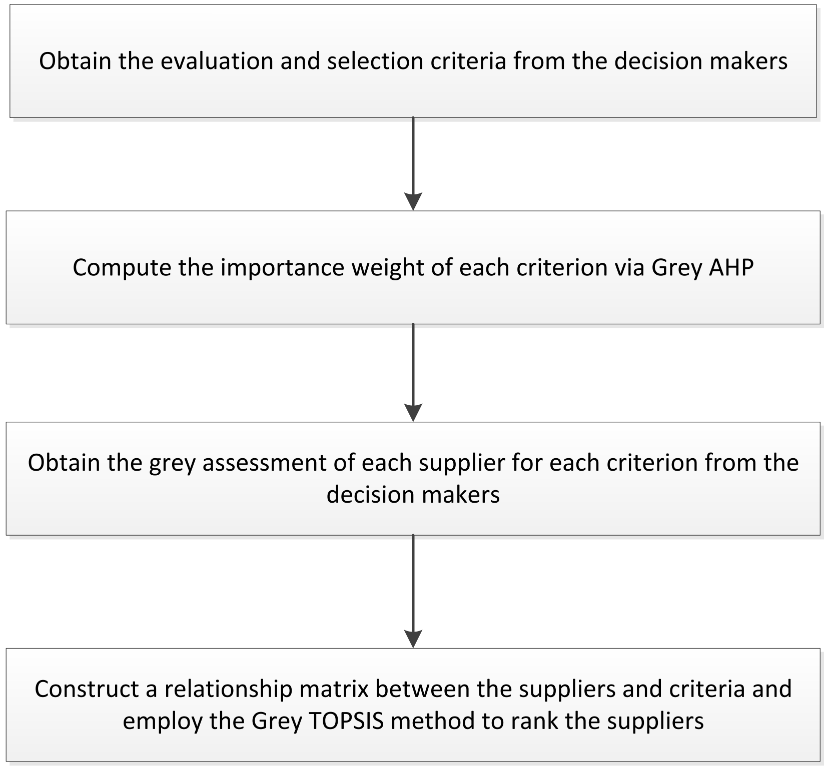

Figure 1. The steps of the proposed methodology

2.1. Grey Systems Theory

Grey systems theory was first introduced by Deng [12] to deal with insufficient and incomplete information. In systems grey theory, if the system information is fully known, the system is called a white system. Similarly, if the information is not known at all, it is called a black system. A system with partially known information is called a grey system. Hence, a grey number is a number with uncertain/incomplete information. A grey number is defined as $\otimes X = [\underline{X}, \overline{X}] = \{X | \underline{X} \leq X \leq \overline{X}, \ \underline{X} \ and \ \overline{X} \ \epsilon \ R\}$. Thus, $\otimes X$ contains two real numbers $\underline{X}$ (the lower limit of $\otimes X$) and $\overline{X}$ (the upper limit of $\otimes X$) is defined as below:

- If $\underline{X} \rightarrow -\infty \ and \ \overline{X} \rightarrow \infty$, then $\otimes X$ is called the black number with no meaningful information,
- Else if $\underline{X} = \overline{X}$, then $\otimes X$ is called the white number with complete information,
- Otherwise $\otimes X = [\underline{X}, \overline{X}]$, $\otimes X$ is called the grey number with insufficient and uncertain information.

Let there are two sets of grey numbers denoted by $\otimes X_1 = \left[\underline{X_1}, \overline{X_1}\right]$ and $\otimes X_2 = \left[\underline{X_2}, \overline{X_2}\right]$. The basic mathematical operations for these two sets of grey numbers are listed below.

$$\otimes X_1 + \otimes X_2 = \left[\underline{X_1} + \underline{X_2}, \overline{X_1} + \overline{X_2}\right] \tag{1}$$

$$\otimes X_1 - \otimes X_2 = \left[\underline{X_1} - \underline{X_2}, \overline{X_1} - \overline{X_2}\right] \tag{2}$$

$$\otimes X_1 * \otimes X_2 = \left[min\left(\underline{X_1}\,\underline{X_2}, \overline{X_1}\,\overline{X_2}, \underline{X_1}\overline{X_2}, \overline{X_1}\,\underline{X_2}\right), max\left(\underline{X_1}\,\underline{X_2}, \overline{X_1}\,\overline{X_2}, \underline{X_1}\overline{X_2}, \overline{X_1}\,\underline{X_2}\right)\right] \tag{3}$$

$$\otimes X_1 : \otimes X_2 = \left[\underline{X_1}, \overline{X_1}\right] * \left[\frac{1}{\overline{X_2}}, \frac{1}{\underline{X_2}}\right] \tag{4}$$

$$k * \otimes X_1 = \left[k\underline{X_1}, k\overline{X_1}\right], \; k \in R \tag{5}$$

$$\otimes X_1^{-1} = \left[\frac{1}{\overline{X_1}}, \frac{1}{\underline{X_1}}\right] \tag{6}$$

2.2. Grey AHP

In order to determine the importance weights of the CRs, Grey-AHP approach is applied. The detailed steps of this approach is provided in the following.

(i) Create a grey decision matrix D where $\otimes X_{ij}$ are linguistic variables. This stage includes the pairwise comparison of the CRs from the decision makers.

$$D = \begin{bmatrix} \otimes X_{11} & \otimes X_{12} & \dots\dots \otimes X_{1n} \\ \otimes X_{21} & \otimes X_{22} & \dots\dots \otimes X_{2n} \\ & \vdots & \\ & \vdots & \\ \otimes X_{m1} & \otimes X_{m2} & \dots\dots \otimes X_{mn} \end{bmatrix} \tag{7}$$

(ii) Normalize the paired comparisons matrix.

$$D^* = \begin{bmatrix} \otimes X_{11}^* & \otimes X_{12}^* & \dots\dots \otimes X_{1n}^* \\ & \vdots & \\ & \vdots & \\ & \vdots & \\ \otimes X_{m1}^* & \otimes X_{m2}^* & \dots\dots \otimes X_{mn}^* \end{bmatrix} = \begin{bmatrix} \left[\underline{X_{11}}^*, \overline{X_{11}}^*\right] & \left[\underline{X_{12}}^*, \overline{X_{12}}^*\right] & \dots\dots \left[\underline{X_{1n}}^*, \overline{X_{1n}}^*\right] \\ & \vdots & \\ & \vdots & \\ & \vdots & \\ \left[\underline{X_{m1}}^*, \overline{X_{m1}}^*\right] & \left[\underline{X_{m2}}^*, \overline{X_{m2}}^*\right] & \dots\dots \left[\underline{X_{mn}}^*, \overline{X_{mn}}^*\right] \end{bmatrix}$$

$$\underline{X_{ij}}^* = \left[\frac{2\underline{X_{ij}}}{\sum_{i=1}^{m}\underline{X_{ij}} + \sum_{i=1}^{m}\overline{X_{ij}}}\right] \tag{8}$$

$$\overline{X_{ij}}^* = \left[\frac{2\overline{X_{ij}}}{\sum_{i=1}^{m}\underline{X_{ij}}+\sum_{i=1}^{m}\overline{X_{ij}}}\right] \tag{9}$$

(iii) Calculate the relative weights of CRs. The relative weights of factors in each level are calculated using normalized paired comparisons matrix according to (10). The calculated weight is (W_i) a Grey number.

$$W_i = \frac{1}{n}\sum_{i=1}^{m}\left[\underline{X_{ij}}^*, \overline{X_{ij}}^*\right] \tag{10}$$

2.3. Grey Topsis

In order to determine the best alternative, Grey-TOPSIS method is utilized. The detailed steps of this method is provided in the following.

(i) Construct a decision matrix R where $\otimes R_{ij}$ are linguistic variables. This stage includes the linguistic assesments of each alternative with respect to each CR from the decision makers.

$$R = \begin{bmatrix} \otimes R_{11} & \otimes R_{12} \dots\dots \otimes R_{1n} \\ \otimes R_{21} & \otimes R_{22} \dots\dots \otimes R_{2n} \\ & \vdots \\ & \vdots \\ \otimes R_{m1} & \otimes R_{m2} \dots\dots \otimes R_{mn} \end{bmatrix} \tag{11}$$

(ii) Normalize the decision matrix. For the benefit type of criteria, (12) is used for the normalization, and for the cost type of criteria (13) is used [13, 14].

$$\otimes r_{ij} = \frac{\otimes R_{ij}}{max_i(\overline{R_{ij}})} = \left(\frac{\underline{R_{ij}}}{max_i(\overline{R_{ij}})}, \frac{\overline{R_{ij}}}{max_i(\overline{R_{ij}})}\right) \tag{12}$$

$$\otimes r_{ij} = 1 - \frac{\otimes R_{ij}}{max_i(\overline{R_{ij}})} = \left(1 - \frac{\overline{R_{ij}}}{max_i(\overline{R_{ij}})}, 1 - \frac{\underline{R_{ij}}}{max_i(\overline{R_{ij}})}\right) \tag{13}$$

(iii) Determine the positive ideal alternative (A^+) and the negative ideal alternative (A^-)

$$A^+ = \left\{(\max_i \overline{r_{ij}} \mid j \in J'), (\min_i \underline{r_{ij}} \mid j \in J'')\right\} = \{r_1^+, \dots\dots, r_m^+\} \tag{14}$$

$$A^- = \left\{(\min_i \underline{r_{ij}} \mid j \in J', (\max_j \overline{r_{ij}} \mid j \in J'')\right\} = \{r_1^-, \dots\dots, r_m^m\} \tag{15}$$

where J' is associated with benefit criteria and J'' is associated with cost criteria. Using (13) as the normalization operator, a cost type of criterion is converted to a benefit type of criterion. Hence, the cost criteria could be handled as benefit criteria.[13]

(iv) Compute the distance of each alternative from A^+ and A^- using (16) and (17). In these equations W_i represents the weight of each criterion calculated in Grey-AHP.

$$d_i^+ = \sqrt{\frac{1}{2}\sum_{j=1}^{m} W_i \left(\left|r_j^+ - \underline{r_{ij}}\right|^2 + \left|r_j^+ - \overline{r_{ij}}\right|^2\right)} \quad (16)$$

$$d_i^- = \sqrt{\frac{1}{2}\sum_{j=1}^{m} W_i \left(\left|r_j^- - \underline{r_{ij}}\right|^2 + \left|r_j^- - \overline{r_{ij}}\right|^2\right)} \quad (17)$$

(v) Compute the closeness coefficient (CC_i) of each alternative

$$CC_i = \frac{d_i^-}{d_i^- + d_i^+} \quad (18)$$

(vi) Rank the alternatives according to the closeness coefficient, CC_i, in decreasing order.

4. CASE STUDY IN DISPENSING SYSTEMS INDUSTRY

The case study is conducted in a leading global manufacturer and distributor of dispensing systems for beauty and personal care in addition to home and consumer health care needs. The U.S. based manufacturing company uses plastics as one of its major raw materials. The study focused on evaluating and selecting supplier(s) of plastics used in the plastic injection molding of innovative dispensing pumps. In order to select the best alternative, thirteen potential suppliers were evaluated according to their performance using eight decision criteria. The evaluation was conducted based on the linguistic judgements of decision makers in the company. The criteria were defined by these experts are given in Table 1 follows:

Table 1. Criteria and their definitions

Criteria	Definition
Cost	A measure related to the order and purchasing cost of the raw material for manufacturing.
Quality	A measure related to the quality of the raw material obtained from the suppliers and its performance in molding and injection processes.
Logistics Operations	A measure related to the service level of transportation and warehousing, on time and full delivery performance operations of the suppliers.
Service Level	A measure related to the response time to customer requests, flexibility and past customer service performance of each supplier.
Financial Position	A measure related to the financial strengths of each supplier for continuous business.
Organization	A measure related to the company size of the supplier, business existence and continuity in industry.
Continuous Improvement	A measure related to the continuous improvement in product capability of suppliers, R&D activities and operational efficiencies.

Green image	A measure related to the energy, waste and natural resources reduction performance of suppliers and environmental policies.

Given the set of above criteria, the decision makers are asked to rank their preference levels for each criterion. Following this, in order to prioritize the green image in the supplier evaluation process, a Grey AHP approach is employed. The evaluation scale used in Grey AHP is provided in Table 2.

Table 2. Comparative linguistic scale for ratings of alternatives and weights of criteria

Linguistic Terms	Grey Numbers
Just equal – [EQ]	[1,1]
Weak importance of one over another – [WI]	[1,3]
Fairly Preferable – [FP]	[3,5]
Strongly Preferable – [SP]	[5,7]
Absolutely Preferable – [AP]	[7,9]
In the pairwise comparison matrix, the value of each criterion *j* compared to criterion *i* is calculated as the reciprocal of the value of criterion *i* compared to criterion *j*	

The data obtained from the decision makers for pairwise comparison is provided in Table 3.

Table 3. Pairwise comparison of criteria collected from decision makers via linguistics terms

Criteria	**Cost**	**Quality**	**Service Level**	**Logistics**	**Financial Position**	**Organization**	**Continuous Improvement**	**Green Image**
Cost	EQ	1/WI	FP	FP	WI	AP	SP	1/FP
Quality	WI	EQ	WI	FP	FP	FP	WI	1/WI
Service Level	1/FP	1/WI	EQ	WI	WI	WI	EQ	1/FP
Logistics	1/FP	1/FP	1/WI	EQ	WI	WI	EQ	1/FP
Financial Position	1/WI	1/FP	1/WI	1/WI	EQ	WI	WI	1/SP
Organization	1/AP	1/FP	1/WI	1/WI	1/WI	EQ	1/WI	1/AP
Continuous Improvement	1/SP	1/WI	EQ	EQ	1/WI	WI	EQ	1/FP
Green Image	FP	WI	FP	FP	SP	AP	FP	EQ

The weights of the main criteria are obtained by applying (7) to (10) and the results are presented in Table 4.

Table 4. Weights of the main criteria

Criteria	Weights
Cost	[0.151,0.240]
Quality	[0.122,0.246]
Service Level	[0.050,0.097]
Logistics	[0.044,0.083]
Financial Position	[0.039,0.087]
Organization	[0.025,0.050]
Continuous Improvement	[0.050,0.094]
Green Image	[0.240,0.383]

The weights of the criteria are used as an input in Grey-TOPSIS method to evaluate the suppliers. Additional inputs are the grey evaluations of the suppliers with respect to each criterion. These are obtained from the decision makers in the company using linguistic terms.

Table 5. Linguistic scale to evaluate the ratings of the suppliers

Linguistic Terms for TOPSIS	Grey Numbers
Very low - [VL]	[0,1]
Low - [L]	[1,3]
Medium - [M]	[3,5]
High - [H]	[5,7]
Very High - [VH]	[7,9]

The evaluation data of each supplier with respect to each criterion obtained from the decision makers are provided in Table 6.

Table 6. Linguistic ratings of each supplier with respect to each criteria

	Cost	Quality	Service Level	Logistics
Supplier 1	M	VH	L	M
Supplier 2	L	H	L	H
Supplier 3	H	VL	M	H
Supplier 4	VH	H	L	L
Supplier 5	L	M	H	VL
Supplier 6	H	M	M	M
Supplier 7	M	H	VH	VH
Supplier 8	L	M	M	H
Supplier 9	M	VH	H	VL

Supplier 10	L	VL	H	M
Supplier 11	M	M	VL	M
Supplier 12	H	L	VH	L
Supplier 13	M	L	L	VH
	Financial Position	**Organization**	**Continuous Improvement**	**Green Image**
Supplier 1	H	VH	H	H
Supplier 2	L	H	VL	VH
Supplier 3	H	VL	L	H
Supplier 4	L	M	H	M
Supplier 5	VL	VH	H	VH
Supplier 6	H	VL	H	M
Supplier 7	L	H	M	L
Supplier 8	M	L	H	M
Supplier 9	VH	VH	M	M
Supplier 10	H	L	H	M
Supplier 11	L	H	L	H
Supplier 12	VL	VH	M	VH
Supplier 13	M	L	M	L

The normalized grey decision matrix is obtained via using (11) and (12) and presented in Table 7. In our study, the first criterion is defined as the cost criteria and the others are defined as the benefit criteria.

Table 7. The normalized grey decision matrix

	Cost	**Quality**	**Service Level**	**Logistics**
Supplier 1	[0.444,0.667]	[0.778,1]	[0.111,0.333]	[0.333,0.556]
Supplier 2	[0.667,0.889]	[0.556,0.778]	[0.111,0.333]	[0.556,0.778]
Supplier 3	[0.222,0.444]	[0,0.111]	[0.333,0.556]	[0.556,0.778]
Supplier 4	[0,0.222]	[0.556,0.778]	[0.111,0.333]	[0.111,0.333]
Supplier 5	[0.667,0.889]	[0.333,0.556]	[0.556,0.778]	[0,0.111]
Supplier 6	[0.222,0.444]	[0.333,0.556]	[0.333,0.556]	[0.333,0.556]
Supplier 7	[0.444,0.667]	[0.556,0.778]	[0.778,1]	[0.778,1]
Supplier 8	[0.667,0.889]	[0.333,0.556]	[0.333,0.556]	[0.556,0.778]
Supplier 9	[0.444,0.667]	[0.778,1]	[0.556,0.778]	[0,0.111]
Supplier 10	[0.667,0.889]	[0,0.111]	[0.556,0.778]	[0.333,0.556]
Supplier 11	[0.444,0.667]	[0.333,0.556]	[0,0.111]	[0.333,0.556]
Supplier 12	[0.222,0.444]	[0.111,0.333]	[0.778,1]	[0.111,0.333]
Supplier 13	[0.444,0.667]	[0.111,0.333]	[0.111,0.333]	[0.778,1]
	Financial Position	**Organization**	**Continuous Improvement**	**Green Image**
Supplier 1	[0.556,0.778]	[0.778,1]	[0.556,0.778]	[0.556,0.778]
Supplier 2	[0.111,0.333]	[0.556,0.778]	[0,0.111]	[0.778,1]

Supplier 3	[0.556,0.778]	[0,0.111]	[0.111,0.333]	[0.556,0.778]
Supplier 4	[0.111,0.333]	[0.333,0.556]	[0.556,0.778]	[0.333,0.556]
Supplier 5	[0,0.111]	[0.778,1]	[0.556,0.778]	[0.778,1]
Supplier 6	[0.556,0.778]	[0,0.111]	[0.556,0.778]	[0.333,0.556]
Supplier 7	[0.111,0.333]	[0.556,0.778]	[0.333,0.556]	[0.111,0.333]
Supplier 8	[0.333,0.556]	[0.111,0.333]	[0.556,0.778]	[0.333,0.556]
Supplier 9	[0.778,1]	[0.778,1]	[0.333,0.556]	[0.333,0.556]
Supplier 10	[0.556,0.778]	[0.111,0.333]	[0.556,0.778]	[0.333,0.556]
Supplier 11	[0.111,0.333]	[0.556,0.778]	[0.111,0.333]	[0.556,0.778]
Supplier 12	[0,0.111]	[0.778,1]	[0.333,0.556]	[0.778,1]
Supplier 13	[0.333,0.556]	[0.111,0.333]	[0.333,0.556]	[0.111,0.333]

The positive ideal alternative (A^+) and the negative ideal alternative (A^-) are calculated using (14) and (15). In our study, the first criterion is defined as the cost criteria and the others are defined as the benefit criteria. For instance, for the criterion Quality, the maximum value of the upper limit is 1 and the lowest value at the lower limit is equal to 0, so that the positive ideal value is set to 1 and the negative ideal value is determined as 0. The distances d^+ and d^- of the each supplier evaluation ratings from A^+ to $A^-$are calculated via (16) and (17). The closeness coefficient, CC_i is computed via (18) and supplier ranking summary is provided in Table 8. The highest closeness coefficient determines the highest rank, implying that Supplier 2 is the best alternative, followed by Supplier 5, 1, 12, 9, 11, 8, 3, 4, 6, 7, 10 and finally, Supplier 13.

Table 8. Ranking of suppliers

Suppliers	**d+**	**d-**	**CC**	**Rank**
Supplier 1	0.361	0.432	0.545	3
Supplier 2	0.342	0.479	0.584	1
Supplier 3	0.476	0.325	0.406	8
Supplier 4	0.477	0.299	0.386	9
Supplier 5	0.365	0.465	0.561	2
Supplier 6	0.471	0.284	0.376	10
Supplier 7	0.510	0.301	0.372	11
Supplier 8	0.453	0.320	0.414	7
Supplier 9	0.425	0.378	0.470	5
Supplier 10	0.506	0.294	0.367	12
Supplier 11	0.420	0.355	0.458	6
Supplier 12	0.414	0.428	0.508	4
Supplier 13	0.560	0.217	0.279	13

4. CONCLUSIONS AND DISCUSSION

AHP and TOPSIS methods are both well known and well studied in multi criteria decision making problems. However, these methods are not applied jointly to solve the green supplier evaluation and selection problem using grey numbers.

In this paper, Grey-AHP is applied to determine the weights of the decision criteria and Grey-TOPSIS is applied to rank the alternatives. In order to demonstrate effectiveness of the proposed approach, the method is then applied to a U.S. based dispensing systems manufacturing company. Eight criteria are determined by the experts along with the linguistic assesments of the poatntial suppliers with respect to each criterion. Eventually, based on this information, the rankings of the suppliers are obtained via the proposed approach.

Grey theory is an effective method when dealing with systems with uncertain information. In grey theory, a system is called “white” if related information is fully known and available, and “black” if the information is unknown and/or not available. Similarly, a system with partial information is called a “grey” system [5].

Grey sets are sometimes perceived as an extension of interval valued fuzzy sets [15-17] with additional advantages over fuzzy systems [1, 17]. Similar to fuzzy theory, grey theory is appropriate for problems with some levels of uncertainty and indetermination. This multidisciplinary and generic theory deals with systems characterized by poor information and/or systems where information is lacking [18]. One of the main factors which make grey theory more advantageous is its ability to consider the condition of the fuzziness and its flexibility when dealing with fuzziness situation [5]. Daisuke et al. [15] argue that even though the grey sets are based on the mapping of fuzzy sets, grey theory allows the introduction of strict values for upper and lower limits whereas fuzzy theory considers those boundaries as fuzzy values. Furthermore, Baskaran et al. [19] stated that in fuzzy approach, the initial representation of criteria would be in fuzzy linguistic values later to be converted into known exact values, while in grey approach, the uncertainty represented in criteria using linguistic values would continue until the estimation of weights and evaluation of alternatives. Supplier selection problem often requires methodologies which are able to handle multiple selection criteria and uncertainty in the model environment making grey theory a very suitable methodology for such problems. As a result, several approaches utilizing fuzzy and grey sets have been proposed to deal with supplier selection problems. A comparative analysis of fuzzy and grey sets in addition to conventional methods and rough sets is provided in Table 9. For additional criteria and further information please see [15].

Table 9. The comparison of classic, fuzzy, grey and rough sets (Partially adopted from[15])

	Classic	**Fuzzy**	**Grey**	**Rough**
Objective	Elucidate property of population	Knowledge expression	Automatic systems control	Knowledge discovery in databases
Uncertainty	Probabilistic events	Degree of cognition	Lack information situation	Conflict between certainty and possibility
Data-type	Observed real values	Real values of membership	Observed real values and interval values	Observed real values and nominal values
Data distribution	Typical distribution-Required in advance	Membership function-Experience	Any distribution-Non-parametric	Any distribution-Non-parametric
Operation	Set or Boolean algebra	Max/Min Selection	Interval Algebra	Set Algebra
Crisp-Conversation	Unnecessary	α-cuts: collection of high membership elements	Whitening Function: Compute one point from interval	*Apr*(X)=Apr(X)* No boundary region state

Grey systems is gaining popularity in the literature due to its ability to cope with uncertainty. In their literature survey, Tozanli et al. [4] stated that the total number of fuzzy articles incorporating grey theory has increased significantly over the past five years. In this study, the decision makers found grey system theory to be a better fit considering its various advantages and utilized grey numbers for the ratings of attributes which were initially expressed using linguistic variables.

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A PARALLEL VARIABLE NEIGHBORHOOD SEARCH BASED SOLUTION APPROACH TO DESIGN THE SERVICE NETWORK FOR A BEVERAGE DISTRIBUTION COMPANY

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Abstract *– The heterogeneous fixed fleet vehicle routing problem (HFFVRP), a more practical variant of vehicle routing problem (VRP), is commonly put into practice in designing beverage, food or dairy distribution network. HFFVRP assumes that the fleet owner has various types and fixed number of vehicles carrying through the delivery operations by visiting all clients at once with the aim of minimizing the total travel distance. In this study, since the problem is NP-hard, a parallel strategy based on variable neighborhood search methodology that utilize savings heuristic and various neighborhood strategies has been adapted to solve HFFVRP. Computational results of well-known benchmark instances confirm the effectiveness of the solution approach. Furthermore, a case study from the beverage industry has been solved under different assumptions. Results indicate the potential of enabling the decision maker to make effective decisions related to design of transportation networks.*

Keywords *– Vehicle routing, heterogeneous fixed fleet, variable neighborhood search*

INTRODUCTION

The distribution of goods is one of the main problems that affect final prices, customer satisfaction, resources of companies and sustainability in the transportation industry. A good distribution system can save company resources. The Vehicle Routing Problem (VRP) [1] is an important problem for providing efficient distribution system whose applications can be seen various real-life problems, such as school bus routing, cargo deliveries, waste recycling routing etc. In this problem, a number of vehicles leaves from a central depot, serve demands of a number of clients in different locations and return to central depot after visiting all clients once with the aim of the minimum total distance. Since the first papers, heterogeneous fleets where the vehicles have different characteristics, plays an important role in development of the related literature.

The VRP with heterogeneous fleet (HFVRP) can be basically categorized into two classes. Fleet size and mixed VRP (FSMVRP) is the first class where the number of vehicles from each type are unlimited. This problem have common application area when the fleet is not yet purchased and choosing the number of vehicles has to be determined. Heterogeneous fixed fleet VRP (HFFVRP) is the second type in which the number of vehicles of each type was fixed in the fleet. This problem is generally called for operational decisions for determining the optimal routes for already contracted customers and assigning vehicles on hand to these routes.

In this study, The HFFVRP is investigated and daily distribution problem of an international beverage company's local dealer is examined as a case study with industry specific constraints. The problem taken into account as HFFVRP with time limit since the fleet is already purchased and all clients have to be served in a preliminary defined time limit restriction.

In the literature, various studies examined the beverage distribution problem as a special application of VRP. Golden and Wasil [2] present a vehicle routing software in the soft drink soft drink products where the delivery of products that have been ordered in advance by customers, and the delivery of soft drink products that are sold by drivers. Cheong, Ong [3] presented a VRP model with fixed fleet of heterogeneous vehicles for a soft drink distribution company. A two phase solution approach (first assign, then route) has been developed to solve the daily VRP. Hoff and Løkketangen [4] considered traveling salesman problem with pickup and delivery (TSPPD). A number of benchmark instances and a case study for breweries where they deliver bottles of beer or mineral water and collects empty bottles are solved with developed tabu search algorithm. Privé, Renaud [5] handled the problem with the distribution of soft drinks and collection of recyclable containers as FSMVRP with time windows. The authors proposed three construction heuristics with an improvement

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procedure and achieved a 23% distance reduction on the real-life case. Kant, Jacks [6] optimized the routes of Coca-Cola enterprise with number of vehicle, vehicle capacity and maximum working time constraints. Their cluster and route based approach studies result in $45 million in annual transportation cost savings in overall enterprise. Zeng, Ong [7] proposed two alternative methods for solving a real-life soft drink distribution problem by considering maximum driving time or distance per day and loading/unloading time. Demir, Van Woensel [8] handled the problem in a multi-depot system with the speed, distance and vehicle related costs for distribution of frozen foods and soft drinks. Kramer, Subramanian [9] addressed a case study in a beverage industry and modeled problem as heterogeneous limited fleet VRP where the distances are asymmetric. A locals search and variable neighborhood descent (VND) heuristic adopted by the authors to solve case study. Jalel and Sana [10] presented a specific variant of VRP with simultaneous full pick- up and delivery problem VRPSFPD and applied it in real case of distribution of soft drink. In order to solve this problem, the authors developed a genetic algorithm and VND based hybrid algorithm.

Since exact solution approaches for solving HFFVRP problems are not practical for large-scale instances and solving the HFFVRP is more difficult than the classical VRP and FSMVRP, heuristic and metaheuristic based approaches have been proposed to solve the problem in the literature [11]. In this study, we therefore used a parallel strategy based on variable neighborhood search (VNS) methodology that utilize savings heuristic and various neighborhood strategies to solve the problem. Well-known benchmark instances from HFFVRP have been solved and performance of the algorithm has been compared with ones existing in the literature. After providing effective solutions for the instances, a real life case study from the beverage industry has been solved with alternative scenarios. The rest of paper is organized as follows: In Section 2, the parallel variable neighborhood search algorithm is proposed. Section 3 presents the details of benchmark problems and computational results. Section 4 presents environment of the case study and numerical results. Finally, conclusions are drawn and suggestions for further research are given in last section.

THE PROPOSED METHODOLOGY

The proposed algorithm consists of an adaptation of the Cooperative VNS presented by Polat [12]. The basic VNS use the impression of systematically changing the neighborhoods to explore the solution space which can not been searched by local search [13-15]. The VNS implements shaking, local search and move or not steps to improve current solution (Figure 1).The search direction of the VNS is defined by the shaking operator with the help of a set of neighborhood structures. Combination of the shaking operator with local search improves the opportunity of reaching a global solution compare to employ a single shaking operator. The variable neighbourhood search (VNS) approach is very efficient solution approach for the VRP variants [12, 14, 16-20].

Initialization: Construct an initial solution x
Set $k \leftarrow 1$
Loop: repeat following steps until stopping condition is satisfied
Shaking: Select a solution x' from kth neighborhood structure of solution x, N_k (k=1,2,…k-max)
Local search: Apply the local search with solution x' as initial solution and obtain incumbent solution x''
Move or not: If *x'' is better than x, set* $x \leftarrow x''$ and $k \leftarrow 1$; otherwise, set $k \leftarrow k+1$

Figure 1. The Phases of the Basic VNS

In this study, we used "asynchronous cooperation with a centralized information exchange strategy" offered by Polat [12] in the parallelization of the VNS approach. The according to the three-dimensional taxonomy of Crainic and Hail [21], this strategy could be classified as *pC*/*C*/*MPSS*. *pC* (p-Control) represents the global search, which is distributively controlled by several processes, *C* (Collegial) represents the data exchanged as asynchronously collegial and *MPSS* (Multiple initial Points, Same search Strategies) represents VNS approaches starting from different initial points and using the same neighborhood combinations and sequences. Algorithmic parameters and shaking, local search and permutation parameters are used as it suggested by [12].

NUMERICAL RESULTS

The proposed CVNS is coded using MATLAB R2013b/Visual C++ 2010 and executed on a computer with two Intel Xeon E5420 – 2.50 GHz Intel processors (4 core) 8 GB RAM. The parallelization of the CVNS algorithm is performed using six cores along with one user interface processor core. The performance of the proposed algorithm is tested using a benchmark problem set for the HFFVRP from Taillard [22]. This problem set includes 8 problem instances, numbered from 13 to 20, in which client numbers vary between 50 and 199. Each instance set have different vehicle types (A to F) that has different capacity and

The performance tests has been carried out on HFFVRP benchmark instances of Taillard (1999) that contained eight problems, numbered from 13 to 20 (Table 1). These problems were built of 50–100 nodes including the depot. There are no route-length restrictions and no customer service times.

Table 1. Characteristics of HFFVRP Benchmark Instances

		A			B			C			D			E			F			Ratio
Inst.	*n*	*Q*	α	*k*	*Q*	α	*k*	*Q*	α	*k*	*Q*	α	*k*	*Q*	α	*k*	*Q*	α	*k*	%
13	50	20	1.00	4	30	1.10	2	40	1.20	4	70	1.70	4	120	2.50	2	200	3.20	2	95.39
14	50	120	1.00	4	160	1.10	2	300	1.40	1										88.45
15	50	50	1.00	4	100	1.60	3	160	2.00	2										94.76
16	50	40	1.00	2	80	1.60	4	140	2.10	3										94.76
17	75	50	1.00	4	120	1.20	4	200	1.50	2	350	1.80	1							95.38
18	75	20	1.00	4	50	1.30	4	100	1.90	2	150	2.40	2	250	2.90	1	400	3.20	1	95.38
19	100	100	1.00	4	200	1.40	3	300	1.70	3										76.74
20	100	60	1.00	6	140	1.70	4	200	2.00	3										95.92

Inst.: Instance number; *n*: number of customers; *Q* capacity of related vehicle type; *α*: variable cost per unit distance of related vehicle type; *k*: available number of related vehicle type; Ratio: 100 × (total demand/total capacity).

The proposed CVNS algorithm was run ten times with the same seed sets for each parameter combination. The results obtained from the proposed CVNS approach on the HFFVRP benchmark instances were compared with the heuristic approaches found in the literature. Taillard [22] proposed heuristic column generation (HCG) based on tabu search (TS) algorithm, Tarantilis, Kiranoudis [11] proposed backtracking adaptive threshold accepting (BATA) algorithm, Tarantilis, Kiranoudis [23] proposed list based threshold accepting (LBTA) metaheuristic, Li, Golden [24] proposed record-to-record travel (HRTR) algorithm, Prins [25] proposed population management based memetic algorithm with alternative search policies (SMA-D2), Li, Tian [26] proposed multistart adaptive memory programming (MAMP) metaheuristic, Brandão [27] proposed TS algorithm, Naji-Azimi and Salari [28] proposed integer linear programming based (ILP) improvement heuristic, Penna, Subramanian [29] proposed iterated local search metaheuristic which uses a variable neighborhood descent procedure (ILS-RVND) and Subramanian, Penna [30] extended ILS-RVND algorithm with a set partitioning (SP) formulation (ILS-RVND-SP). In Table 2, total distance of solutions (*d*), average solution for eight instance (*Avg d*) and average computation times for eight instance (*Avg t*). Average solution (*ad*) and computational time (*t*) for the CVNS are also given in this table. Overall best solutions of each problem instance are highlighted in bold.

Table 2. Computational Results for HFFVRP Benchmark Instances

	HCG [22]	BATA [11]	LBTA [23]	HRTR [24]	SMA-D2 [25]	MAMP [26]	TS [27]	ILP [28]	ILS-RVND [29]	ILS-RVND-SP [30]	CVNS (This study)		
Inst.	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*d*	*ad*	*t*
13	1518.05	1519.96	1519.96	**1517.84**	**1517.84**	1525.09	**1517.84**	**1517.84**	**1517.84**	**1517.84**	**1517.84**	1517.84	35.12
14	615.64	612.61	611.39	**607.53**	**607.53**	**607.53**	**607.53**	**607.53**	**607.53**	**607.53**	**607.53**	607.53	35.26
15	1016.86	1017.94	**1015.29**	**1015.29**	**1015.29**	**1015.29**	**1015.29**	**1015.29**	**1015.29**	**1015.29**	**1015.29**	1015.29	41.51
16	1154.05	1148.19	1145.52	**1144.94**	1144.94	1178.96	**1144.94**	**1144.94**	**1144.94**	**1144.94**	**1144.94**	1144.94	62.67
17	1071.79	1071.67	1071.01	**1061.96**	1065.85	**1061.96**	**1061.96**	**1061.96**	**1061.96**	**1061.96**	**1061.96**	1061.96	43.28
18	1870.16	1852.13	1846.35	**1823.58**	**1823.58**	**1823.58**	1831.36	1837.39	**1823.58**	**1823.58**	**1823.58**	1823.58	91.45
19	**1117.51**	1125.64	1123.83	1120.34	1120.34	1120.34	1120.34	1120.34	1120.34	1120.34	1120.34	1120.88	134.2
20	1559.77	1558.56	1556.35	**1534.17**	**1534.17**	**1534.17**	**1534.17**	1556.32	**1534.17**	**1534.17**	**1534.17**	1534.17	89.43
Avg *d*	1240.48	1238.34	1236.21	1228.21	1228.69	1233.37	1229.18	1232.70	1228.21	1228.21	1228.21	1228.27	
Avg *t*	2011.13	222.63	607.13	285.75	94.76	130.38	151.63	14.39	31.89	4.03	66.61		

Inst.: Instance number; *n*: number of customers; *Q* capacity of related vehicle type; *α*: variable cost per unit distance of related vehicle type; *k*: available number of related vehicle type; Ratio: 100 × (total demand/total capacity).

When the results of CVNS algorithm compared with the reference solutions from literature, it can be seen that proposed algorithm reaches the best known solution for 7 out of 8 problem instances. For the remaining one instance, the gap between the results of the CVNS and the best-known solution is around 0.25%. Considering HFFVRP benchmark instances of Taillard [22], it that can be drawn that the CVNS algorithm provides adequate solutions in reasonable time. Therefore, proposed algorithm is used to solve daily distribution problem of an international beverage company's local dealer with industry specific constraints.

CASE STUDY

In this study daily distribution problem of an international beverage company's local dealer is considered. The company is located in Denizli, Turkey and distributes various types and sizes of beverages including carbonated soft drink, mineral water, soda and fruit juice. These beverages are produced in one of the regional factories in Turkey and delivered to this local dealer. Local dealer is responsible from storage of beverage products in a depot and distribution of them to local shops, markets, cafes and restaurants. Because of the local and the global competition in this sector, the company is forced to decrease the transportation cost and time while meeting demand of the customer.

In the case study, the sales representatives of the dealer collect demands of the customers by site visiting and enter these demands to the software of the global company via hand terminals. At the end of each day, the decision maker used the software to design daily distribution network. The dealer has around 300 customers, however, number of customers that have to be visited changing in each service day due to daily demands. The company owns seven trucks in different sizes. One truck's capacity is 6500 kg, three trucks' capacity is 8000 kg and remaining three trucks' capacity is 9000 kg. These are decreased capacities due to size and volume differences of the beverages. Therefore, route plans made according to total weight of customer's demand. Since most of the bottles are plastic, can, carton and non-returnable bottles, the number of backhaul returnable bottle is very limited. Therefore, backhauls from customers are not considered, since longhaul demand always much more than backhaul demand. The trucks starts their routes from a central depot located in district of Denizli and return to the same depot at the end of the day after visiting all assigned customers. The demands are known and cannot be divided.

In our investigation, the travel durations between locations are obtained from Google Distance Matrix API by considering traffic congestions. Therefore, we used asymmetric durations between locations which means the ongoing and returning duration between two location is usually not identical. The aim is minimizing total travel durations by the fleet in each planning day. The demand of a preliminary selected day that has 242 customers obtained and solved with proposed CVNS algorithm. Results are compared with results provided by global company's software. Table 3 presents current distribution network provided by global company's software for selected day.

Table 3. Current Distribution Network

Route	Truck type	Truck capacity (kg)	Total load (kg)	Total travel duration (m)	Total duration with service time (min)	Total duration time with lunch break (min.)	Route start time	Route end time
1	1	6500	5185.60	23.25	463.85	523.85	09:30	18:13
2	2	8000	6241.10	47.01	561.31	621.31	09:30	19:51
3	3	9000	4293.70	28.05	574.05	634.05	09:30	20:04
4	3	9000	3668.00	33.54	372.34	432.34	09:30	16:42
5	2	8000	7227.30	31.31	549.51	609.51	09:30	19:39
6	3	9000	3402.00	43.40	300.70	360.70	09:30	15:30
7	2	8000	5524.30	26.64	518.34	578.34	09:30	19:08
		Total	35542.10	**233.21**	3340.11	3760.11		

The total travel duration of the current network is 233.21 minutes and there are unbalanced durations between routes that may demonstrate problems within drivers. The total duration of Route 2, 3 and 4 are also more than legal daily single driver limitations (540 minutes) which require assignment of second driver.

Then, soft time limit (540 minutes) and hard time limit (600 minutes) restrictions on total route limitation is implemented and problem is converted to HFFVRP with time limit (HFFVRPTL). The routes are allowed to pass soft time limit constraint but slightly penalized, but exceeding hard time limit is not allowed. Table 4 presents results with the HFFVRPTL restrictions.

Table 4. Proposed Distribution Network with the HFFVRPTL Restrictions

Route	Truck type	Truck capacity (kg)	Total load (kg)	Total travel duration (m)	Total duration with service time (min)	Total duration time with lunch break (min.)	Route start time	Route end time
1	1	6500	5037.90	16.53	442.18	502.18	09:30	17:52
2	2	8000	5470.30	41.72	523.72	583.72	09:30	19:13
3	3	9000	1780.10	17.42	255.37	315.37	09:30	14:45
4	3	9000	5218.00	33.35	519.35	579.35	09:30	19:09
5	2	8000	6988.40	29.78	536.58	596.58	09:30	19:26
6	3	9000	6237.40	37.58	512.88	572.88	09:30	19:02
7	2	8000	4810.00	28.22	505.82	565.82	09:30	18:55
		Total	35542.10	**204.60**	3295.90	3715.90		

When the time limit restrictions are implemented, total route durations is decreased around 14% compared to the current network of the company by providing more balanced and near legal route durations. On the other hand, this result include less truck usage ratios that result of domination of time limit restrictions to truck capacity constraint.

CONCLUSION

In this paper, we used a parallel variable neighborhood search approach to solve the heterogeneous fixed fleet vehicle routing problem. From the numerical results, it can be concluded that the proposed CVNS algorithm generates efficient solutions compared to existing solution methods for the heterogeneous fixed fleet vehicle routing problem (HFFVRP). For 7 out of the 8 benchmark instances from Taillard [22], the CVNS algorithm is able to reach the best known solutions. After obtaining efficient solutions for HFFVRP benchmark instances in reasonable time, a case study from beverage industry has been solved. The obtained results were compared with company's own solution. The proposed algorithm provide very efficient solutions compare to current distribution network of the company. The proposed results are not only efficient but also more balanced and legal limits in terms of drivers' total durations on route including traveling and service time. The proposed parallel algorithm could be used a variety of other vehicle routing problems.

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BUSINESS INTELLIGENCE SYSTEM SELECTION FOR LOGISTICS COMPANIES

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Abstract *− Organizations in today's competitive markets are forced to implement new and advanced technical tools to add value to their businesses. Business Intelligence (BI) is one of the important and popular tools nowadays, which is a set of methodologies, processes, architectures, and technologies that enable the processing of large amounts of data and their transformation into a high-quality and useful information and knowledge. BI is applied in all logistics systems for monitoring performance and business processes, receiving reports on systems operation and analysis of business indicators. The selection and implementation of such systems can be very challenging. In this study, a SWOT-based Multi Criteria Decision Making (MCDM) methodology is proposed for solving the effective BI selection problem. Analytic Hierarchy Process (AHP) is applied to find the weights of each defined SWOT factors based on wide literature survey and experts' opinion. Finally, the optimal BI alternative is selected from different alternative BI vendors (SAP, Oracle, Microsoft, SAS etc.) with VIKOR method. A case study is provided in order to demonstrate the potential of the proposed approach. Obtained results are interpreted and their plausibility is discussed.*

Keywords − Business intelligence, Logistics sector, SWOT, MCDM, AHP, VIKOR

INTRODUCTION

Today's business in logistics sector has different dimensions on which any organization get the unique place in the eyes of customers. Business Intelligence (BI) is one of the important subjects nowadays. BI is the software business tool which is integrated with different modules like Human Resources (HR), marketing, sales, finance etc. BI helps the organizations to provide flowing the business data among the different departments as a common entity [1].

Every department in logistics sector can have exact and accurate data without having the interaction with individuals of different organizations through BI. Owing to huge investment on enterprise resource planning (ERP), supply chain management (SCM), customer relationship management (CRM), and product lifecycle management (PLM), enterprise software selection has become much more important than before [9]. In particular, choosing software platform is quite different from buying products or services in many ways because the software needs to be ''maintained'', ''updated'', and ''repaired'' [10,11]. There are some differences between various types of software solutions because of their serves of purpose. ERP software provides integration of the important parts of company's business which it manages, while CRM software aims to improve company's business relationships with customers by managing and analyzing customer interactions and data. Business Analytics (BA) and BI have similar functions as using statistical analysis, data mining and quantitative analysis to identify past business trends, however, BA realizes predictive modeling by using these data. The selection of software solution depends on organizations' goal. In the logistics sector, BI is generally appropriate for achieving the goal of the companies. Any organization who wants to implement the BI must understand the organizational mission and vision. In order to decide on a BI solution and planning for the overall project, managers or executives need to answer the following questions: [12] (1) Why do you want to implement BI? (2) What are your business requirements? (3) What is your expected ROI (return on investment)? Hence, the aim of this study is to propose a model for BI alternative selection problem in logistics sector by using analytical tools. In order to highlight the importance of non-functional features, a SWOT based framework is implemented in this context [5].

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Based on the theory of technology acceptance model, software users do not care about whom they buy from, but they concern more about perceived usefulness and ease-of-use. BI is one of the most though, time-consuming and costly process which takes more than 2 or 3 years to get fully implement in the organization [2]. Different factors affect the success of BI implementation process. These factors can be examined with the help of analytical tools. SWOT analysis is one of these analytical tools. SWOT analysis is the tool used for analysis and planning to evaluating the factors affecting on the achievement of business [3].

This paper will highlight the SWOT analysis for the organization which plans to implement BI system. In this context, some factors are considered to be effective on BI system selection for logistics companies. A model is proposed with adequate criteria decided by a large literature survey and weighted by using AHP (Analytic Hierarchy Process). VIKOR method is used to determine the appropriate alternative BI vendor. The paper is organized as follows: Next section provides a literature survey for BI. The following section presents the proposed methodology and applied methods. In latter, a case study is given and last section concludes the study.

LITERATURE REVIEW

BI continues to be a growing and highly competitive market. Most vendors featured in this Decision Matrix reported double-digit growth figures, with rapidly growing vendor reporting greater than 80% year-on-year revenue growth [4].

In the literature, although many studies have been done on BI, there is not much work done about the selection of BI systems. In 2009, Lin al. [7] formulated an analytic network process (ANP) based on assessing the effectiveness of BI systems. In 2012, Rouhani et al. [6] represented a new model to provide a new approach to evaluate institutional systems in BI aspects. In 2013, Vukšić et al. [26] emphasized the importance of business process management and BI systems. Nofal and Yusof [27] reviewed the articles published between 2000 and 2012 regarding the integration of BI and ERP. In 2015, Wang [5] proposed a fuzzy MCDM (multi-criteria decision making) based QFD (quality function deployment) support system to aid to supplier recommendation for BI systems. Antoniadis et al. [20] examined the implementation of ERP systems and the expansion of BI usage. Kubina et al. [15] described the possibility of improving efficiency by using BI systems. In 2016, Hanine et al. [28] proposed an integrated methodology for the evaluation of Geospatial BI alternatives. Peters et al. [29] developed a theoretical model that considers three concepts of BI quality as: performance measurement, organizational learning and the knowledge-based view of the firm. Ram et al. [31] investigated the role and implication of Big Data analytics on BI for the data collected from social media channels. In 2017, Vajirakachorn and Chongwatpol [31] described a way for integrating a BI framework to manage and turn data into insights for festival tourism. Polyvanyy et al. [32] represented a framework for devising process querying methods and models that describe relationships between processes.

According to the literature survey, there are not many studies about BI on account of a fact that is a new approach. MCDM methods are more appropriate than the other methods for solving BI system selection problem; hence, one of them will be used. Also, this paper will highlight the SWOT analysis which combined with AHP and VIKOR for the organization which goes to effective BI selection.

PROPOSED METHODOLOGY

In this paper, an integrated SWOT methodology that is combined with AHP VIKOR is proposed. AHP approach is used for determining the relative importance of factors within each SWOT group as well as the relative importance of factors across SWOT groups, while VIKOR is used for evaluating the best BI system alternative with respect to SWOT factors.

The reason behind selecting SWOT analysis is to see the internal and external factors affecting the success of the BI alternative together. AHP method has been chosen because it is a well-proven, systematic, easy to use the method and it validates consistency and it builds alignment around factor priorities. In order to rank the BI alternatives and select the best alternative, VIKOR method is used. The reasons of selecting VIKOR method is its ability of considering group utility and the individual regret of alternatives and proposing compromise solution(s) by using the "closeness" measure to the "ideal" solution.

The methodology proposed in this paper consists of three basic steps:
Step 1. Determine the BI alternatives and the factors for evaluating BI alternatives by SWOT analysis. Propose an evaluation model that will enable logistics companies to decide on most suitable BI alternative.
Step 2. Determine the weights of the evaluation criteria by using the AHP method.
Step 3. Select the most suitable BI alternative by using the VIKOR method and rank the alternatives.

Evaluation Alternatives

According to Gartner's report [8], the top five key players in the BI market, including SAP (21.6%), Oracle (15.6%), SAS (12.6%), IBM (12.1%) and Microsoft (10.7%). Obviously, different players have their relative strengths and weaknesses on handling large volumes or high-dimensional big data, dealing with data velocity, data variety (structured and unstructured), and data visualization (dashboards and scorecards). As known, SAP and Oracle already own a huge market base in the BI (enterprise resource planning) field. In addition, SAS is a well-known statistics package provider and Microsoft is the dominant player in the operating systems of personal computers. Therefore, the evaluation BI alternatives in this paper are assigned as SAP, Oracle, SAS, and Microsoft.

Evaluation Factors by SWOT Analysis

The SWOT Analysis is a tool which is used to highlight the different factors affecting the business process that organizations plan to design and implement for achieving the mission and vision of the organizations. The SWOT analysis firstly described by the American business and management consultant Albert S. Humphrey in the 1960 and 1970. The SWOT stands for Strengths, Weaknesses, Opportunities, and Threats [13].

This technique is supposed to identify both the targets of a project and the positive or negative internal or external factors which will be in effect during the achievement process. In this regard, a survey about BI system selection is done [14]. Figure 1 shows SWOT factors in the studied case. It should be noted that these factors include 5 strengths, 5 weakness, 5 opportunity and 5 threat factors. These factors are determined by a literature survey [6-15] and compared together by experts.

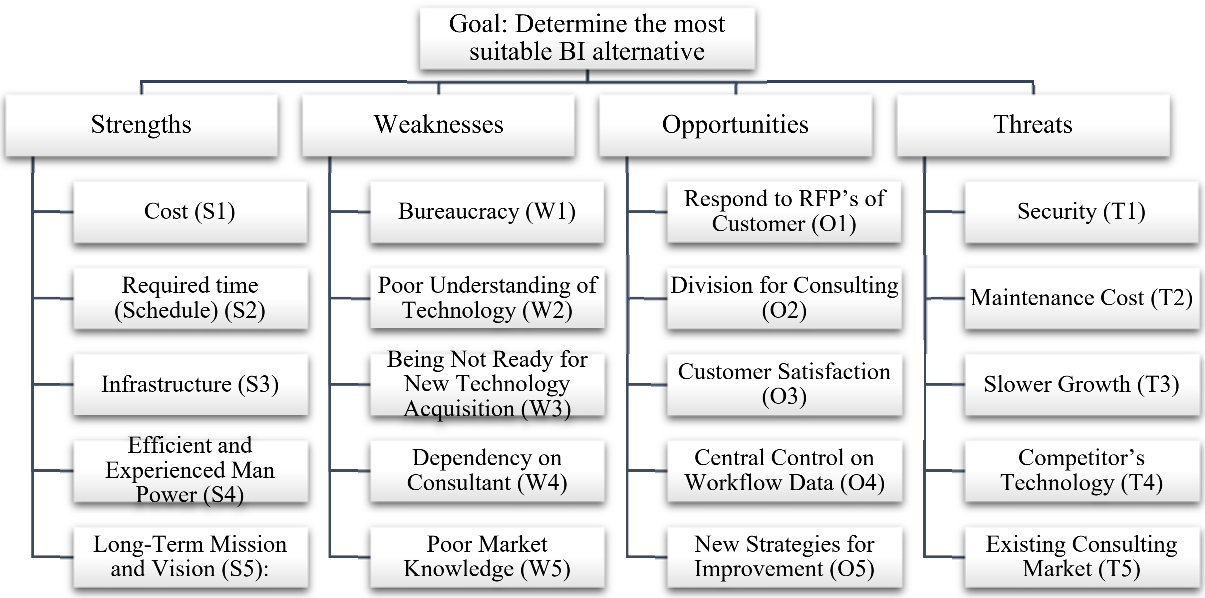

Figure 1. Model with SWOT Factors

BI Strengths:

- *Cost (S1):* The organization has a strong financial hand can go for any new change in the organization and as BI needs lots of money so cost can be one of the important strength of the organization [2].
- *Required time (Schedule) (S2):* BI implementation is a long and time-consuming process so, it requires more time schedule for better implementation. If the organization has enough time, it will be more beneficiary for BI.
- *Infrastructure (S3):* If the organization already has the better infrastructure in hand it makes more easily to BI implementation otherwise more time take to create a new setup for the new technology deployment.
- *Efficient and Experienced Man Power (S4):* If the organization has the more efficient and experienced man power, so the things will easily be adopted and implemented perfectly in most of the cases.
- *Long-Term Mission and Vision (S5):* Long-term mission and vision in top-level management the organization will always stand as supporting poll for the BI development team as a parental tree to achieve the goals and objective [3].

BI Weaknesses:

- *Bureaucracy (W1):* If decision-making is having any bureaucratic nature of the top level management during the implementation, the people on another level of the organization may not have faith on the top level and it may affect very badly on the BI implementation.
- *Poor Understanding of Technology (W2):* Sometimes all the people of the organization may not technically sound as compared to the BI development team. If they fail in understanding the technology, it will be one of the weakest things for the organization.
- *Being Not Ready for New Technology Acquisition (W3):* Sometimes, the people of the organization are not in a position to change their traditional working environment and they are not in a position to acquire the new technology. It can be more dangerous for the organization to acquire the new technology [15].
- *Dependency on Consultant (W4):* Most of the organization hired the consultants for implementation and deployment of the BI. After finishing the task, the consultant leaves the organization. Here the problem arises in the regard of maintenance of the BI and absence of people who have the enough knowledge of BI technology deeply so, again the consultation process gets started and it increases the cost of processes.
- *Poor Market Knowledge (W5):* Most of the organizations fail to analyze the need of market and customer requirement and by poor knowledge of the market the BI implementation may get failed [16].

BI Opportunities:

- *Respond to RFP's of Customer (O1):* While considering the opportunities in the market for an organization, the first element is customer and BI will create the rapid and corrective responses to the request for proposals (RFP's) of customers.
- *Division for Consulting (O2):* BI can create consultant division in the market for the BI implementation for other non-BI implemented organization.
- *Customer Satisfaction (O3):* With the help of rapid responds to the RFP's of customers, the BI creates the opportunities to make the customers satisfied at a certain level.
- *Central Control on Workflow Data (O4):* With the help of BI, it is possible to have an idea about how data flowing among the different processing activities in an organization, which keeps top-level management updated.
- New Strategies for Improvement (O5): The BI gives the better understanding of the current organizational workflow and fund-flow which help the organization to change its tactical decisions by creating new strategies for the improvements [2].

BI Threats:

- *Security (T1):* Providing the data which comes from different individuals, divisions, departments, offices, and plant, sometimes at the same location or different geographical location, needs more security.

- *Maintenance Cost (T2):* One of the costliest threats for the BI implementation is maintenance cost of BI system which requires continuous monitoring, time and people in the process.
- *Slower Growth (T3):* Sometimes, slow growth of the organization also plays serious a role in the process where the organizational growth is not up to the mark as per decided by the top level management during the BI implementation.
- *Competitor's Technology (T4):* Competitor is the biggest threat to any organization. If the competitor is more advanced in technology as compared to our technology, there is nothing worse than it.
- *Existing Consulting Market (T5):* After completing BI implementation, some people from the organization must have the technical knowledge to solve the problems, which can reduce the dependency on the BI development consultant which are outsiders for the organization and it will defiantly reduce the cost of maintenance [17].

AHP Method for Determining the Relative Importance of Factors

AHP was developed by Saaty [22] probably the best-known and most widely used model in decision-making. AHP is a powerful decision-making methodology in order to determine the priorities among different criteria. To make a decision in an organized way to generate priorities have to decompose the decision into steps.

VIKOR Method for Evaluating BI System Selection with SWOT Factors

VIKOR method was introduced by Opricovic (1998) and Opricovic and Tzeng (2002). This methodology solves decision-making problems with the Lp-metric concept. [23] This method aims to rank and choose from number of alternatives [24]. It is a technique for optimization of complicated systems with multi-criteria because it considers different conflicting criteria [23]. The alternatives are defined as a1,a2, ..., aJ. For alternative aj, the rating of the ith aspect is indicated by fij (ith criteria function for the alternative aj) [31].

IMPLEMENTATION OF THE PROPOSED METHODOLOGY

The proposed method will be tested on a real industrial case to verify its usability. There is a logistics company, ABC, which wants to invest in technological solutions to create operational efficiency through access to real-time data. In the first phase, ABC considers to implement an IT solution, however, choosing between different software alternatives was complicated. First, the goal and requirements of the company are determined. The goal of ABC is informed decision-making as well as problem identification and resolution and the requirement of ABC is an analysis of historical data from multiple sources and access to real-time data. Secondly, different types of tools existing in the IT market is analyzed. For example, BA is a tool for foreseeing the future developments while BI is a tool for regarding the historical developments using historical data from one minute ago to many years ago. Furthermore, ERP software is for providing an integrated and continuously updated view of core business processes, while CRM software is for managing a company's interaction with current and potential customers. After some research and considering the requirement of the company, ABC decides to invest in BI technology, because BI tools meet the needs of the company. Thus, the company aims to select the best BI system in the market to gain a competitive advantage by accessing real-time data and analyzing historical data. However, there are different BI vendors in the market. In order to implement the best BI alternative, the marketing department analyses different BI vendors in the market and ABC decides to evaluate them with scientific methods. There are four possible vendor alternatives to BI system: A1 is SAP, A2 is Oracle, A3 is Microsoft and A4 is SAS. The company must make a decision according to the four criteria (S,W,O,T) and twenty sub-criteria explained in the previous section. The criteria are identified based on academic research and professional opinions of the industrial experts. The experts are the IT manager, logistics department manager and computer systems analyst. The IT manager has a background about BI technology, logistics department manager has some insights about supply chain operations and logistics processes, computer system analyst has the technical information about software implementation. The decision support system used in this study consists of integrating the SWOT analysis, AHP method and the VIKOR method.

SWOT-Stage 1. BI alternatives and the factors for implementing BI alternatives by SWOT analysis are determined.
SWOT-Stage 2. A model that will enable logistics companies to decide on the most suitable BI alternative is proposed (Figure 1).

AHP-Stage 1. In the first phase, decision maker evaluated the 4 main criteria (S,W,O,T) and pairwise comparison matrix is constructed and Table 2 shows the matrix. Each entry a_{jk} of the matrix A represents the importance of the j^{th} criterion relative to the k^{th} criterion. The entries a_{jk} and a_{kj} satisfy the following constraint: $a_{jk}.a_{kj} = 1$.

(1)

Obviously, $a_{jj} = 1$ for all j.

Table 1. Table of relative scores

Value of a_{jk}	1	3	5	7	9
Interpretation	*j* and *k* are equally important	*j* is slightly more important than *k*	*j* is more important than *k*	*j* is strongly more important than *k*	*j* is absolutely more important than *k*

To make comparisons, a scale of numbers is needed, which indicates how many times more important or dominant one element is over another element with respect to the criterion or property with respect to which they are compared. Table 1 exhibits this scale [23].

Table 2. The pairwise comparison matrix of the main criteria

Factors	**S**	**W**	**O**	**T**
S	1	6	5	4
W	0.17	1	0.5	1
O	0.2	2	1	4
T	0.25	1	0.25	1

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column, i.e. each entry a *jk* of the matrix A_{norm} is computed as:

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{jk}}. \quad (2)$$

Finally, the criteria weight vector w is built by averaging the entries on each row of A_{norm},

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m}. \quad (3)$$

AHP-Stage 2. Use the priorities obtained from the comparisons to weigh the priorities in the level immediately below. Do this for every element. Then for each element in the level below add its weighed values and obtain its overall or global priority. Continue this process of weighing and adding until the final priorities of the alternatives in the bottom-most level is obtained [24]. Table 3 shows the weights of the main criteria.

Table 3. The weights of the main criteria

Criteria	**S**	**W**	**O**	**T**
Weight	0.590	0.094	0.218	0.098
Ranking	1	4	2	3
C.I.	0.070			

AHP-Stage 3. AHP also calculates an inconsistency index. The inconsistency index in both the decision matrix and in pairwise comparison matrices could be calculated with the equation:

$$\text{CI} = \frac{\lambda_{max} - N}{N-1}. \quad (4)$$

AHP-Stage 4. Decision maker evaluated 20 sub-criteria located under main criteria and the same steps are applied for determining the weights of each criterion. Table 4a and Table 4b shows the weights of the sub criteria.

Table 4a. The weights of the sub-criteria

Criteria	**S1**	**S2**	**S3**	**S4**	**S5**	**W1**	**W2**	**W3**	**W4**	**W5**
Weight	0.177	0.032	0.103	0.080	0.198	0.016	0.018	0.015	0.030	0.016
Ranking	2	10	3	4	1	15	14	19	11	17
C.I.	0.056					0.087				

Table 4b. The weights of the sub-criteria

Criteria	O1	O2	O3	O4	O5	T1	T2	T3	T4	T5
Weight	0.064	0.018	0.041	0.047	0.047	0.039	0.015	0.016	0.009	0.019
Ranking	5	13	8	6	7	9	18	16	20	12
C.I.	0.073					0.067				

At the end of the AHP process, the most important criterion is Long-Term Mission and Vision (S5), the second is Cost (S1) and Infrastructure (S3) has become the third.

VIKOR-Stage 1. The decision maker evaluated four alternatives with respect to 20 criteria. The benefit and the cost criteria are accepted as:

- *Benefit Criteria:* S3, S4, S5, O1, O2, O3, O4, O5, T1, T5.
- *Cost Criteria*: S1, S2, W1, W2, W3, W4, W5, T2, T3, T4.

Table 5 and Table 6 shows the decision maker's evaluation of the alternatives with respect to the benefit and cost criteria.

Table 5. The evaluation alternatives of decision maker for benefit criteria

Aj	S3	S4	S5	O1	O2	O3	O4	O5	T1	T5
A1	9	7	5	3	3	8	7	3	1	7
A2	5	3	9	5	3	7	9	2	9	3
A3	3	6	4	3	5	5	5	7	4	7
A4	9	5	7	3	8	8	1	7	3	9

Table 6. The evaluation alternatives of decision maker for cost criteria

Aj	S1	S2	W1	W2	W3	W4	W5	T2	T3	T4
A1	7	3	9	7	5	5	5	5	3	3
A2	9	8	5	5	7	1	5	3	3	2
A3	5	5	3	5	2	3	3	6	7	5
A4	8	5	3	7	5	3	5	9	5	2

VIKOR-Stage 2. The ideal f_i^* and the worst f_i^- values of all criteria functions (i=1,2,…,n) with respect to benefit or cost functions are determined. If the ith function symbolizes a benefit, then:

$$f_i^* = \max f_{ij} \ , \quad f_i^- = \min f_{ij} \tag{5}$$

If the ith function symbolizes a cost, then:

$$f_i^* = \min f_{ij} \ , \quad f_i^- = \max f_{ij} \tag{6}$$

VIKOR-Stage 3. The values Sj and Rj, j=1,2,...,J, are calculated by:

$$S_j = \sum_{i=1}^{n} w_i \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)} \tag{7}$$

$$R_j = \max \left[wi \frac{(f_i^* - f_{ij})}{(f_i^* - f_i^-)} \right] \tag{8}$$

Where w_i refers to weights of criteria, expressing their relative significance.

VIKOR-Stage 4. The values Q_j, j=1,2,...,J, are calculated by:

$$Q_j = v \frac{(S_j - S^*)}{(S^- - S^*)} + (1-v) \frac{(R_j - R^*)}{(R^- - R^*)} \tag{9}$$

$$S^* = \min S_J, \qquad S^- = \max S_j \tag{10}$$

$$R^* = \min R_J, \qquad R^- = \max R_j \tag{11}$$

where v refers to the weight for the strategy of the maximum group utility, whereas 1-v is the weight of the individual regret. In this study, the value of v is taken as 0.5. These values are calculated as: of S* = 0.485, S- = 0.552, R* = 0.132, R- = 0.198.

VIKOR-Stage 5. The S, R and Q values are sorted in decreasing order. The results consist of three lists of ranking. Table 7 shows the results of VIKOR method.

VIKOR-Stage 6. A compromise solution the alternative (a') which is best by the minimum Q value is suggested if these two circumstances are satisfied:

C1. Acceptable Advantage:

$$Q(a'')-Q(a')\geq DQ \quad (12)$$

Where a'' is the alternative in second position in the ranking list by Q ; DQ = 1/(J -1); J is the number of alternatives. a'' is A2 and a' is A4 and DQ = 1/(4 -1)= 0.333; 0.380-0.000≥0.333 therefore, C1 is satisfied.

C2. Acceptable stability in decision-making:

The best ranked ones by the S and/or R values also must be alternative a'. A1 is the best-ranked alternative in Sj, Rj and Qj, therefore C2 is also satisfied. This compromise solution is consistent with the decision-making process.

Table 7. The ranking table

Aj	Sj	Ranking	Rj	Ranking	Qj	Ranking
A1	0.520	3	0.159	2	0.462	3
A2	0.491	2	0.177	3	0.380	2
A3	0.552	4	0.198	4	1.000	4
A4	0.485	1	0.132	1	0.000	1

Ultimately, SAS has become the most desirable BI alternative among four alternatives with the final Qj value of 0.000; while Oracle has positioned at the second with Qj value as 0.380. SAP has become the third with Qj=0.462 and Microsoft has become the fourth with Qj=1.000, respectively.

CONCLUSION

Today, BI has become a popular enterprise information system to significantly improve information quality and decision timeliness. Typical BI users involve financial analysts, marketing planners, and general managers. Unfortunately, most of them may not have sufficient IT backgrounds.

In order to help these users, this study presents a systematic framework to connect company requirements with technical attributes. In this paper, SWOT and MCDM schemes are appropriately fused into the VIKOR combined AHP framework and the main contribution of this paper are highlighted as follows:

- The SWOT analysis creates a new path for the organization. The importance weights of SWOT components are systematically derived (via AHP),
- The performance scores of BI vendors are efficiently generated (via VIKOR) for accomplishing supplier benchmarking.

The proposed model supplies a useful frame to select the most appropriate BI system. The managers can benefit from this approach to make their decisions more effectively.

In this study, the interactions between criteria are not considered. One of the perspectives for future work can be to consider the dependence of the criteria, the interaction between the criteria, and to extend our analysis by applying the ANP approach [23]. In general, strategic decision problems adhere to uncertain and imprecise evaluation data. In order to model this kind of uncertainty in human preferences, fuzzy logic [33] is applied very successfully. Thus, concerning this second perspective, evaluation procedures will be performed under fuzzy environment.

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AN INTEGRATED FORWARD-REVERSE LOGISTICS NETWORK DESIGN FOR ELECTROLYTIC COPPER CONDUCTOR REEL DISTRIBUTION

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Abstract *− In this study, integrated logistics network design problem for electrolytic copper conductor companies has been investigated. This problem includes decisions regarding forward logistics operations for distribution of reels from factories to customers and reverse logistics operations for collection of empty reels from customers. Another important decision for this industry is transfer method of the goods. Electrolytic copper conductor reels can be send to costumers by using partial loading method (less than container load - LCL) or complete loading method (full container load - FCL), or both depending of their tonnages. If goods are transferred by using FCL methods, containers are sent directly to final shipment point. If LCL method is selected, goods can be directly sent to final shipment point in higher costs compared to FCL. On the other hand, goods of near located customers can be combined and send to a depot as FCL. From the depot, good can be sent to customers as LCL. The same problem also exists in collection of the empty reels for reverse logistics. In this study, a mixed integer linear programming model has been proposed for integration both forward and reverse logistics network design under the problem specific constraints with the aim of minimization of total cost. A real case study from the industry with sensitivity analysis has been solved. The results show that the proposed model provides very efficient results compared to current network of the company which does not include depot alternatives. The proposed model can help decision makers to build effective transportation networks at the operational level and to make better investment decisions at strategic level.*

Keywords − Reverse Logistics, network design, hub location

INTRODUCTION

Copper is used mainly as an electrical conductor in industry. Electrical conductivity, the most distinguished property of copper, is improved to the required level by electrolytic refining. After several operations including melting, refining, casting, wire drawing, plating and bunching, the electrolytic copper wires are made ready in accordance with the customers' requests and standards. After wrapping and packing, the electrolytic copper conductor reels are distributed to the customers. After usage of the full reels by customers, the empty reels are usually stored by customers and returned to the factory with certain periods.

Growing number of customers all around the world significantly increase part of logistics costs in total costs for electrolytic wire companies. This change leads companies with large customer portfolio to better concentrate in the fields of service network design and reverse logistics.

This study includes integration of forward and reverse logistics network design and allocation hub location selection problem for an electrolytic wire company. It is aimed to make logistics processes more efficient by eliminating wastes. For this aim, a mixed integer linear programming model is proposed and solved. Having proposed efficient approach in economic sense, this study intends to reduce transportation costs, improve the efficiency of transportation activities, increase customer satisfaction by delivering in a short time, expand the customer portfolio and therefore maintain competitive advantage of the company.

When the related literature is investigated, integration of forward and reverse logistics network have been studied in last two decades. Salema, Póvoa [1] have studied to determine depot locations within an integrated network. Listeş [2] has set a network design involving manufacturing and remanufacturing topics together in the study. Besides, Ko and Evans [3], Pishvaee, Jolai [4], Pishvaee, Farahani [5], El-Sayed, Afia [6], Khajavi, Seyed-Hosseini [7], Vahdani, Tavakkoli-Moghaddam [8], Keyvanshokooh, Fattahi [9], Ramezani, Bashiri [10], Hatefi and Jolai [11], Hatefi, Jolai [12], Soleimani and Zohal [13] and Fattahi and Govindan [14] have conducted different studies about uncertainties in integrated forward and reverse logistics networks.

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Considering the studies in the literature, according to best of authors' knowledge, there is no study conducted relevant to integrated logistics network design in electrolytic copper conductor industry. This study, unlike other theoretical studies, contains the implementation of electrolytic copper reel allocation problem with industry specific constraints. Furthermore, in this study it is possible to decide the type of loading method to be used. The network is designed to provide service to the customers both from the production center and the distribution center in case it is open. The decision of where the customer to be provided service from is made after economic evaluation. In this study considering partial loading (less than container load - LCL) and complete loading method (full container load - FCL) together, only full container load is delivered to distribution center -if open- in order to benefit from economy of scale. Providing both forward and reverse direction service to customers, the most economical loading type is preferred between LCL and FCL. It is not obligatory for delivering vehicle to be fully loaded up to its maximum capacity. Depending on the sales amount, flow cost in case of FCL and flow cost in case of LCL are compared.

This study enables efficiently use of elements in the system by dealing with the concept and process of logistics with a broad perspective. The rest of paper is organized as follows: In Section 2, the problem environment is defined. Section 3 presents environment of the case study and numerical results. Finally, conclusions are drawn and suggestions for further research are given in last section.

THE PROBLEM ENVIROMENT

This study is based on converting LCL into FCL by benefiting from economy of scale in forward and reverse logistics integration to reduce logistics costs. Third party logistics sources are used during logistics activities. The work enables enterprises to decrease the number of partial loads while increasing complete loads through logistics network design and optimization and distribution center to be opened in case which is economical. Thus this will lead logistics costs to be reduced remarkably. LCL is perceived and made as a loading method used according to orders customers have made. LCL makes it possible to get flows together despite it is hard to estimate the time of flow. The enterprise is able to provide service to customers through most economical route by means of forward and reverse logistics thanks to two way distribution network design. In the process of deciding how a customer to be served, efficient solution options will be provided at operational level depending to orders in termly (weekly, monthly) basis.

There is a minimum number of empty reels to be returned from customers. The amount of empty reels remaining at the customer will be either sold to this customer or return to distribution center. Through reverse logistics network design, backward logistics costs will be reduced. Figure 1 shows proposed integrated forward-reverse network design. From a factory to a customer can be transformed in three way. In the first way (1), the demand of customers delivered third party logistics company as FCL which means the containers are only loaded with single customer's goods and transported to customers without visiting a distribution center for transfer purposes. In the second way (2), the demands of various customers merged in a single container in factory, delivered third party logistics company as FCL and send to a distribution center in which consolidation costs are paid by factory (2a). The goods come from in a single container transferred to different containers according to their final destination area in distribution centers and send to customers as LCL with goods of different companies (2b). In the last way (3), the demands of customers delivered to third party logistics company as LCL and the logistics company responsible from all transportation and transfer operations till goods arriving to customer. In the model, if a customer's demand is more than capacity of a container, the model could select two different ways together. All loads could be send by using first way without fully loading container or some part of demand that fully loads containers by the first ways and remaining goods could be send by using the second or the third way. Moreover, if a customer or distribution center is served by FCL, the reverse transportation costs for empty reels as FCL from this customer to factory are usually much less than forward transportation. This situation usually is defined by agreements, but the logistics companies are generally giving less prices to backward way after sending a truck to that location. The distribution centers have usually minimum number of handling operation limit in the total of forward and reverse operations. The handling cost of a full reel is usually less than handling of an empty reel.

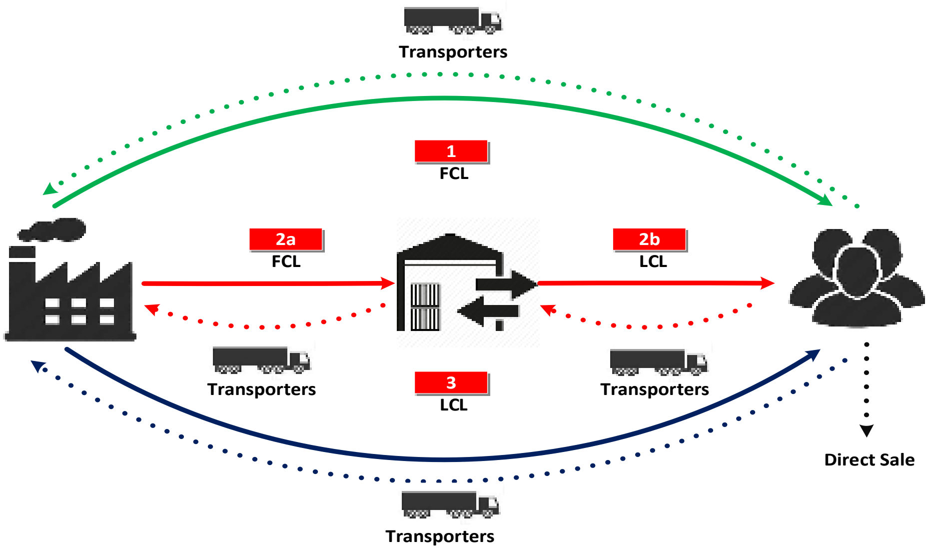

Figure 1. Integrated forward-reverse service network design

The indices, parameters, decision variables and objective function of the mathematical model are listed below.

Indices

f= factories,

m= customers,

d= depots,

Parameters

D_m= Demand of customer m,

U_m= Direct sales price of an empty reel on customer zone m,

TD_m= Total number of empty reels at customer m,

TA_m= Number of empty reels at customer m that have to be collected,

E_f= Marginal income from returning one unit empty reel to factory f *(due to not buying a new reel at factory f)*,

S_f= Unit (kg) production cost at factory f,

C^1_{fm}= Unit (container) FCL sending cost from factory f to customer m,

C^2_{fd}= Unit (container) FCL sending cost from factory f to depot d,

B^1_{fm}= Unit (kg) LCL sending cost from factory f to customer m,

B^2_{dm}= Unit (kg) LCL sending cost from depot d to customer m,

TC^1_{mf}= Unit (container) empty reel FCL sending cost from customer m to factory f,

TC^2_{df}= Unit (container) empty reel FCL sending cost from depot d to factory f,

TB^1_{mf}= Unit (kg) empty reel LCL sending cost from customer m to factory f,

TB^2_{md}= Unit (kg) empty reel LCL sending cost from depot d to factory f,

O_d= Opening/settlement cost of depot d,

H_d= Unit (container) handling cost of depot d,

K_d= Capacity of depot d,

M= Maximum number of available depots,

Q= Vehicle capacity,

QF_f= Production capacity of factory f,

L= Minimum required handling amount (container) for opening a depot,

Decision variables

A_d= 1, if depot d is opened; 0, otherwise,

X_{fm}= FCL amount from factory f to customer m,

XX_{fm}= Number of FCL travel from factory f to customer m,

Y_{fm}= LCL amount from factory f to customer m,

Z_{fdm}= LCL amount from factory *f* to customer *m* via depot *d*,
N_{fd}= Number of FCL travel from factory *f* to depot *d*,
R_m= Number of empty reel direct sales at customer *m*,
TX_{mf}= Empty reel FCL amount from customer *m* to factory *f*,
TXX_{mf}= Number of empty reel FCL travel from customer *m* to factory *f*,
TY_{mf}= Empty reel LCL amount from customer *m* to factory *f*,
TZ_{mdf}= Empty reel LCL amount from customer *m* to factory *f* via depot *d*,
TN_{df}= Number of empty reel FCL travel from depot *d* to factory *f*,

Objective function:

Depot opening and handling cost

$$Min \sum_d O_d \cdot A_d + \sum_f \sum_d \sum_m H_d \cdot Z_{fdm} + \sum_f \sum_d \sum_m H_d \cdot TZ_{mdf}$$

Forward logistics transportation cost

$$+\sum_f \sum_m C^1_{fm} \cdot XX_{fm} + \sum_f \sum_d C^2_{fd} \cdot N_{fd} + \sum_f \sum_m B^1_{fm} \cdot Y_{fm} + \sum_f \sum_d \sum_m B^2_{dm} \cdot Z_{fdm}$$

Reverse logistics transportation cost

$$+\sum_f \sum_m TC^1_{fm} \cdot TXX_{mf} + \sum_f \sum_d TC^2_{fd} \cdot TN_{df} + \sum_f \sum_m TB^1_{fm} \cdot TY_{mf} + \sum_f \sum_d \sum_m TB^2_{dm} \cdot TZ_{mdf}$$

Production cost

$$+\sum_f \sum_m S_f \cdot X_{fm} + \sum_f \sum_m S_f \cdot Y_{fm} + \sum_f \sum_d \sum_m S_f \cdot Z_{fdm}$$

Empty reel direct sales and return income

$$-\sum_m U_m \cdot R_m - \sum_f \sum_m E_f \cdot TX_{fm} - \sum_f \sum_m E_f \cdot TY_{fm} - \sum_f \sum_d \sum_m E_f \cdot TZ_{fdm}$$

Objective function aims to minimize total cost regarding depot opening and handling cost, forward and reverse logistics transportation cost and production cost. The income from empty reel direct sales at customers and the marginal revenue regarding the return of a reel to factory and using it again are additional terms for decreasing total cost of the company.

CASE STUDY

In the content of the study, only the customers located in Europe region, where 78% of total export sales are made, is considered. In the region, there are 90 customers located in 18 countries. There are also 8 different distribution center alternative in this region. The problem is solved for one-term demand period for the company.

The solution of the problem is different depending on the number of distribution centers. Since the decision of the maximum number of distribution centers to be opened is made previously and the decision of economically optimum number of distribution centers to be opened is given by mathematical model, this mathematical model shows both exogenous and endogenous characteristics. The mixed integer linear programming model contains 2296 variables and 8606 constraints. All experiments were performed using the ILOG CPLEX 12.7.1 solver.

First, we solved the current case that any distribution center not allowed to be opened. In this case, the objective value of mathematical model is found to be 329,397$. This is the best solution for customer service when distribution of goods is made directly from current facility by using the first way or third way. This value is also in consistent with current logistics costs of the company for a period.

Then, the model is again solved again by setting maximum number of distribution center as 8. The most efficient solution for the problem is obtained in each case when only one distribution center is opened. In this 60 out of 90 customers are provided service through distribution center in forward and 63 of 90 customers provided service through distribution center in reverse. The objective value of the model is reduced by 8.21% to 302,342$ with the usage of a distribution center for a one month period.

CONCLUSION

In this study, a mixed integer linear programming model allows to obtain network design and optimization of enterprises having forward and reverse logistics network for an electrolytic wire company is presented. The results of the study suggests that enterprises, desiring to reduce their costs by reusing the materials which have been used in forward flow from company to customer, could go through reverse logistics network design efficiently. Enterprises would have the possibility to choose what type of loading to use in operational level according to customer demands.

The output of this study could be used to get efficient results by enterprises having production centers, distribution centers, logistics processes including customers and such similar factors and enterprises desiring to benefit from reverse logistics implementation and enterprises considering opening distribution center. Particularly, it helps enterprises with high export rates to make decisions at operational level network design and to make investment decisions at strategic level. Therefore, it is expected that export rates increase even higher. The growth in export rates decreases current deficit of the country and therefore contributes to country's economy. In the future studies, the logistics cost terms are used as fuzzy numbers because of the pricing of third party logistics companies are very hard to estimate in advance.

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A CLOSED-LOOP SUPPLY CHAIN NETWORK DESIGN FOR WEEE INCLUDING REFURBISHING DECISIONS

Leyla Özgür Polat[1], *Aşkıner Güngör*[2]

Abstract *– Waste Electrical and Electronic Equipment (WEEE) have large share among waste types in terms of the amount and generation speed with the rapid development of technology and increased consumption. However, within the framework of social responsibility, the management of the used and/or end-of-life electronic products to remanufacture and recycling has become an important research area in recent years due to economic and environmental factors. Manufacturers need to take responsibility for costs related to collection, transportation, recycling and disposal of WEEE according to Regulation on the Control of WEEE. Therefore, closed loop supply chain network needs to be designed and managed optimally according to specified objective including refurbishing decisions which play an important role to minimize total costs. In order to contribute to the fulfillment of this need, a mixed integer linear programming model is proposed to maximize total profit of the closed loop supply chain network. The proposed model has been solved with a theoretical case study by using CPLEX 12.0 solver.*

Keywords – Network design, WEEE, closed loop supply chain network, reverse logistic, refurbished products

INTRODUCTION

Consumption of natural resources and pollution of nature have increased around the world over the last couple of decades. As a result of diminishing natural resources and escalating ecological imbalance, the idea of sustainability found its way into all managerial and technical issues in various aspects of life. According to UNEP [1] annually between twenty and fifty million tons of Waste Electrical and Electronic Equipment (WEEE) are generated around the world and the growth rate of WEEE is about three times higher than other waste types. Both governments and civil initiatives are working together to create social awareness to struggle with sharply increasing e-waste production and to develop necessary management practices. The recycling of WEEE is also crucially important since it handles hazardous waste according to regulations and retrieves the valuable materials. Due to environmental, social, health and legal outcomes of WEEE, it has become important to construct sustainable WEEE management system.

In European Union, in order to ensure sustainable WEEE management, to increase the efficiency world's limited resources and to contribute the economy and environment with the specified recycling and recovery targets [2], the directives on the restriction of the use of certain hazardous substances (RoHS) in electrical and electronic equipment (EU 2003, EU 2011), and waste electrical and electronic equipment (WEEE) were published [3, 4]. In parallel to RoHS and WEEE directives, in Turkey, a regulation on control of WEEE (ÇSB 2012) from The Ministry of Environment and Urbanization of The Republic of Turkey was published the Official Gazette on 22.05.2012. This regulation imposes essential responsibilities to the stakeholders such as producers, distributors, consumers, municipalities and waste treatment plants for the collection, transportation, recycling and recovery of WEEE or disposal in accordance with the regulation. According to this directive [5], for example, municipalities with the population of 400,000 or more, need to collect WEEE starting from May 2013. Please see AEEEKY [5] (in Turkish) for more detailed information on WEEE collection. The manufacturers are also responsible for establishing the system to carry out the collection, transport, recycling and disposal costs of WEEE within the framework of the "extended producer responsibility" principle (REC, 2016). Therefore, manufacturers need to redesign the most efficient forward and reverse supply networks to minimize the costs and maximize revenues. In this respect, it is imperative that the beneficiaries of the WEEE are separated by means of sales and refurbishment activities and the inclusion of non-waste products into the system in a way that will increase the incomes of the producers.

Refurbishment activities are meant to make returned products functional after testing, inspection and repair. Refurbishment supports the environmentally friendly strategies because it prevents unnecessary waste

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production, the damage prevention strategy because it prevents damaged product losses for the firm and cost reduction by providing product and price diversity for the customer [6]. The manufacturers have to carry out effectively the reverse flow chain due to the increase in quality, quantity and type of products collected. For this reason, the closed loop supply chain plays an important role in efficient management and recovery of products. The closed loop supply chain handles forward and reverse activities in the supply chain in a single system.

When the recent studies about WEEE, closed loop supply chain and product refurbishment are examined, Yoo and Kim [6] intend to examine the complexity of their work in the first and second hand markets, including pricing decisions for new and refurbished products in the closed loop supply chain. Chen, Chan [7] optimized the closed-loop supply chain with nonlinear integer programming aiming at total cost minimization, taking into account the product refurbishment process, uncertainty and stocks. Dai and Li [8] considered reuse of especially packaging materials such as pallets, cartons, remanufacture and repair from closed loop supply chain network types. Kilic, Cebeci [9] examine the WEEE amounts to be produced in Turkey in 10 different scenarios and implemented the logistic network design with mixed integer programming with the goal of cost minimization over the minimum recycling rates of WEEE. Özceylan, Demirel [10] implemented a closed loop supply chain network design in Turkey to recycle the life-span vehicles with purpose of maximization of income and minimization total costs.

For more information on the closed loop supply chain, please consider literature reviews by Akçalı, Çetinkaya [11], Jayant, Gupta [12], Huscroft, Hazen [13] and Govindan and Soleimani [14]. According to the related literature [15] there are shortcomings related to designing closed-loop supply networks considering all together many issues like the quantity, quality and types of collected products, collection operations, recycling processes, environmental, economic and social effects. This study aims to contribute to the reduce this shortcoming by proposing an integrated network design.

THE MODEL STRUCTURE

The main structure of the model is shown in Figure 1. This study provides the decision support required by manufacturers to efficiently manage processes in addition to minimize costs imposed due to the producer responsibility in accordance with the regulation. In the model, manufacturers carry out production, refurbishment and disassembly processes in order to reduce the increase in the prices of refurbished and new products in the framework of the results found in the literature. Manufacturer (*s*), carries out the sales transactions in different stores *(c)*, purchases returned product *(i)* that has damage condition *(j)* with varying buying prices from stores and sells new products. The stores carry out pricing and inspection procedures. It may be a better option to handle some used products (especially collected from the stores) by the refurbishment process. The recovery center *(r)* carries out the inspection, refurbishment and disassembly of the products and decides the processes of refurbishment or decomposition of fractions (including partial and/or completely disassembled materials) *(u)* and hazardous materials *(h)* of the collected products after the inspection according to the damage conditions. At the same time, the recovery center sends the fractions that are used for remanufacturing to the manufacturer, sells the excess demand of fractions in the secondary market, and sells the refurbished products to the stores. Product collection points *(k)* are managed by different channels such as municipalities as specified in the WEEE directive. WEEE collected in collection points are purchased with a buying price to support the municipalities in the process. However, they may have a lower quality than the products collected from stores. Landfill *(l)* performs waste disposal operations such as incineration and burial of unused hazardous materials *(h)* which are harmful to nature. Carriers (*t*) with various capacity and types carry out the delivery of products, fractions and hazardous materials.

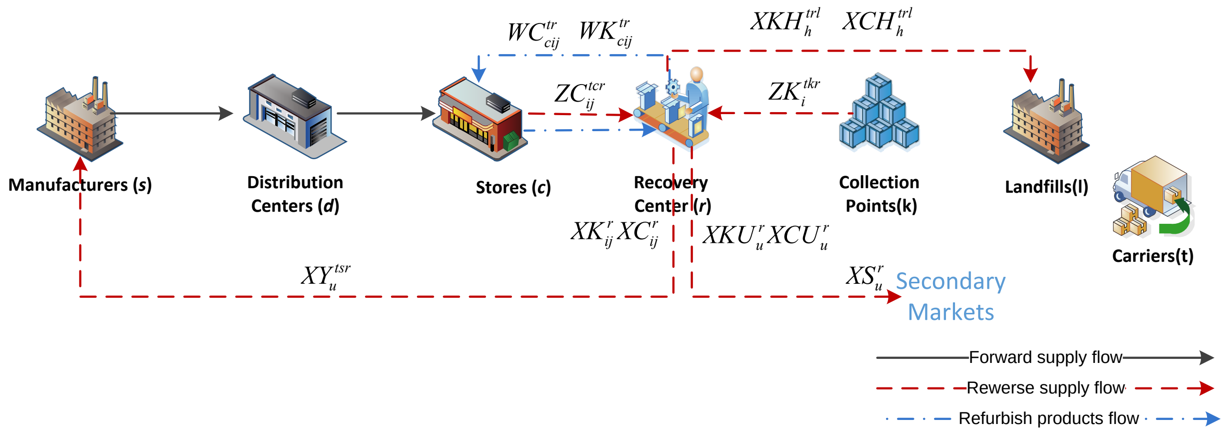

Figure 1. Closed loop supply chain network design

It is necessary to make some assumptions in order to reflect the problem that exists in real life. Accordingly, the model assumptions are below:

- All parameters are deterministic and known.
- There is no cost associated with management of stores, manufacturers, refurbishing centers etc.
- Sale prices for each products are fixed during the planning period.
- Collection costs of stores and collection points are not considered.
- All excess demand of fractions are sold to secondary markets.
- All production of hazardous materials are sent to landfills.
- Capacities of stores are not considered for collection of the used or end of life products.
- One planning period is considered.
- Demands are divisible.

The decision variables in the model are listed below.

Decision variables

Q_{ci}^{tds}	Amount of demand to be fulfilled in store c for product i by using carrier t and distribution center d from manufacturer s
WC_{cij}^{tr}	Amount of demand to be fulfilled by stores in store c for refurbish product i by using carrier t from recovery center r
WK_{cij}^{tr}	Amount of demand to be fulfilled by collection points in store c for refurbish product i by using carrier t from recovery center r
ZK_i^{tkr}	Buying amount of product i from collection point k to refurbishing center r by using carrier t
ZC_{ij}^{tcr}	Buying amount of product i in damage condition j from store c to recovery center r by using carrier t
XC_{ij}^{r}	Disassembly amount of product i in damage condition j from store c to recovery center r
XK_{ij}^{r}	Disassembly amount of product i in damage condition j from collection point k to recovery center r
XKU_u^r	Amount of fraction u for product i in damage condition j from collection point k to recovery center r by using carrier t
XCU_u^r	Amount of fraction u for product i in damage condition j from store c to recovery center r by using carrier t
XKH_h^{trl}	Sending amount of hazardous material h for product i in damage condition j from collection point k to recovery center r by using carrier t to landfill l

XCH_h^{trl}	Amount of hazardous material *h* for product *i* in damage condition *j* from store c to refurbishing center *r* by using carrier *t* sent to landfill *l*
XY_u^{tsr}	Amount of demand to be fulfilled in manufacturer *s* for fraction *u* by using carrier *t* from recovery center *r*
XS_u^r	Sales amount of fraction *u* from recovery center *r*
YS_{ci}^{tds}	1: if store *c* product *i* by using carrier *t* and distribution center *d* from manufacturer *s* uses this path; 0: otherwise.
YR_{cij}^{tr}	1: if store c product *i* in damage condition *j* by using carrier *t* from recovery center *r* uses this path; 0: otherwise.
RI_i	Total income related to new product *i* and refurbish product *i (sales revenue)*
RU_u	Total income related to fraction *u (marjinal revenue+sales revenue)*
CIF_i	Forward cost related to new product *i (production+depot)*
CTF_i	Forward logistic cost related to new product *i (transportation cost)*
CTR_i	Reverse logistic cost related to used /end of life and refurbish product *i (transportation cost)*
CIR_i	Reverse cost related to used /end of life and refurbish product *i* (*buying+inspection+refurbishing+disassembly*)
CU_u	Total cost related to fraction *u (transportation cost)*
CH_h	Total cost related to hazardous material *h (disposal cost+transportation cost)*

Objective function:

$$\text{maximize} \quad \sum_{i\in I}\left(RI_i - CIF_i - CTF_i - CTR_i - CIR_i\right) + \sum_{u\in U}\left(RU_u - CU_u\right) - \sum_{h\in H} CH_h$$

Objective function maximizes the total profit for the closed-loop supply chain network. It contains sales revenue of new and refurbished products and fractions and costs related to production, depot, purchasing, inspection, refurbishing, disassembly, disposal and transportation. Model constraints define production/ refurbishing/transportation/depot capacity, demand fulfillment, the product balance, minimum acceptable production/refurbishment quantities, conversion values of fractions and hazardous materials, minimum collection target, minimum recovery limit and structure of variables. Due to the space limitation, the full model is not presented here.

CASE STUDY

In this section, numerical results of the proposed model are presented using a sample case study. For this reason, the damage conditions of the products, the product contents, cost information of these damage cases and the purchasing data are systematically reflected and integrated as in real life problems in operation. The sample network has five stores selling five types of products in the forward supply chain channel. These products can be supplied by two distribution centers with single carrier from a single manufacturer. The reverse supply chain consists two recovery centers, one landfill and two collection centers. In addition to collection centers, the stores also collect products from customers at different prices for four different damage conditions. The recovery centers are connected to the manufacturer and perform refurbishment or disassembly processes. Product damage conditions, capacities and demands are affected during refurbishment or disassembly processes. Refurbished products are returned to the stores. Eight different fractions obtained by the disassembly process are sent to manufacturer or secondary markets. Two different hazardous materials are sent to the landfill. Transportation capacities are not taken into account in the sample study. Figure 2 shows the relevant case study for proposed closed-loop supply chain network.

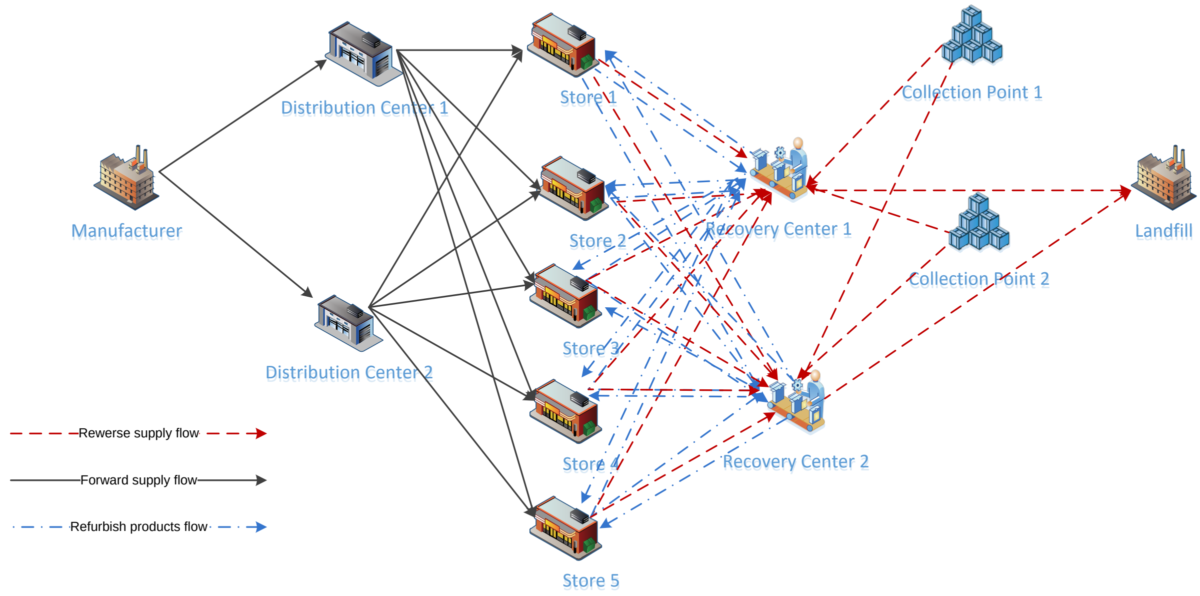

Figure 2. The case study

Some of the specific variables and parameters used in the case study are shown between Table 1-3. The other tables are not show in the study due to space and page restrictions.

Table 1. Data related to products

(i)	**Product's Name**	e_i	b_i	in_i	a_i	$minr_i$	$mins_i$	pc_i^1
1	PC	3.1	4	0.005	9.71	0.75	3000	0.50
2	LCD TV	2.3	2.6	0.003	4.62	0.75	5000	0.40
3	LCD	2.0	2.5	0.002	7.24	0.70	4000	0.34
4	CRT TV	1.6	2	0.004	34.27	0.75	500	0.20
5	CRT	1.6	2.1	0.0025	16.04	0.70	300	0.18

Table 1 shows the data for refurbished product's unit sales price, new product's unit selling price, unit inspection cost, weight of products, minimum recovery rate of products, minimum collection quantity and unit production cost for product groups. Table 2 contains data for purchasing costs of collected products from stores and probability values of collected products from collection points according to damage conditions. Table 3 shows the data for unit refurbishing cost and productivity rate according to recovery centers.

Table 2. Buying costs and probability values according to product *i* with damage condition *j*

	i	*j1*	*j2*	*j3*	*j4*	*j5*
	1	0.50	0.40	0.30	0.20	0.50
	2	0.40	0.30	0.22	0.14	0.40
gc_{ij}	3	0.34	0.28	0.20	0.12	0.34
	4	0.20	0.16	0.12	0.08	0.20
	5	0.18	0.14	0.10	0.04	0.18
	1	0.01	0.027	0.263	0.7	0.01
	2	0.05	0.1	0.25	0.6	0.05
pp_{ij}	3	0.06	0.04	0.2	0.7	0.06
	4	0.09	0.11	0.2	0.6	0.09
	5	0.1	0.3	0.2	0.4	0.1

Table 3. Data related to recovery center *r* according to product *i* with damage condition *j*

	i	*j1*	*j2*	*j3*	*j4*	*j5*
qr_{ij}^{r1}	1	0.25	0.50	1.00	1.10	0.25
	2	0.20	0.40	0.80	0.90	0.20
	3	0.17	0.34	0.60	0.70	0.17
	4	0.10	0.20	0.40	0.50	0.10
	5	0.12	0.18	0.36	0.46	0.12
qr_{ij}^{r2}	1	0.27	0.53	0.96	1.14	0.27
	2	0.19	0.50	0.75	0.89	0.19
	3	0.27	0.40	0.60	0.80	0.27
	4	0.12	0.29	0.43	0.54	0.12
	5	0.17	0.14	0.32	0.48	0.17
sl_{ij}^{r1}	1	0.95	0.86	0.75	0.65	0.95
	2	0.9	0.85	0.70	0.60	0.90
	3	0.9	0.85	0.75	0.70	0.90
	4	0.85	0.82	0.75	0.60	0.85
	5	0.8	0.79	0.70	0.55	0.80
sl_{ij}^{r2}	1	0.95	0.90	0.77	0.66	0.95
	2	0.95	0.88	0.71	0.61	0.95
	3	0.95	0.89	0.76	0.72	0.95
	4	0.9	0.85	0.78	0.63	0.90
	5	0.8	0.80	0.75	0.62	0.80

NUMERICAL RESULTS

Mixed integer programming model contains 1116 variables and 269385 constraints. All computational experiments were conducted on a workstation with Intel Core i7, 3.4 GHz processor and 8 GB of RAM. All experiments were performed using the ILOG CPLEX 12.7.1 solver under 0,2 CPU seconds. The results are reported in Table 4-7.

Table 4. Monetary results of solutions (x 1000)

Total profit	12.284,24
Total income	17.672,39
i sales revenue RI	17.649,4
u sales revenue RU	22.99
Total Cost	5.388,15
CIF(Forward cost of new product)	1.812,54
CTF(Forward logistic cost of new product)	2.396,03
CTR(Reverse logistic cost)	943.74
CIR(Reverse cost)	1.179,51
CU(Total cost related to fractions)	18.601
CH(Total cost related to hazardous materials)	0.07

Table 5. Demand fulfillment details in relation to stores WC_{cij}^{tr}

c	*i*	*j*	*t*	*r*	**Quantity**
3	3	1	1	1	182
4	1	1	1	1	180
1	2	1	1	1	160
3	2	1	1	2	139
1	3	1	1	1	124
2	2	1	1	2	120
2	1	1	1	1	120
4	2	1	1	1	119
4	3	1	1	1	118
5	1	1	1	2	114
1	1	1	1	1	100
5	3	1	1	1	90
3	1	1	1	2	90
2	3	1	1	1	70
5	2	1	1	2	65

Table 6. Demand fulfillment details in relation to collection points WK_{cij}^{tr}

c	*i*	*j*	*t*	*r*	**Quantity**
5	2	1	1	2	35
4	2	2	1	2	1
3	2	1	1	2	1

Table 7. Demand fulfillment details in relation to fractions XY_{u}^{tsr}

u	*t*	*s*	*r*	**Quantity**
8	1	1	2	60
6	1	1	2	60
4	1	1	2	60
7	1	1	2	30
5	1	1	2	30
3	1	1	2	30
2	1	1	2	29.93
1	1	1	2	10
2	1	1	1	0.060

When the results are examined, the total profit is calculated as 12.284.240 TL. Since the store capacities are not taken into consideration, it is seen in Tables 5 and 6 that the quality products in the stores are preferred in the model instead of the poor quality products in the collection centers. Highest cost values are forward supply chain costs, and then reverse supply chain costs are the highest.

CONCLUSION

In this study, the closed loop supply chain network design is provided through compliance with the regulation, taking into account the manufacturer responsibility and minimum recovery targets in AEEEKY [5]. In the future, the model can be applied to a rea life case and the model's flexibility can be evaluated through various strategies. In addition, the fuzzy nature of the real life situations related to damaged conditions, demands and return quantities with different quality can also be integrated into the model.

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GROCERY LAST MILE DISTRIBUTION: RESULTS FROM THE U-TURN PILOT 3

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Abstract *– With emerging convenience services such as online shopping, people now choose to shop online almost anything, including groceries. Online grocery purchase and delivery services are recognised as a key offering by major retailers in the UK and it has resulted in retailers' having their own fleets to satisfy the consumers' home delivery demand with inevitable inefficiencies in the distribution operation. In this paper, we focus on the last mile delivery of groceries purchased online and investigate the benefits of logistics collaboration among retailers. Our methods comprise grocery demand estimation and capacitated vehicle routing. We compare the base case where each retailer operates their own fleet with a theoretical case where retailers collaborate. Our results suggest, on average, 10% reduction in the distance travelled, and 16% reduction in the time required to deliver the orders. Future work could incorporate simulation to verify and stress-test the optimisation results.*

Keywords – Food logistics, Grocery distribution, Logistics collaboration, Vehicle routing

INTRODUCTION

Managing urban areas has become one of the most significant development challenges of the 21st century. The urban population has grown from 746 million in 1950 to 3.9 billion in 2014, and the world's population in 2050 is projected to be 66% urban [1]. The world is expected to have 41 mega-cities with more than 10 million inhabitants by 2030, necessitating urgent attention to urban planning for easy access to education, healthcare, infrastructure and services where transport is a key aspect of the smooth functioning of city life. Especially urban freight transport has significant impact on the quality of life in urban environments through traffic congestion, vehicle emissions, and noise pollution [2].

The developments in information and communication technologies and the Internet have enabled new convenience services such as online shopping, using desktop computers and more recently mobile devices. Along with books, fashion items, flight tickets, and hotel bookings, people now choose to shop online almost anything, including groceries. In the USA, across Europe, and especially in the UK, online grocery purchase and delivery services are offered by many players in the market, with rapidly emerging new business models. Online grocery service has been recognised as a key service offering by major retailers in the UK, which then has resulted in retailers' having their own fleets to satisfy the consumers' home delivery demand and inevitable inefficiencies within the distribution operation. As part of the U-TURN project funded by the EU's Horizon 2020 programme, in this paper, we focus on the last mile delivery of groceries purchased online and investigate the benefits of logistics collaboration among retailers. Our methods comprise grocery demand estimation and capacitated vehicle routing to inform a comparative analysis of independent and collaborative logistics operation to fulfil grocery home deliveries. We compare the base case where each retailer operates their own fleet with a theoretical ideal where retailers collaborate in the last mile distribution.

The flow of grocery orders can be conceptualised in Figure 1 where large flows from picking locations of retailers are transported to micro-hubs in residential areas, which serve as a cross-docking facility to perform the last mile delivery of grocery orders to consumers' addresses. It is also possible to plan this micro-hub as a click & collect location, where consumers can pick their orders on their preferred day and within their preferred time window. Three flows are conceptualised in the UK Pilot: 1) large flows from picking locations to micro-hubs, 2) small flows from micro-hubs to consumers' addresses with time window constraints, and 3) small flows

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with space and time window constraints where consumers collect their orders. In this paper, we focus on the flows from picking locations to micro-hubs (red arrow in Figure 1).

Figure 1. Conceptualisation of Online Grocery Flows

Picking locations, as the name implies, are fulfilment centres, dark stores, or large stores from which home deliveries of online grocery orders are picked. We propose the idea of micro-hubs which are envisaged to be run by third parties to fulfil the last mile delivery of online grocery orders. We treat postcode sectors in London as drop zones and propose a micro-hub per postcode sector which has an average area of 8 km^2. The contribution of this paper can be summarised in two aspects: 1) We investigate the increasingly growing phenomenon of online grocery orders and the corresponding home delivery demand that follows. In this respect, we develop a novel method to estimate annual home delivery demand for groceries purchased online using secondary and primary data sources. 2) We implement the well-known capacitated vehicle routing problem in the absence and presence of logistics collaboration in fulfilling the home delivery demand. Henceforth, we identify the circumstances that result in higher benefits from collaboration in terms of distance reduction.

LITERATURE REVIEW

The grocery retail sector in the UK is famous for its severe competition and it is no surprise that the major retailers have started investing large sums in the online channel more than a decade ago [3]. On the other hand, the sustainability of distribution operation has been a growing concern ever since the introduction of the online channel and home deliveries. This is mainly due to the high impact of the online channel on the physical network that fulfils the service demand together with stringent service parameters such as 1-hour delivery windows and booking of deliveries in advance. Similar to other online retail services, online grocery purchase and the following home delivery service bring upon changes in shopping habits of consumers. Convenience comes at an economic, environmental, and social cost in the form of higher prices, increasing CO_2 emissions, and additional congestion on the roads. This new way of shopping groceries affects online grocery retail revenue models as well as carbon emissions in the last mile distribution due to increased convenience through pay-per-order and subscription-based service models [4].

Numerous factors such as drop density, distance, and vehicle type affect the emissions from home delivery services. Emissions from the average shopping trip of a consumer, particularly by private car, can be greater than emissions from all upstream logistical activities [5]. On the other hand, emissions from delivery vans can be reduced if it is possible to combine the deliveries over spatially and temporally comparable grocery orders. In that respect, a classic combinatorial optimisation problem, vehicle routing, has become a key aspect of managing distribution operations [6]. The vehicle routing problem (VRP) domain is rich with many extensions including but not limited to capacitated VRP, VRP with time windows, or VRP with pickup and deliveries. The origins of the VRP, which is a generalisation of the travelling salesperson problem (TSP), can be traced back to [7]. The TSP determines the shortest route that passes n locations, only once. When each pair of locations are linked, the total number of routes through n locations is $1/2 \times n!$; a number that grows very large very fast: the total number of possible routes for 10 locations is 1,814,400. The TSP is generalised to VRP by imposing capacity constraints that are smaller than the total demand of all locations to be visited. In that case, multiple vehicles are needed to satisfy the total demand in the service area.

In fact, the retailer's physical network characterised by the density, size, and location of stores affects operating costs and environmental costs [8]. It has been a long debate whether consumers' travelling to stores causes higher carbon emissions than retailers' delivering orders to consumers' homes. The answer is not trivial because it is affected by not only the store network, but also the shopping preferences and the shopping frequency of consumers. The store network could comprise *few and far* stores where the journey to the store takes a significant travel distance and time or *many and close* stores where the shopping trips are shorter. Consumers may perceive shopping as a leisure time activity and allocate several hours of travel and shopping time on a regular basis or as a chore that has to be done quickly and at minimum cost.

METHODOLOGY

In modelling the grocery last mile distribution, we have an integrated two stage methodology to test the potential benefits of collaboration: demand estimation and capacitated vehicle routing problem. In the demand estimation stage, we generate daily grocery orders to be delivered in postcode sectors of London. In the second stage with the capacitated vehicle routing problem, we solve the daily grocery order delivery problem with the minimum distance in the objective function. We design an experiment based on vehicle capacity (four capacities tested) and picking location (two locations tested) and logistics operation (independent and collaborative) among two hypothetical retailers, the data of which are informed by both primary and secondary data as explained in the following subsection.

Data

Our work is informed by primary data from an online grocery retailer (Retailer R) operating in London. The data is a summary of the average number of orders per postcode over one year. Specifically, it includes 346,745 transactions from 01/06/2014 to 31/05/2015 and shows the daily distribution of grocery orders and peaks on Fridays and Mondays. Since this is the only primary data, we use secondary data from publications, reports, and websites of retailers as explained in Table 1 to design an analysis framework with the same spatiotemporal data from more than one retailer that can demonstrate the likely benefits such as distance and delivery time reduction owing to logistics collaboration.

Table 1. Data and Sources Used in This Paper

Data	**Source**
UK Online Grocery Market Size and Share	Mintel
Average basket size	Retailers' reports and industry knowledge
UK Population	ONS
Retailer store footprint	Websites of retailers
Demand seasonality	Primary data of Retailer R
Postcode sectors	Primary data of Retailer R

In addition to the above, we also use the latitude and longitude of postcode sectors in our distance calculations for the vehicle routing problem. Postcodes in the UK are alphanumeric references comprising an outward code of 2-4 characters and an inward code of three characters. The postcode is structured hierarchically, supporting four levels of geographic unit: postcode area (124), postcode district (3,114), postcode sector (12,381), and building postcode (approximately 1.75 million). We limit our area of analysis to 265 postcode sectors in London, for which we have primary data (Figure 2).

Figure 2. Map of London; Study Area Shaded in Grey

For each postcode sector in Figure 2, we downloaded the longitude and latitude data from https://www.freemaptools.com/download-uk-postcode-lat-lng.htm on 2016-06-03. We then used the `geosphere` package and `distGeo` function in R Language to estimate the distance between postcode sectors and the picking locations. The `geosphere` package implements spherical trigonometry functions for geographic applications. The `distGeo` function produces a highly accurate estimate of the shortest distance between two points on an ellipsoid. We prefer to use this package and function due to the high number of postcode sectors that need to be visited every day and the need for an efficient way of estimating the distances between them.

Demand Estimation

To evaluate the three flows identified in the Introduction section, ideally, we need grocery demand and distribution data from multiple retailers operating in the same geography over the same period. It proved to be extremely difficult to retrieve this primary data from retailers operating in our pilot city: London. Hence, we revert to secondary data sources and apply a demand estimation methodology that takes as input the total annual demand for grocery orders and produces the output of daily grocery orders per postcode sector for home delivery. This demand estimation methodology comprises six steps as follows:

1. Estimate the UK online grocery market size from published sector reports.
2. Apportion market size in line with the market share of retailers that offer online grocery service.
3. Calculate number of orders per capita considering the UK population.
4. Assess store footprint of each retailer by postcode area.
5. For each postcode sector generate the number of online orders based on population and store footprint (e.g. size of store, consideration of industrial / residential mix per postcode).
6. Run a Monte Carlo simulation to distribute the annual number of orders to days of the year based on the seasonality distribution of Retailer R.

In *Step 1*, we find from Mintel that the total grocery market size of the UK is £8.65B in 2015, which is the year comparable to the primary data from Retailer R. In *Step 2*, we apportion the grocery sales to six major retailers (Tesco, Sainsbury's, Asda, Ocado, Waitrose, and Morrisons) that comprise 85% of the online grocery market in the UK in 2015. In *Step 3*, we identify the average basket size for each retailer from their annual reports and other publicly available data to estimate the number of grocery home delivery orders / year. With an average basket size of £101.37, the total number of grocery orders / year in the UK is 85,321,786. To estimate the annual grocery orders / postcode sector we use the UK census in 2011 and the population projection for 2015. This then informs the population per postcode sector to estimate the annual grocery home delivery orders / postcode sector. A novelty of our approach is to incorporate the store footprint of retailers as an estimator of home delivery orders of groceries in *Step 4*. We assess the store footprint of retailers based on the types of stores and the distribution of stores in the postcode sector. The types we consider are large, standard, small, convenience, and filling stations stores (smallest store format in gas stations). We set the sales of a standard store to 1 and assume a large store sells 75% more than the standard store, whereas a small store sells 50% less than the standard store. The corresponding indices for convenience and filling station stores are 7% and 5%, respectively. In *Step 5* we take a weighted contribution of population and store footprint per postcode sector to estimate the annual grocery home delivery orders. We assign the weights of population and store footprint to minimise the estimation error with the primary data of Retailer R. The optimum weights for population and store footprint are 50% and 50%, respectively, with a mean absolute percentage error of 47.8%. We show an example output of Steps 1-5 in Table 2 for two postcode sectors in London.

Table 2. Estimated Annual Online Grocery Orders per Retailer per Postcode Sector

Postcode Sector	Tesco	Sainsbury's	Asda	Ocado	Waitrose	Morrisons
E10 5	8,299	4,085	2,208	3,593	864	791
E10 6	9,139	4,499	2,432	3,957	951	871

As the *Step 6* implies, we use Monte Carlo simulation to incorporate the uncertainty in grocery orders into our analysis framework. The simulation model is deterministic [9] in the sense that the total number of grocery orders / year is fixed, but the exact values of its inputs (when the orders will be placed across the year – the daily grocery delivery demand) are uncertain so these values are sampled from a prior input distribution (empirical seasonality distribution from primary data of Retailer R) through Monte Carlo methods run on MATLAB. Monte Carlo simulation is a commonly used technique to assess the impact of uncertainty in input parameters on the variability of the outputs from the system. In this case, the demand is the most critical uncertain element that governs the grocery distribution operation.

Capacitated Vehicle Routing Problem

In a capacitated vehicle routing problem, the main inputs are customers, a depot, the distances between all locations, demand, and vehicle capacity. Let N be the set of customers, $N = \{1, 2, \dots, n\}$ and let 0 denote the depot. Then the set of all locations is denoted by P, where $P = N \cup 0 = \{0, 1, \dots, n\}$. An undirected graph $G(P, E)$ denotes the edges between the set of all points in P. For each edge, an associated travel cost c_{ij} is defined, and it can correspond to the distance from point i to point j, $\forall\, i, j \in P$. K denotes the fixed number of identical vehicles (size of fleet) in the depot 0, each with a capacity C, measured in the same unit as the demand d_i of customer i. The binary decision variables x_{ij} take the value 1 if the vehicle travels from point i to point j, otherwise zero. The continuous decision variables u_i are used to eliminate subtours and bounded between the demand of the customer and the capacity of the vehicle. Then, the capacitated vehicle routing problem can be formulated as follows:

$$\min Z = \sum_{i=0}^{n} \sum_{j=0}^{n} c_{ij} x_{ij} \qquad i \neq j \tag{1}$$
$$\sum_{i=0}^{n} x_{ij} = 1 \qquad \forall j \in N \tag{2}$$
$$\sum_{j=0}^{n} x_{ij} = 1 \qquad \forall i \in N \tag{3}$$
$$\sum_{j=1}^{n} x_{0j} \leq K \tag{4}$$
$$u_j - u_i + C * x_{ij} \leq C - d_i \qquad \forall i \in N, \forall j \in N, i \neq j \tag{5}$$
$$d_i \leq u_i \leq C \qquad \forall i \in N \tag{6}$$

Equation (1) is the objective function, which minimises the cost of deliveries depending on the distance. Equations (2) and (3) ensure each customer is visited once, each vehicle visiting a customer also leaves the customer. Equation (4) is the bound on the total number of vehicles to be used (or it is the minimum possible number of routes [10]). Equation (5) is the subtour elimination to achieve a single connected tour from the depot location to the customers on the route. In other words, the inequalities involving u_i eliminate tours that do not begin and end at depot 0 [11]. Finally, Equation (6) sets lower and upper bounds on the subtour elimination variable u_i.

Design of Experiments

We used the design of experiments to derive valid statistical inferences from our experimental observations. In these experiments, we made purposeful changes to the input variables of the grocery home delivery system and observed their impact on the benefits from logistics collaboration. We follow the factorial design where each complete trial of the experiment investigates all possible combinations of the levels of the factors [12]. We consider picking locations, vehicle capacity, and logistics operation as the factors that affect the distance travelled to fulfil home deliveries of groceries purchased online. Table 3 shows the levels of each factor.

Table 3. Design of Experiments

Picking Locations	Vehicle Capacity	Logistics Operation
West and North (2)	10, 15, 20, and 25 orders (4)	Independent (2) and Collaborative (1)

We ran the mathematical model explained in the Methodology section for each picking location, for each capacity, for each logistics operation (two for independent operation of retailers and one for joint logistics operation), and for each day; resulting in $2 \times 4 \times 3 \times 364 = 8736$ runs. We use R Language to prepare the input data and AMPL software to run the mathematical model using CPLEX solver. We limit the run time of CPLEX to 60 seconds across all instances and record the solution available at the time the solver is interrupted.

The mathematical model coded in AMPL is provided in the Appendix. We read the outputs from AMPL into R to analyse the results.

RESULTS

We examine the benefits from logistics collaboration in the large flows from picking locations to micro-hubs under a two-retailer scenario where Retailer 1 (R1) has a market share comparable to that of Morrisons and Retailer 2 (R2) has a market share similar to that of Ocado. The estimated total number of grocery home delivery orders is 13.3M per annum, which corresponds to 16% of the online grocery market. We assume both retailers operate two picking locations (West and North as introduced in the Design of Experiments section) that serve consumers living in London (shaded area in Figure 2), in 265 postcode sectors, each of which is served by a single picking location. The West picking location serves 67 postcode sectors and the North picking location serves 198. Our analyses are based on a static physical network which does not change within the experiment.

As an example, Table 4 shows the summary of the VRP solution on Day 1 for independent operation of R1, independent operation of R2, and collaborative operation of R1 and R2 for the West picking location with a vehicle capacity of 15 orders. It should be noted that the routes identified in the solution are feasible routes rather than optimal routes because the CPLEX solver is run for 60 seconds per problem instance.

Table 4. Comparison of Independent and Collaborative Logistics for Day 1

	R1 Independent	R2 Independent	R1 and R2 Collaborative
Day 1 Demand	98	389	487
Distance (km)	264	821	979
Postcode sectors served	51	67	69
Vehicles needed	7	29	34

It can be seen in Table 4 that while R1 serves 51 and R2 serves 67 postcode sectors on Day 1, 49 of these postcode sectors are common and a distance saving of 11% is possible (979 km instead of 1,085 km). Similarly, the total number of routes needed to fulfil the demand of both retailers is 6% lower on this day. We present a comparison of distance travelled across the year (364 days) for vehicle capacity 20 in Figure 3. The mean distance reduction is 10% (Figure 3, right panel), when the two retailers run a joint logistics operation for home deliveries of groceries.

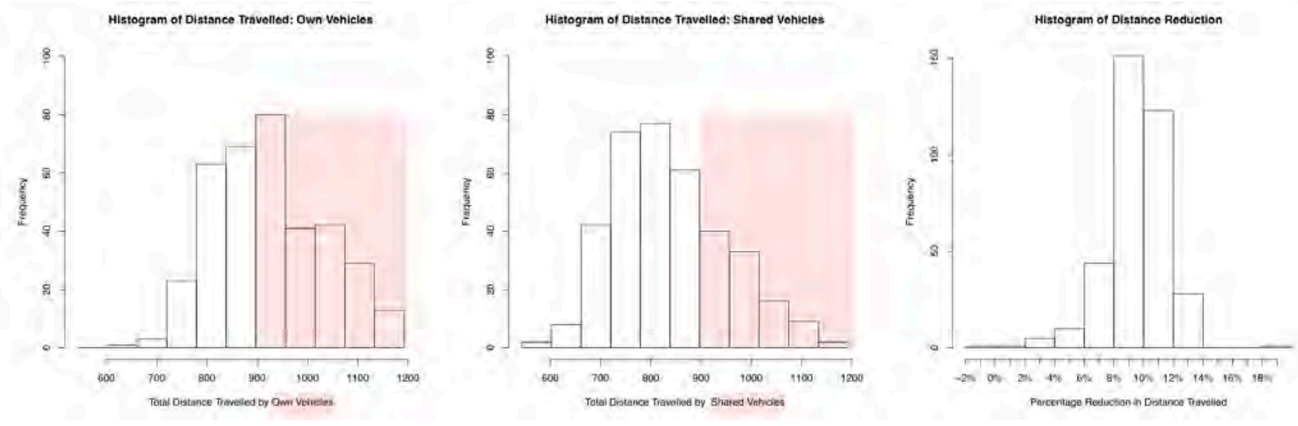

Figure 3. Distance Reduction in Independent Operation through Collaboration

Another relevant performance metric in this vehicle routing problem is the time needed to complete deliveries. Again, collaboration is expected to reduce the time needed by pooling demand from both retailers on the same day and reducing the total number of stops per route. To do this analysis, we assume a 10-minute parking time per postcode sector and a two-minute delivery time per order. We also assume that the trucks travel at 20 km/h speed. The comparison of total time in minutes needed to fulfil the delivery orders independently on the left panel, the total time needed in the collaborative logistics operation in the middle panel, and the percentage savings in terms of operational time on the right panel of Figure 4.

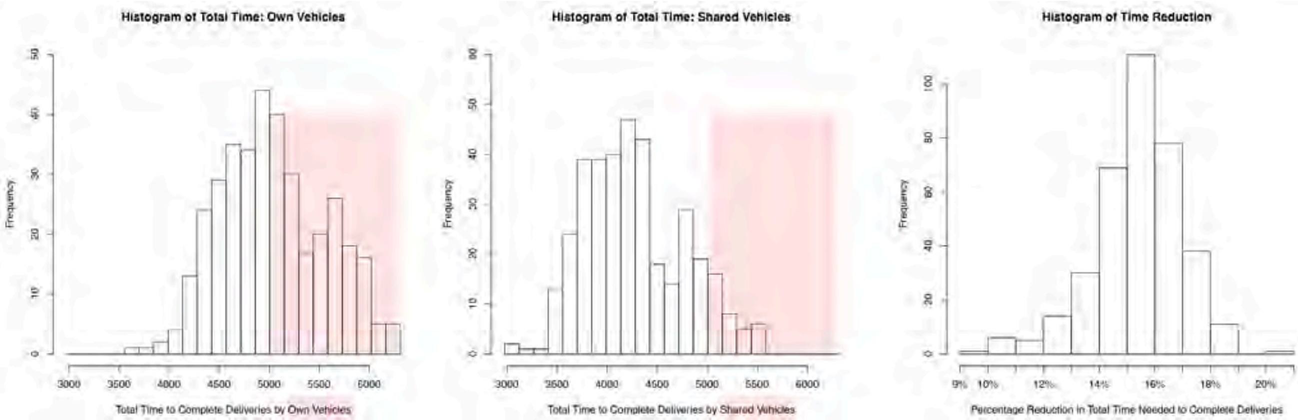

Figure 4. Reduction in Total Delivery Time in Independent Operation through Collaboration

The benefits from a collaborative operation in terms of delivery time ranges from 9% to 21% with an average of 16%. We finally present the comparative results of vehicle capacities in Figure 5.

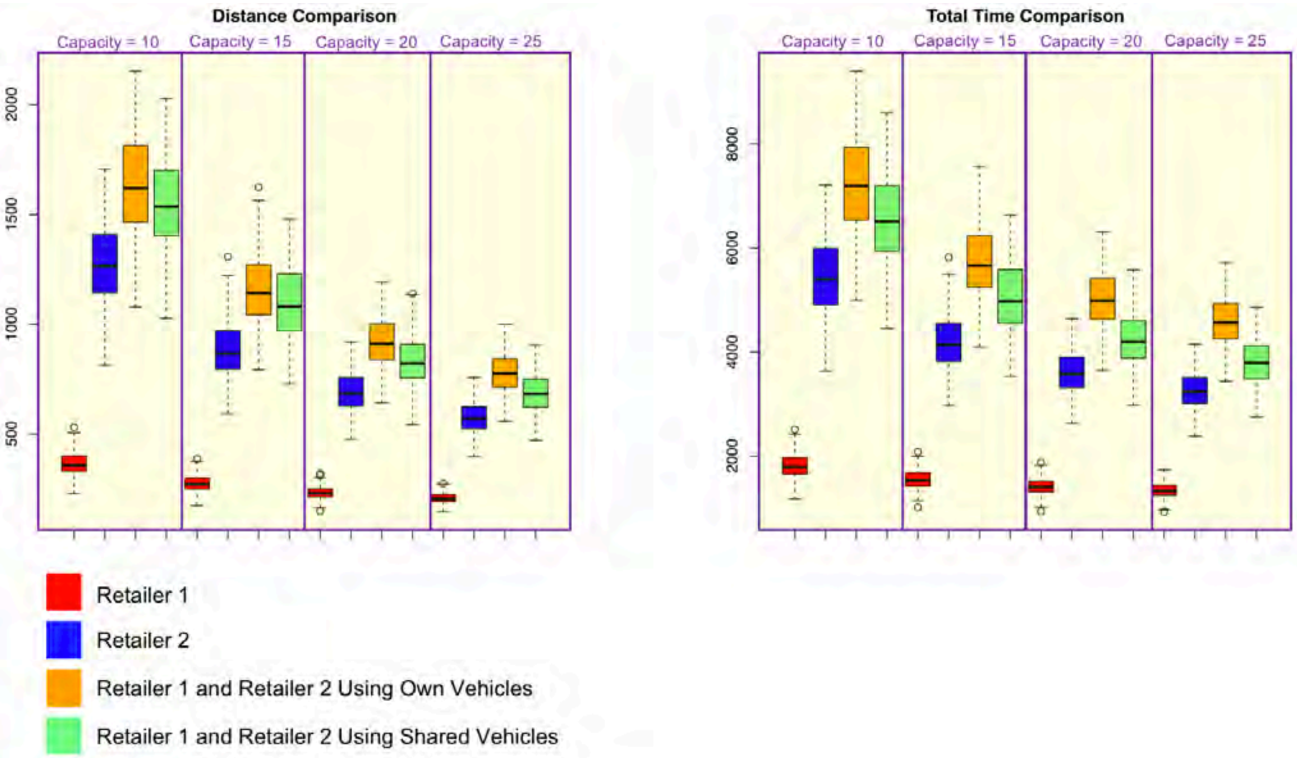

Figure 5. The Impact of Vehicle Capacity on Distance and Total Delivery Time

The benefits from collaboration are evident in Figure 5 both in terms of distance and total delivery time needed to satisfy the orders with increasing benefits as the capacity of vehicle increases. This is not surprising as the route would need fewer stops if it is possible to fit in more orders from the same postcode sector. Table 5 presents the impact of vehicle capacity on the reduction that can be achieved in distance and total delivery time. As the capacity of the vehicle increases the reduction potential also increases. The benefits are higher in the area served by the North picking location since this picking location serves 198 postcode sectors with relatively high drop density compared to the 67 postcode sectors served by the West picking location; this, in turn, makes it easier to combine orders in the same postcode sector into one vehicle and consequently reduce the distance travelled and the total delivery time.

Table 5. Capacity Impact on the Reduction in Distance and Total Delivery Time with Logistics Collaboration

	West Picking Location				North Picking Location			
Capacity	C=10	C=15	C=20	C=25	C=10	C=15	C=20	C=25
Distance	5.5%	5.7%	9.4%	11.7%	6.4%	8.6%	10.1%	11.5%
Total Time	9.5%	12.0%	15.3%	17.0%	9.5%	12.8%	14.9%	16.2%

DISCUSSION AND CONCLUSION

In this paper, we investigate the increasingly predominant nature of online grocery retail channel and the subsequent home delivery service. We focused on the UK online grocery market and proposed a collaborative logistics operation among online grocery retailers for the last mile delivery of groceries. At the moment, the major retailers in the UK online grocery market make operational decisions individually to maximise their profits without collaborating with each other. This means that each retailer invests in its own fleet of trucks and drivers as well as distribution centres, solving its own routing problem daily. This independent logistics operation results in inefficiencies in terms of multiple visits to the same locale from different retailers around the same time of the day. The delivery operation can improve if the barriers to collaboration can be overcome.

Drop density is one of the most important factors that affect the profitability of the home delivery services [5]. Collaboration, theoretically, is able to achieve higher reductions in distance and total operation time in postcode sectors with higher daily orders through combining the orders of the same postcode sector in fewer vehicles. We investigate a new physical network design for the online grocery retail where micro-hubs located in postcode sectors are proposed to fulfil the online grocery last mile distribution. Our analyses of the distance from picking locations to these micro-hubs suggest improvements of up to 18% in total distance when two retailers collaborate. Savings in total delivery time reach up to 21% across the simulated period. In line with that, the average reduction in distance travelled is 10% and the average reduction in the time required to complete the last mile distribution is 16%. The reduction in distance is a precursor of the reduction in carbon emissions due to the strong correlation between the distance travelled and the carbon emissions. It is plausible to estimate a comparable rate of reduction in carbon emissions as well.

Our results show the theoretical savings in distance travelled and total time; however, the practicalities are likely to be different because we do not formally evaluate the time and the cost implications of enabling collaboration between two retailers. The unsustainable nature of the current last mile delivery of groceries purchased online is recognised by many stakeholders. In the future, new business models offering a service like our micro-hub idea are expected to emerge due to the business needs of providing more convenience at a better value. Future work is envisaged to investigate the size and the minimum drop density of the catchment area of micro-hubs to make them economically viable. Future work can also incorporate simulation to verify and stress-test the optimisation results.

Several limitations of our work should be recognised. The annual grocery demand estimation is based on ballpark figures without a chance to validate the apportioning results. We have not considered socio-demographical characteristics of postcode sectors in the apportioning of the total annual demand for grocery orders to individual postcode sectors. Therefore, the real demand structure is expected to be different than what we estimate. In our input calculations for the VRP, we use symmetric distances approximated from the longitude and latitude of postcode sectors. In reality, the distances between micro-hub locations are likely to be asymmetrical; and our distance estimations can be improved by incorporating actual road distances into the distance matrix c_{ij}. Due to the complex nature of the VRP and the large problem instances, we ran the CPLEX solver for a short period of time for each problem instance. Longer runs may show that the benefits from collaboration could be higher than what we report. Despite these limitations, we still conclude that the issues presented are valuable to retailers operating their own fleets to satisfy home delivery demand of online grocery orders, to policy makers devising plans to improve the sustainability of urban life and to third party service providers who are likely to come forward with this micro-hub concept in the near future.

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Appendix

The mathematical model code in AMPL

```
set N; # Set of demand points
set P; # Set of all points including the depot
param K >= 0; # Number of vehicles available in the fleet
param C >= 0; # Capacity of the vehicle
set A := {i in P, j in P: i <> j}; # Set of distances
param c{A} >= 0; # Distances
param d{i in N}; # Demand of demand points
var x{A} binary; # The locations to be visited
var u{i in N} >= 0 ; # Variable to prevent sub-tours
minimize cost: sum{i in P, j in P: i<>j} c[i,j]*x[i,j]; # Distance
s.t. incoming{j in N}: sum{i in P: i <> j} x[i,j] = 1; # Incoming flow
s.t. outgoing{i in N}: sum{j in P: j <> i} x[i,j] = 1; # Outgoing flow
s.t. vehicles: sum{j in N} x['E3 3TT',j] <= K; # Max vehicles
s.t. subtour{i in N, j in N: i <> j}: u[j] - u[i] + C*x[i,j] <= C -
d[i]; # Subtour elimination
s.t. bound{i in N}: d[i] <= u[i] <= C; # Vehicle capacity
```

AN INTEGRATED APPROACH FOR MULTI-ECHELON INVENTORY MANAGEMENT PROBLEM

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Abstract *– This study develops a two-phased integrated approach for multi-echelon inventory management decision-making problem by considering the whole supply chain as a single unit. In the first phase, demand forecasting of the supply chain is conducted by using the simple average, moving average, weighted moving average and ARIMA methods. In the second stage, the forecasts obtained from the first stage are placed on the multi-echelon mathematical model by considering multi-item, multi-supplier and multi-buyer in order to determine how much stocks to be held in each member of the chain and how much items to be sent to the members of the chain. The objective function of the model tries to minimize the joint total cost of the supply chain consisting of the supplier, the distributor, and the buyer. A real-life case study in a distribution company performing in Turkish Informatics and Communication Technologies in Turkey is conducted to demonstrate the applicability and validity of the approach.*

Keywords – Demand forecasting, inventory management, multi-echelon

INTRODUCTION

Due to the increasing competitiveness and market globalization, companies should develop effective supply chains to improve their customer service level and reduce their operational costs. To satisfy customer demand on time and prevent stock-outs, companies make high investments in safety stocks. To determine safety stock, companies could use two approaches such as single-echelon and multi-echelon inventory management. According to single-echelon approach, entities in the supply chain network determine their demands and safety stocks level independently of the other entities in the network. On the other hand, multi-echelon approaches consider all entities in all stages of the supply chain together and aim to optimize inventory decisions simultaneously [1]. Compared to single echelon approaches, multi-echelon approaches are highly cost-effective techniques by reducing safety stock levels and improve customer service level preventing stock-outs [2]. However, they need more computational efforts and interactions between entities compared to the single echelon approaches.

In the literature, there are several studies addressing multi-echelon inventory management. Zhou et al. (2013) developed a multi-product and multi-echelon inventory control model and to solve the model, they proposed a genetic algorithm (GA) and validated the GA method effectiveness by using simulated ordering strategies [3]. Guo and Li (2014) investigated supplier selection problem and inventory control problem together by developing a single-item, multi-echelon mixed integer nonlinear mathematical model taking into consideration stochastic demand and lead times. To solve the model, they used decomposition method [4]. Topan et al. (2017) investigated two-echelon, multi-item inventory problem and proposed a heuristic solution approach based on the greedy algorithm and Lagrangian heuristic and also, they provided an efficient lower bound on the optimal total cost. They showed that the policy parameters in the single item, single echelon models are not valid for multi-echelon, multi-product systems [5]. Wang and Lee (2015) developed a bi-level stochastic programming model and a revised ant algorithm was proposed to solve the model [6].

Nasab and Naseri (2016) proposed a multi-period, multi-echelon mixed integer programming model to solve both location/allocation problem, routing, and inventory problems through a petroleum supply chain and applied this model to an Iranian petroleum supply chain [7]. Pasandideh et al. (2015) developed a bi-objective, multi-product, multi-period, multi-echelon mixed integer linear programming model and their model aim to minimize total cost and maximize the amount of products sent to customers [8].

Peidro et al. (2010) developed a fuzzy mixed integer linear programming model for a multi-echelon, multi-product, multi-period and multi-level supply chain by taking into consideration the uncertainties in demand, process, and supply. They applied this model to the real-life case of an automobile company [9]. Gumus et al. (2010) proposed a methodology to handle multi-echelon inventory problem based on neural network simulation and neuro-fuzzy demand and lead time forecasting and to calculate the performance of the methodology, SCOR model was used [2].

Yang and Lin (2010) developed a mixed integer nonlinear programming model to solve multi-echelon inventory problem under uncertain delivery lead times and quality unreliability and they applied particle swarm

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optimization (PSO) to improve the results of the mathematical model [10]. You and Grossmann (2009) developed a multi-echelon mixed integer nonlinear programming model to optimize transportation, inventory and network structure of supply chain and proposed a spatial decomposition algorithm based on Lagrangian relaxation and piecewise linear approximation [11].

In this study, a two-phased integrated approach is presented to solve multi-echelon, multi-period and multi-product inventory management problem. In the first phase, demand forecasting techniques are compared and in the second phase, a mixed integer programming model is developed and applied to a real-life case of an IT retailer in Turkey.

The remainder of this paper is organized as follows: In Section 2, in the first phase, different demand techniques are applied and compared and then multi-echelon, multi-product, multi-period mixed integer programming model is developed and applied to the real-life case of a leading IT retailer in Turkey. In the last section, conclusions and limitations are presented.

METHODOLOGY AND APPLICATION

As shown in Figure 1, a general supply chain network includes suppliers, manufacturers, distributors, retailers, and customers. In this study, we only address the inventory management problem of a specific part of this supply chain consisting manufacturer, distributor, and retailer in the perspective of the distributor. This distributor is one of the leading IT products retailers in Turkey that have many distribution points in Turkey. They import products such as smartphones, computers, tablets, accessories etc. from overseas manufacturers and then they distribute these products to retailers. In each echelon, every entity makes its own demand forecasting and determine safety stocks level without information exchange with other entities. This single echelon approach has computational advantages, on the other hand, it causes the poor customer service level, stock-outs or excessive stocks. If these entities make their demand forecasting and inventory planning simultaneously by exchanging information with each other, costs of stock-outs and excessive stocks could be decreased significantly. In this study, we will discuss this multi-echelon inventory management problem in two phases. In the first phase, different demand forecasting techniques will be used and compared according to their error rates. After determining the demands, a mixed integer programming model is developed to determine purchasing amounts and inventory level in each period. The company exports many products, but in the context of this study to show the efficiency of the multi-echelon approach, we only take into consideration one product, Apple lightning to USB cable. For this product, there is one manufacturer in abroad and two main retailers in Turkey.

Figure 1. Overview of a general supply chain

Demand Forecasting

In IT retail market, technological innovation and R&D capabilities are highly advanced, because of this, product life cycles are getting shorter day by day. Therefore, demand forecasting of IT products is a challenging issue. Frequently preferred techniques such as naïve method, exponential smoothing, regression, moving averages, and ARIMA are used and the results are compared according to their MAD, MSE, RMSE and MAPE values. There are weekly total sales and inventory levels data for the year 2015.The results of the demand forecasting are shown in Table 1. According to all aspects, moving average (3 weeks) has the best results. Also, ARIMA(1,1,2) has higher performance compared to others. Also in figures 2-9, comparison graphics of actual and predicted values calculated by using each technique are shown.

Table 1. Results of the demand forecasting techniques

Forecasting Method	**MAD (Mean Absolute Deviation)**	**MSE (Mean Square Error)**	**RMSE (Root Mean Square Error)**	**MAPE (Mean Absolute Percentage Error)**
Naive	103.1373	22135.88	148.7813	11.70023
Moving Average (3 weeks)	86.48667	13167.04	114.7477	9.557715
Moving Average (4 weeks)	112.9337	21275.33	145.8607	11.92664
Exponential Smoothing (α=0.1)	106.0843	22635	150.4493	11.89539
Exponential Smoothing (α=0.01)	103.1849	22165.64	148.8813	11.68825
Exponential Smoothing (α=0.9)	206.3165	67984.7	260.7388	20.12547
Regression (R^2=0.36)	210.1133	58078.67	240.9952	22.88172
ARIMA (1,1,2) (Damped-trend linear exponential smoothing)	99.63221	21317.32	146.0045	11.419
ARIMA (1,1,0) (Differenced first-order autoregressive model)	101.7763	22050.2	148.4931	11.6355

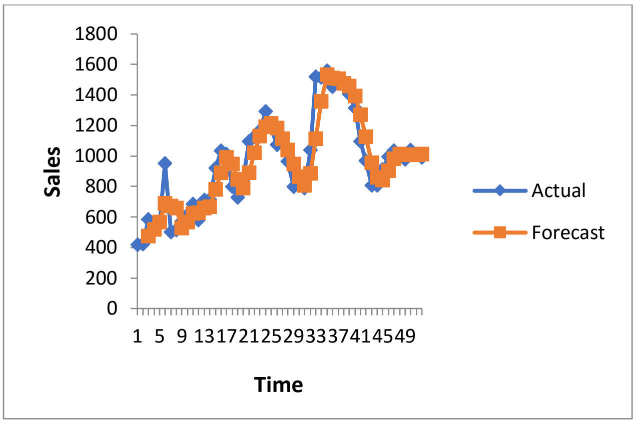

Figure 2. Moving average (3 weeks)

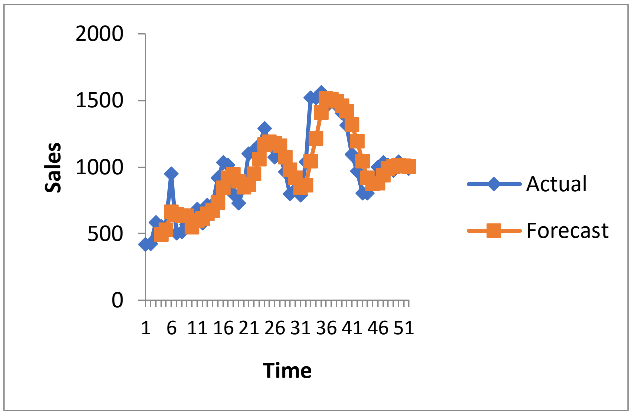

Figure 3. Moving average (4 weeks)

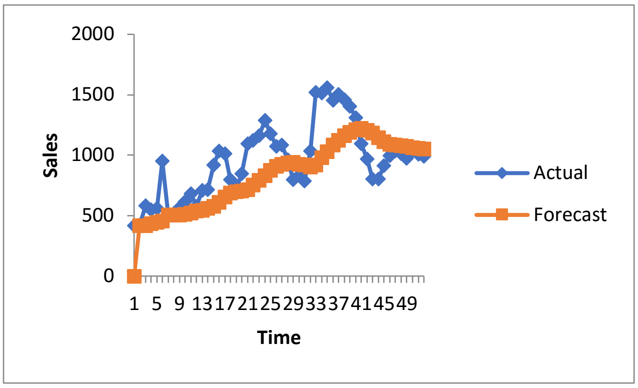

Figure 4. Exponential Smoothing (α=0.1)

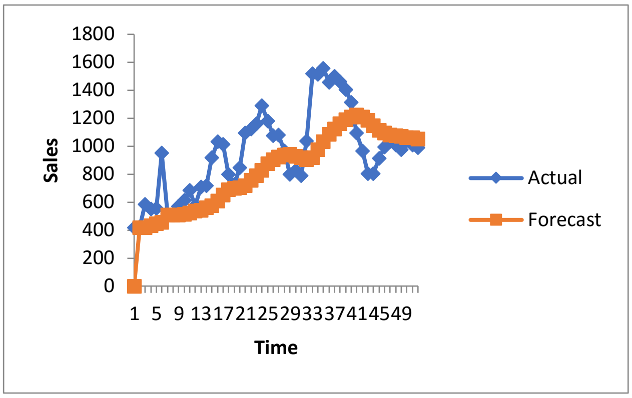

Figure 5. Exponential Smoothing(α=0.01)

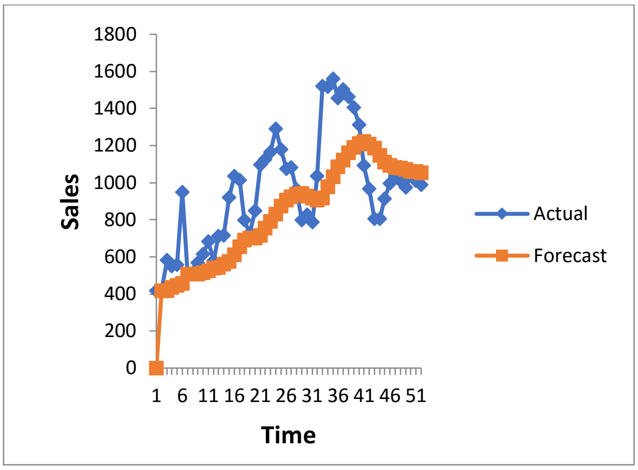

Figure 6. Exponential Smoothing(α=0.9)

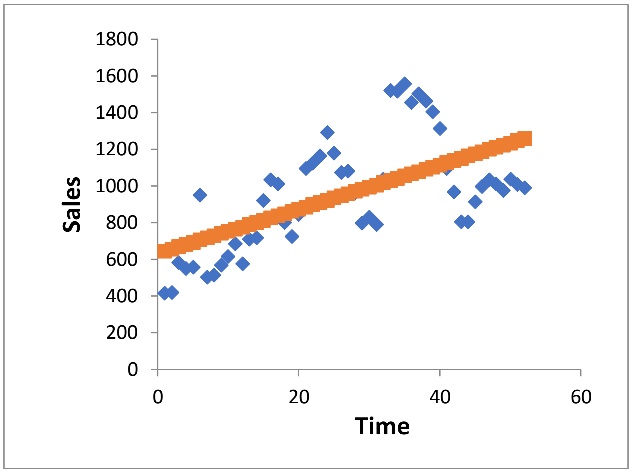

Figure 7. Regression

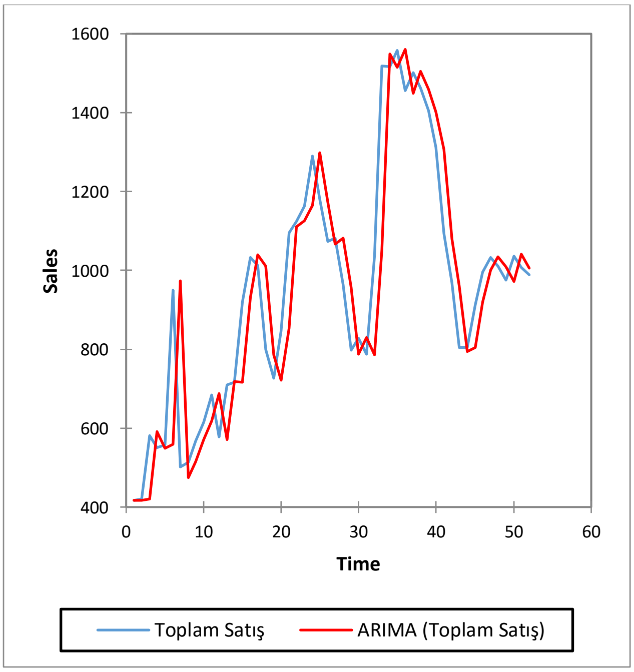

Figure 8. ARIMA (1,1,0)

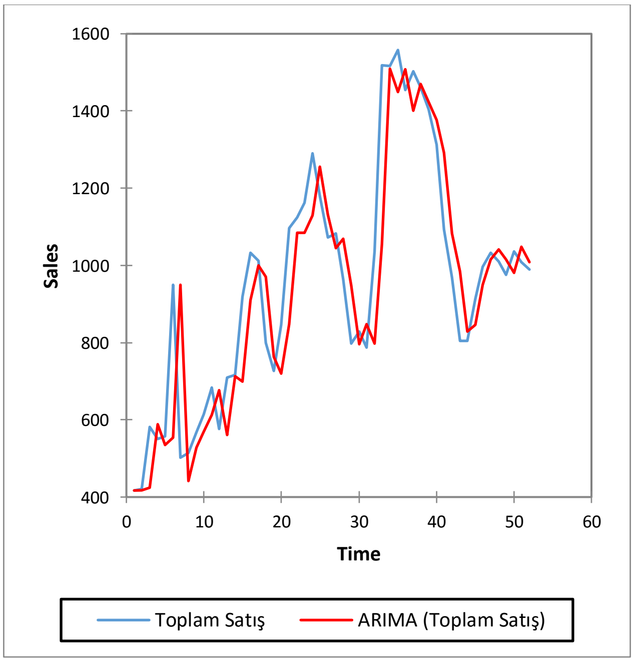

Figure 9. ARIMA (1,1,2)

Mathematical Model

In order to determine purchasing amounts from suppliers, distributed amounts to retailers and safety stock levels in the depots of the distributors, a multi-echelon, multi-period mixed integer programming model is developed. This model aims to minimize total inventory, stock-out and purchasing costs. Also, this model allows multi products to flow between the entities. The details of the model are given below.

Sets :

p : Product types
t : Time periods
i : Manufacturers
j : Distributors
r : Retailers

Parameters:

h^1_{jpt} : inventory holding cost of distributor j during period t
h^2_{rpt} : inventory holding cost of retailer r during period t
p^1_{ijp} : procurement cost of distributor j to buy product p from manufacturer i
p^2_{jrp} : procurement cost of retailer r to buy product p from distributor j
α_{jpt} : stock-out costs of distributors
β_{rpt} : stock-out costs of retailers
s_{ijpt} : amount of product p that manufacturer i can send to distributor j during period t
d^1_{jpt} : demand of distributor j in period t
d^2_{rpt} : demand of retailer r in period t
L^1_{ijp} : lead time of product p that manufacturer i can send to distributor j
L^2_{jrp} : lead time of product p that distributor j can send to retailer r
q^1_{jp} : initial amount of inventory in distributor j
q^2_{rp} : initial amount of inventory in retailer r

Decision variables:

x_{ijpt} : Amount of product p that will be sent from supplier i to distributor j in period t
y_{jrpt} : Amount of product p that will be sent from distributor j to retailer r in period t
I^1_{jpt} : Amount of inventory in distributor j in period t
I^2_{rpt} : Amount of inventory in retailer k in period t
u^2_{rpt} : unsatisfied demand of the retailer k in period t
u^1_{jpt} : unsatisfied demand of the distributor j in period t

Mathematical Model:

$$\begin{aligned} Z_{min} = & \sum_i\sum_j\sum_p\sum_t p^1_{ijp}x_{ijpt} + \sum_j\sum_r\sum_p\sum_t p^2_{jrp}y_{jrpt} \\ & + \sum_j\sum_p\sum_t h^1_{jpt}I^1_{jpt} + \sum_r\sum_p\sum_t h^2_{rpt}I^2_{rpt} \\ & + \sum_j\sum_p\sum_t \alpha_{jpt}u^1_{jpt} + \sum_r\sum_p\sum_t \beta_{rpt}u^2_{rpt} \end{aligned} \quad (2.1)$$

s.t.

$$x_{ijpt} \leq s_{ijpt} \quad (2.2)$$

$$I^1_{jpt-1} + x_{ijp(t-L^1_{ijp})} + u^1_{jpt} = d^1_{jpt} + I^1_{jpt} \quad (2.3)$$

$$I^2_{rpt-1} + y_{jrp(t-L^2_{jrp})} + u^2_{rpt} \ = \ d^2_{rpt} + I^2_{rpt} \quad (2.4)$$

$$y_{jrpt} \leq \ I^1_{jpt} + \ x_{ijp(t-L^1_{ijp})} \quad (2.5)$$

$$I^1_{jpt} \leq I^1_{jpt-1} + \ x_{ijp(t-L^1_{ijp})} \quad (2.6)$$

$$I^2_{rpt} \leq I^2_{rpt-1} + y_{jrp(t-L^2_{jrp})} \quad (2.7)$$

$$u^1_{jpt} \leq d^1_{jpt} \quad (2.8)$$

$$u^2_{rpt} \leq d^2_{rpt} \quad (2.9)$$

$$I^1_{jp"0"} = q^1_{jp} \quad (2.10)$$

$$I^2_{rp"0"} = q^2_{rp} \quad (2.11)$$

$$x_{ijpt}, y_{jrpt}, I^1_{jpt}, I^2_{rpt}, u^1_{jpt}, u^2_{rpt} \quad \geq 0, integer \quad (2.12)$$

The objective function of the mathematical model (2.1) aims to minimize total purchasing costs, inventory holding costs and stock-out costs during 52 weeks period. Constraint set (2.2) ensures the total amount which manufacturer could send to distributer should be less than the capacity of the manufacturer. Constraint sets (2.3) and (2.4) are the balance constraints. Constraints (2.3) ensures that sum of the previous period stock, the total amount of products coming from manufacturers to distributors and unsatisfied demand of the distributor is equal to the sum of the demand of the distributor and amount of the stock which should be held in this period. Constraints (2.4) ensures that sum of the previous period stock, the total amount of products coming from distributors to retailers and unsatisfied demand of the retailer is equal to the sum of the demand of the retailer and amount of the stock which should be held in this period. In the balance constraints, lead times of the products are also taken into consideration.

Constraint set (2.5) provides the total amount products coming from the distributors to retailers should be less than the total amount of the products which should be sent from distributors. Constraints (2.6) ensures that the amount of the stocks in distributors should be less than previous period stock and that sum of the previous period stock and the total amount of products coming from manufacturers to distributors. Constraints (2.7) ensures that the amount of the stocks in retailers should be less than previous period stock and that sum of the previous period stock and the total amount of products coming from distributors to retailers.

Constraints (2.8) and (2.9) ensures that the unsatisfied demands of the distributors and retailers should be less than the predicted demands of the facilities. Constraints (2.10) and (2.11) provide the initial stocks held in the distributors and retailers in the beginning of the planning period. Constraints (2.12) are the sign restrictions, each variable should be an integer and greater than 0.

This mathematical model is solved by using GAMS/Cplex solver. The results of ARIMA (1,1,2) calculated in the first phase are used as demands of the customers. Other parameter values are given by the company. As a result, the total cost is approximately 1,110,000 €. The total cost of the unsatisfied demand of the distributor is equal to 126,000 €. For the retailers, the total cost of the unsatisfied demand is equal to 63,000 €. The cost of the distributor falls by about 33% according to the actual cost of the company.

In order to test the model validity and how changes in important variables such as demand, lead time and the number of customers affect the optimal solution and inventory planning of the company, some sensitivity analyses are made. In the previous section, customer demand is predicted by using different forecasting techniques. The results of these methods are used as different demand scenarios in the mathematical model and model is solved according to these scenarios. The results of this analysis are shown in Table 2. As seen in Table 2, exponential smoothing (α=0.9) gives the minimum total cost and ARIMA (1,1,2) has the maximum total cost value. Total inventory cost did not change according to the different demand scenarios. Also, solution time of all scenarios is less than one second.

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Table 2. Results of the mathematical model based on different demand scenarios

Forecasting Method	**Objective Function Value (€)**	**Total cost of Inventory (€)**	**Total cost of unsatisfied demand (€)**	**Solution Time**
Naive	1082924.000	126.000	62298.000	≤ 1 sec
Moving Average (3 weeks)	1060060.250	126.000	39930.000	≤ 1 sec
Moving Average (4 weeks)	1044616.687	126.000	32197.500	≤ 1 sec
Exponential Smoothing (α=0.1)	1079727.456	126.000	61031.456	≤ 1 sec
Exponential Smoothing (α=0.01)	1082679.369	126.000	62226.569	≤ 1 sec
Exponential Smoothing (α=0.9)	937416.546	126.000	22255.936	≤ 1 sec
Regression	1026715.753	126.000	4336.781	≤ 1 sec
ARIMA (1,1,2)	1098551.750	126.000	62298.000	≤ 1 sec
ARIMA (1,1,0)	1084367.258	126.000	62696.592	≤ 1 sec

CONCLUSION

Globalization and increasing competitiveness force companies to build effective supply chains to improve their customer service level. In this study, a two-phased integrated approach is presented to solve multi-echelon, multi-period and multi-product inventory management problem. In the first phase, demand forecasting techniques such as naïve method, moving averages, exponential smoothing, regression and ARIMA methods are compared. As a result of this comparison, moving averages (3 weeks) and ARIMA (1,1,2) give better results according to MAD, MSE, MAPE and RMSE values. In the second phase, a multi-echelon, multi-period and multi-product mixed integer programming model is developed and applied to a real-life case of an IT retailer in Turkey. This mathematical model aims to minimize total inventory holding cost, purchasing costs, and unsatisfied demand (stock-out) costs. According to the solution of the mathematical model shows that the total cost of the company should be reduced by 33% by using multi-echelon inventory management approach.

Due to the complexity of the problem, this model is solved only for one product supplied by only one manufacturer. As a future research, the number of products should be increased. Also, in the literature, there are several studies addressing multi-echelon inventory problem under uncertainty conditions. This study should be also extended to handle uncertain demands and lead times.

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THE ATTITUDES TOWARDS DEVELOPMENT OF LOGISTICS PERSONNEL THROUGH TRAININGS IN POLISH COMPANIES REPRESENTING DIFFERENT SIZES AND TYPES OF BUSINESS ACTIVITY

Edyta Klosa[1]

Abstract. *Nowadays the role of logistics staff in the achievement of corporate goals is perceived by Polish companies as increasingly important. It's also worth noticing a continuous formalization of the logistics function in those companies. As a consequence, more attention is paid to ensure proper qualifications of logistics personnel, among others, by trainings. The main purpose of this paper is to present the attitudes of Polish companies representing different sizes and types of business activity towards organization of trainings for the logistics personnel. In particular, this paper presents the results of research conducted among 402 enterprises. The outcomes presented in this paper made it possible to fulfil the gap in the literature which is related to the development of logistics staff competences. The results can also serve as a guideline for managers responsible for human resources in the area of logistics.*

Keywords – logistics,logistics personnel, logistics competences, trainings

INTRODUCTION

Forces and trends influencing today's businesses like globalization or rapidly improving information technologies make day-to-day reality more demanding for both employers and employees. For the latter ones occupational perspectives seem to be far less definable and predictable, and changing a job is more frequent and difficult than in the past. Thus, today's workers need to constantly develop their skills and competences so that they can become lifelong learners who can use modern technologies, focus rather on flexibility than stability, maintain employability, and create new career development opportunities [12]. On the other hand, today's employers need to possess not only the ability to recruit workers with the above stated skills and competences but also to enhance those skills and competences with various methods of professional development, e.g. trainings.

AN IMPORTANCE OF TRAININGS FOR LOGISTICS STAFF

Logistics management, as a key business function, should be of special interest from the perspective of professional trainings because of its complex nature. Just a quick review of its popular description proposed by CSCMP is enough to understand its extraordinary complexity [2]. The official CSCMP glossary states that this function encompasses, among others: "transportation management, fleet management, warehousing, materials handling, order fulfilment, logistics network design, inventory management, supply/demand planning, and management of providers of third party logistics services". Kisperska-Moroń [5] claims that growing requirements addressed to logistics professionals change patterns of their professional development. In conclusions related to her research project she states, among others, that the value of a logistician is an effect of skills and other competencies she or he has acquired, and that professional career depends rather on preparedness of a worker for potential employment and ability to become an asset for potential employers. Halley and Guilhon [3] add that "logistics is based on sustained human resources management (training, motivation, involvement and hiring) that encourages involvement by all members of the firm".

Unfortunately, Mangan and Christopher claim that the need for data related to the types, quantities and effectiveness of trainings for employers responsible for logistics and supply chain management still exists [7]. The research conducted by Mangan et al. [8] show most common types of training in which participated logistics managers who were their respondents: "formal college, in-house training, seminar/workshop, 'on the job', and in-house training with an external trainer". Thomas and Mizushima [16] imply numerous benefits of a comprehensive, sector-specific logistics training and certification programmes such as effectiveness and increased efficiency of logistic operations or external verification of skills. As this paper deals with business training courses provided by companies (employers or special training agencies) instead of formal courses

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offered by education institutions, it's worth discussing benefits and limitations of the former ones. Palšaitis and Bazaras [10] mention that commercial trainings offer "much more non-formal education methods or group management methods", they are organized in a "very attractive and pleasant form for the participants", and "create comfort and safe atmosphere" for learning. On the other hand, such courses, because of the fact that participants (or their employers) sometimes pay substantial amount of money paid for them, are more focused on offering the "show" instead of providing deep, systematically developing knowledge.

TRAININGS FOR LOGISTICS STAFF FROM THE PERSPECTIVE OF COMPANY'S BUSINESS ACTIVITY TYPE AND SIZE

There is a lack of studies related to the problem of trainings (in general) and trainings in the area of logistics (in particular) in companies representing various business activity types, i.e. manufacturers, service providers and trading companies. This problem can be potentially interesting because different nature of operations managed by those enterprises can result in distinct attitudes towards training of their logistics staff. In the literature we can find studies dedicated to trainings in different sectors separately, such as Kucherov's and Manokhina's research exploring training evaluation practices among Russian manufacturers [6] or Wickramasinghe's and Fonseka's [17] article where they imply some suggestions that human resources are a more critical factor for service providers. However, Wickramasinghe's and Fonseka's [17] admit that they couldn't find studies comparing HR practices between manufacturing and service companies. Again, in the literature there are some interesting studies about trainings for logisticians – for example [9] or [11] – but they don't include comparisons between manufacturers, service providers and trading companies. Thus the first research question (RQ1) was formulated: "What is the approach towards organization of trainings for logistics personnel companies within the sample according to their business activity type?"

The issue worth discussing is also a possible influence of a company's size on the development of its logistics staff through trainings. Most of the authors agree that training investments done by small and medium enterprises (SMEs) are significantly lower than those of larger firms (this can be an effect of financial constraints and fear that well-trained employees will change the employer for a more attractive one). On the other hand, from a content point of view, SMEs needs related to trainings for employees do not differ from those of larger firms [1]. Research projects related to trainings in SMEs bring rather pessimistic conclusions. For example, Thassanabanjong et al. [15] prove that: SMEs' owners or managers tend to provide few if any employees with training for the shortest possible time; they invest negligible percent of their income in training; and that those trainings mostly consist of simple, informal on-the-job instructions. At the same time, Hashim and Wok [4] claim that SMEs can achieve a greater benefit from trainings "than large companies in terms of knowledge and skills, particularly in the area of new technology adoption, new product development and technology transfer". However, the literature review done for the purpose of this paper shows that there is still a lack of publications matching topics of SMEs, trainings, and logistics. Thus the second research question (RQ2) formulated for this study is: "What is the approach towards organization of trainings for logistics personnel companies within the sample according to their size?"

RESEARCH METHODOLOGY

Data used to answer the above stated research questions were derived from a complex data base developed for the purposes of a larger research project in which the author of this paper was involved. That data base was a result of a survey conducted among logisticians representing 402 Polish companies. The sample was selected purposefully – the key factors to include a company in it were: (1) accessibility and willingness of its representatives to participate in a survey, and (2) respondent's experience (only persons working as logisticians at least 1 year could have been chosen as respondents). The survey was based on paper interviewer-administered questionnaires which involved multitude of questions related to different aspects of possessing and developing logistics personnel. Part of the questions included in the questionnaire was related to trainings organized for logistics staff – this part was chosen to answer research questions presented in this paper. In particular, 14 questions (variables) were derived for further quantitative analysis, namely:

- 5 variables describing a surveyed company, i.e. (1) type of business activity, (2) employment volume, (3) existence (or non-existence) of logistics department, (4) number of units responsible for logistics, (5) type of unit responsible for logistics. Variables (1), (3) and (5) were measured by nominal scales, variable (2) was measured by an ordinal scale, and variable (4) was measured by a ratio scale.

- 4 variables describing interlocutors, i.e. (6) sex, (7) age, (8) position in the company, and (9) total years of service on a current position. Variables (6) and (8) were measured by nominal scales and variables (7) and (9) were measured by ordinal scales.
- 5 variables describing attitudes towards organization of trainings, i.e. (10) willingness of the company to organize trainings for logistics staff, (11) subject of trainings organized for logistics staff (12) change in the number of trainings, (13) engagement of logistics staff in organization of trainings, (14) training's provider and character. Each of those variables was measured by nominal scales.

For variables related to surveyed companies and interlocutors basic statistical descriptions were provided (frequencies) and nonparametric one-sample tests comparing observed and hypothesized data were used. In particular, for variables (3) and (6) – because of their dual character – a binominal test was used; for variable (4) being the only one measured by ratio scale a Kolmogorov-Smirnov test was used; and a Chi Square test was used for the rest of variables measured by nominal and ordinal scales (assumed $p \leq 0.05$).
In the main part of the research, because of nominal and ordinal character of scales used to measure explored variables, frequency distribution's and correspondence analysis was conducted [14]. Regarding correspondence analysis assumed number of dimensions in solution was 2, a distance measure was Chi Square and a symmetrical method was used for normalization.
IBM SPSS Statistics tool, ver. 24.0 as well as Microsoft Office Excel 2010 were used to conduct the statistical analysis.

SAMPLE DESCRIPTION

Having in mind the main aim of the research, both in-depth characteristics of companies within the sample (employers who organize trainings) as well as their representatives (respondents being employees for whom the trainings are organized) were crucial for further part of the research. To investigate 9 variables describing the above mentioned issues frequencies were calculated and one-sample nonparametric tests were used to verify their distributions. For all variables, for which Chi Square and binominal tests were used, categories within them occur with different probabilities ($p = 0.000$). A Kolmogorov-Smirnov test used for variable (4) proved that distribution of that variable isn't normal ($p = 0.001$).
Firstly, 402 companies within sample were described according to:

- type of business activity (i.e. manufacturing, trade, services),
- employment volume (i.e. less than 10 employees, 10-49 employees, 50-249 employees, 250 employees and more),
- existence (or non-existence) of a logistics department,
- number of units responsible for logistics,
- type of unit responsible for logistics.

First of all, statistical analysis of data related to variables enlisted above revealed that service providers were the best represented group within the sample (65.2%). It is worth emphasizing that 56.2% of those entities were logistics service providers whereas the rest represented other types of services. 29.9% of the sample was comprised of trading companies and only 5.0% - of manufacturers. Companies within the sample were also analyzed according to the employment volume. The results showed that micro companies (employing less than 10 persons) had 9.5% of share in the sample, small companies (employing from 10 to 49 persons) – 32.6%, medium companies (employing from 50 to 249 persons) – 46.3%, and large companies (employing 250 and more persons) – 11.7%. It is visible that entities of the smallest and largest employment volume were least represented in the sample. Further analysis showed that 76.1.% of the companies have settled a department specifically responsible for logistics, which can suggest that in Polish business environment the logistics concept is rather well recognized and that there is a tendency to formalize it within the organization. On the other hand, a more detailed analysis of the amount and types of units responsible for logistics in the examined companies revealed multitude and inconsistent ways of formalization of this function. Firstly, however, data analysis shown that 65.3% of investigated companies have centralized logistics function within one specific unit, it also revealed various types of positions and units responsible for logistics within that subgroup. Only 36.4% of those companies set up a logistics department – in the remaining cases the following persons or departments were responsible for logistics: company's owner, president/CEO, single person on

especially designated position (other than owner/president/CEO), purchasing department, distribution department, sales/marketing department, transport/forwarding/shipping department, supply chain management department. It is also worth emphasizing that in 34.4% of the entities the responsibility for logistics function is dispersed on more than 1 unit. Within that subgroup 40.6% of the entities have 2 units responsible for logistics, 31.2% - 3 units, 22.5% - 4 units. 5.8% of the companies have even 5-7 units responsible for logistics. Those results imply that implementing such a complex business function as logistics into organizational forms is not easy and that it's difficult to find an obvious way to formalize it.
Data related to interlocutors were also statistically analysed. In particular, the analysis encompassed the following issues:

- sex (female or male),
- age (21-26 years, 27-32 years, 33-38 years, 39-44 years, 45-50 years, 51-56 years, 57-62 years, and 63-68 years),
- position in the company (CEO/director, vice-director, department manager, subdepartment manager, section manager, main specialist, specialist),
- total years of service related to actual positon (1-3 years, 4-6 years, 7-9 years, 10-12 years, 13-15 years, 16 and more years).

According to the results two third of the respondents were males (61.4%). 71.6% of interlocutors were middle-aged persons (from 33 to 50 years old) with a dominant representation of persons being 39-44 years old. Exploration of their positions and working experience showed that the higher their position in the company and experience related to keeping that position is, the lower their share in the sample is. In other words, specialists (60.2%) and main specialists (16.7%) were best represented within the group, whereas vice-directors (2.0%) and CEOs and directors (2.2%) constituted the smallest group. Most of the respondents kept their current position from 1 to 6 years (63.9%) and only 4.5% - for 16 years and longer.

APPROACH TOWARDS ORGANIZATION OF TRAININGS FOR LOGISTICS STAFF ACCORDING TO TYPE OF BUSINESS ACTIVITY AND COMPANY'S SIZE

The main part of the research was related to approach towards organization of trainings for employees responsible for logistics presented by surveyed companies of different business profiles and sizes. In particular, 5 issues describing such approach were investigated, namely:

- willingness of the company to organize trainings for logistics staff (provision or non-provision of trainings);
- subject of trainings organized for logistics staff (logistics, occupational health and safety, marketing/sales, manufacturing, purchasing, finances/accounting, quality management, human resources management, information technologies, company's goods/processes);
- change in the number of trainings (increased number, the same number, decreased number, no trainings for logistics staff);
- engagement of logistics staff in the organization of trainings (decisions about trainings made by HR department only without consulting them with logistics staff; consultations about trainings with logistics staff are organized but not always considered when making decisions; consultations about trainings with logistics staff are organized and always considered when making decision);
- training's provider and character (outdoor company and open formula, outdoor company and closed formula, indoor entity).

For first two of above mentioned issues simple frequency distribution analysis was provided. For the rest of issues initial data review revealed existence of significant relations and because of that, regarding nominal character of scales measuring those variables, correspondence analysis was conducted (assumed $p \leq 0.05$).
At first the attitude towards organization of trainings for logistics personnel was investigated from the perspective of the business activity type of surveyed companies.
The lowest willingness to organize trainings for logistics staff was observed among manufacturing companies (only 50% of their investigated employees were provided with training). Percent share of trained employees in trading and service companies was higher (57.5% and 69.5% respectively), yet still unsatisfying. The most

popular subjects of trainings organized for logisticians were: (1) occupational health and safety (35%) and logistics (15%) – in manufacturing companies; (2) occupational health and safety (43.3%), company's goods and processes (26.7%), and logistics and marketing/sales (24.2%) – in trading companies; (3) logistics (47.3%) and occupational health and safety (32.1%) – in service companies.
The analysis of variables 12-14 revealed, in general, that trading companies seem to differ from service and manufacturing companies (see Figure 1). The analysis of correspondence between change in the number of trainings and type of business activity implied two dimensions, the first of which describes about 90% of the sample (Chi Square value = 59.657, p = 0.000). The results of the correspondence analysis suggested that trading companies had the biggest share (82.8%) in the answer 'no trainings for logistics staff'. On the other hand, service providers were the biggest group of companies which indicated the same (71.7%) and decreased (72.0%) number of trainings. Manufacturer's indications had the largest share (12%) in the declarations about decreased number of trainings.

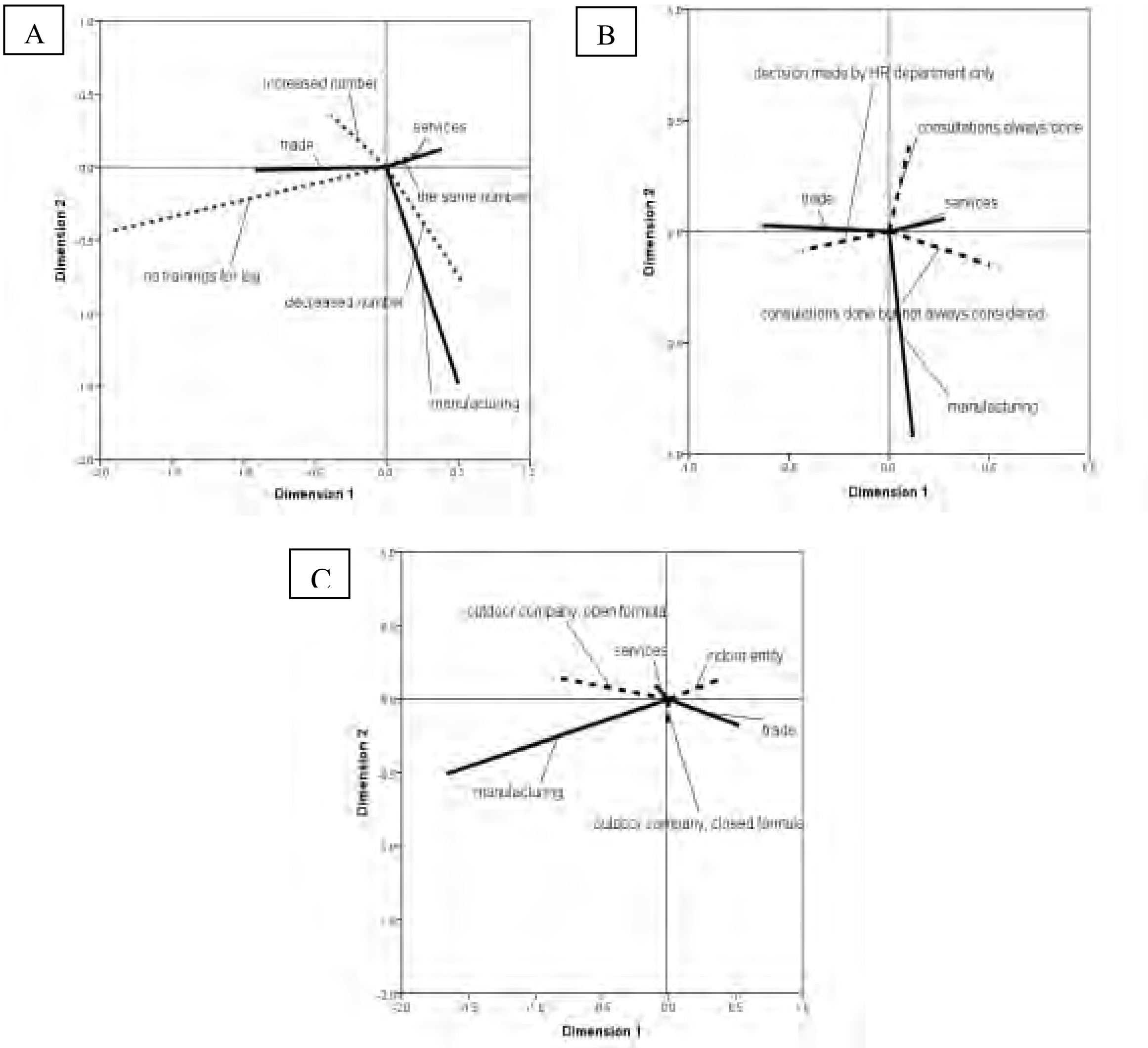

Figure 1. Change in the number of trainings (A), engagement of logistics staff in organization of trainings (B) and training's provider and character (C) from the perspective of business activity type

The correspondence analysis considering the engagement of logistics staff in organization of trainings and type of business activity implied two dimensions, when the first one describes about 93.6 % of the sample (Chi Square value = 12.699, p = 0.013). The largest percentage share of trading companies' answers was most visible for the declaration that decisions about trainings are made by HR department only without consulting them with logistics staff (38.1%). The share of service providers was prevailing for the answer that consultations about trainings with logistics staff take place but are not always considered by the unit responsible for trainings (73.9%). Manufacturer's answers weren't explicitly prevailing in any case, however,

their answers have the biggest share for declarations that decisions about trainings are made by HR department only without consulting them with logistics staff (5.1%) and that consultations about trainings with logistics staff take place but are not always considered by the unit responsible for trainings (6.0%).
Regarding training's provider and character, the analysis implied two dimensions, the first of which describes about 98.3 % of the sample (Chi Square value = 9.361, p = 0.050). Trading companies had biggest share of answers for indoor trainings (31.3%). On the other hand, as far as service providers and manufacturers were concerned the biggest share of indications was observed for trainings conducted by an outdoor company in an open formula (77.3% and 9.1% respectively).
Next, attitude towards organization of trainings for logistics personnel was investigated from the perspective of surveyed companies' size (understood as employment volume). The percent share of trained logisticians equaled: 47.4% in micro-enterprises, 58% in small enterprises, 75.8% in medium enterprises, and 55.3% in large enterprises. The most popular subjects of trainings in the smallest companies were: occupational health and safety (34.2%), marketing/sales, finances/accounting and human resources management (18.4%), and logistics (15.8%). Among small companies the most common subjects were: occupational health and safety (40.5%), logistics (25.2%), and marketing/sales (21.4%). In medium companies two most popular subjects were logistics (57.5%) and occupational health and safety (34.4%). Finally, the most popular trainings in the largest companies were related to: company's goods and processes (34%), occupational health and safety (27.7%), and logistics (21.3%).

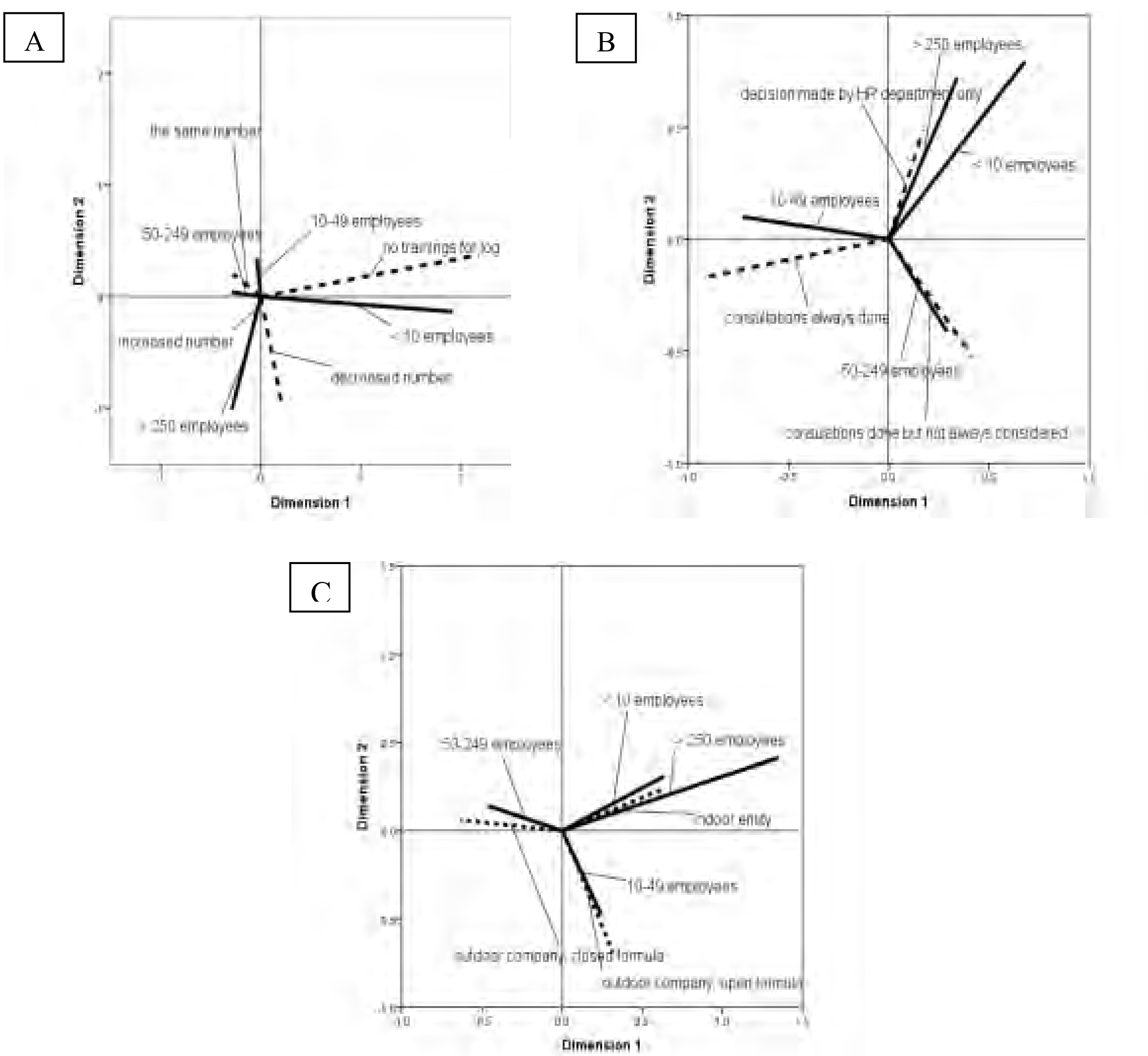

Figure 2. Change in the number of trainings (A), engagement of logistics staff in organization of trainings (B) and training's provider and character (C) from the perspective of company's size

The results of correspondence analysis regarding attitudes towards organization of trainings for logistics staff in companies of different sized are presented on Figure 2. In particular, the analysis of correspondence between change in the number of trainings and company's size implied two dimensions, the first of which describes about 79% of the sample (Chi Square value = 79.533, p = 0.000). The results indicated that large and medium enterprises tend to differ from smaller ones. Large companies had the biggest share (24.0%) in the answer 'decreased number of trainings' and medium companies – in the answer 'increased number of trainings' (58.3%). On the other hand, small companies achieved the biggest share of answers for 'the same number of trainings' (37.1%) and they also have relatively significant share in the answers indicating that the company doesn't organize trainings for logistics staff at all (34.5%). The indications for the latter statement were most frequent for micro enterprises (48.3%).
The correspondence analysis considering engagement of logistics staff in organization of trainings and company's size implied two dimensions, the first of which describes about 64.2 % of the sample (Chi Square value = 46.044, p = 0.000). For this issue small companies tend to differ from large, medium and micro companies. The largest percentage share of medium companies' answers was the most visible for the declaration that decisions consultations about trainings with logistics staff take place but are not always considered by the unit responsible for trainings (61.9%). Small companies achieved the biggest shares in the answers implying that consultations about trainings with logistics staff always take place and are considered by the unit responsible for trainings (54.3%). Finally, the smallest and the largest entities have the biggest share in the answers stating that decisions about trainings are made by HR department only without consulting them with logistics staff (14.2% and 16.5%respectively).
Considering training's provider and character, the analysis implied two dimensions, the first of which describes about 92.0 % of the sample (Chi Square value = 33.273, p = 0.000). In that case medium companies tend to differ from the rest of surveyed entities. They achieved the biggest share in the answers implying that trainings for logistics staff are organized by an outdoor company in a closed formula (70.3%). Small companies have the biggest share in answers indicating that trainings are conducted by an outdoor company in an open formula. Finally, the biggest share in the answers given by the smallest and the largest companies was noticed for indoor trainings (10.1 and 19.2% respectively).

CONCLUSIONS

When answering (RQ1): "What is the approach towards organization of trainings for logistics personnel companies within the sample according to their business activity type?" it can be concluded that manufacturers are less willing to organize trainings for logistics staff then other companies. Logistics was the most popular subject of trainings in service companies when in trading companies it was less popular then trainings in occupational health and safety or company's goods and processes. Trading companies seem to have a different approach towards organizing trainings for logistics staff than service providers and manufacturers. The biggest share of their answers was observed for the following declarations: company organizes no trainings for logistics staff; decisions about trainings are made by HR department only without consulting them with logistics staff; and indoor trainings. On the other hand, the answers of service providers were the most frequent ones for the following statements: company organizes the same or decreased number of trainings; consultations about trainings with logistics staff take place but are not always considered by the unit responsible for trainings; trainings are conducted by an outdoor company in an open formula. For the first and last issue shares of manufacturer's answers were similar to service providers. The result related to organization of the same or even decreased number of trainings by service providers can be seen as contrary to the remarks of Wickramasingh and Fonseka [17] about more and more importance being paid for human resources in those companies.
Considering (RQ2): "What is the approach towards organization of trainings for logistics personnel companies within the sample according to their size?" the analysis implied that medium companies are most willing to organize trainings for their staff – mainly related to logistics. Interesting results were obtained for the largest companies – the analysis revealed they prefer to train logistics staff on their goods and processes while logistics was on the third place. Regarding change in the number of trainings large and medium enterprises tend to differ from smaller ones, in particular, they had the biggest share in the answers indicating changing number of trainings. The results obtained for that issue correspond with Antonioli and Della Torre remarks about lack of funds in SMEs for investment in trainings [1]. Considering engagement of logistics staff in organization of trainings small companies tend to differ from large, medium and micro companies having the biggest share in answers indicating that consultations with logistics staff always take place and are considered

by unit responsible for trainings. Finally, in relation to training's provider and character medium companies tend to differ from the others – they achieved biggest shares of answers implying that trainings are organized by an outdoor company in a closed formula.
However this study presents results of a research conducted among logistics staff from Polish companies only, they can be potentially interesting for managers and investors from other countries. In recent years Poland become one of the largest emerging economy of the European Union and very attractive business partner for companies from other, mostly Western countries. As a result, there is a growing need for skilled logistics workers from Poland [18] and for understanding patterns of trainings provided for them. This paper can be useful to satisfy those needs to a certain extent.

CONCLUSIONS

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THE TWO-PICKER ORDER PICKING PROBLEM

Serhat Saylam[1], Haldun Süral[2], Melih Çelik[3]

Abstract *– In this study, we consider the two-picker order picking problem in a parallel aisle warehouse that contains crossovers only at the end of aisles. We here aim to balance the workload of each of two pickers by minimizing the maximum distance traveled by any one of the pickers while forcing them to use the minimum routes possible by applying a dynamic programming algorithm. By using this heuristic algorithm, we not only approximate an efficient solution for the two-picker order picking problem, but we also get the optimal route for the single order picking problem. So, decision maker can choose to go with either a single picker or two pickers by comparing the results.*

Keywords – Dynamic Programming, order picking, routing, VRP, warehousing.

INTRODUCTION

In this study, we consider the two-picker order picking problem (2P-OPP) in a parallel aisle warehouse that contains crossovers only at the end of aisles. We aim to balance the workload of each picker by minimizing the maximum distance traveled by the pickers while forcing them to use the minimum routes possible.

In the classical vehicle routing problem (VRP) the main objective is to minimize the total overall distance traveled. However, in the order picking problem (OPP) with more than one picker, minimizing the travel distance of the latest picker (min-max VRP) adds value since the order picking process is completed at the latest completion time. It is also a way to balance the workload between pickers. To formulate the problem, we propose a min-max VRP formulation by extending the MTZ formulation proposed by Toth and Vigo [1]. The objective is to minimize the maximum distance traveled by the order pickers. Then, we develop a dynamic programming algorithm by modifying the famous single picker-single block algorithm proposed by Ratliff and Rosenthal [2]. Finally, we consider an example to illustrate the algorithm and compare the performance of the models.

The single-block parallel aisle warehouse considered in this paper is given in Figure 1. It contains crossovers only at the front and back of the pick aisles and no middle cross aisle exists. A picker starts his tour from pickup-and-deposit (P&D) point, collects all the items in the pick list and returns back. P&D point is at the very right bottom corner. Figure 2 shows the graph representation of the routes in the warehouse using edges (*i,j*) along with the location of the ordered items using nodes (v_i) while v_0 is the P&D point. a_j and b_j nodes represent the front and back of pick aisle *j*.

LITERATURE REVIEW

This work is relevant to the OPP and VRP literature. Ratliff and Rosenthal [2] introduced a dynamic programming algorithm for the OPP that runs in $O(m + n)$ time, where *m* is the number of picking aisles and *n* is the number of ordered items. In this algorithm, the number of picking aisles determines the stages, while the location of ordered items determines the length of the possible connections. For each stage, these connections form seven different states using partial tour subgraph (PTS) concept. These states called equivalence classes. The stopping criteria is to form the classes for the last stage and choose the shortest distance solution among the classes satisfying the minimum length completion requirement.

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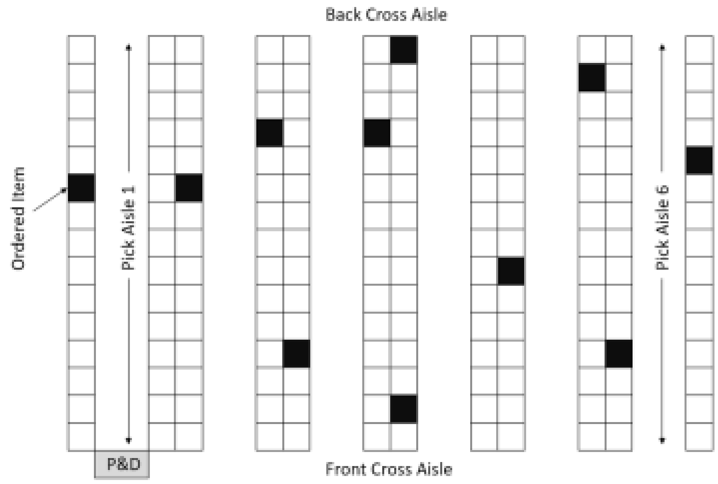

Figure 1. An OPP instance of the single-block parallel aisle warehouse

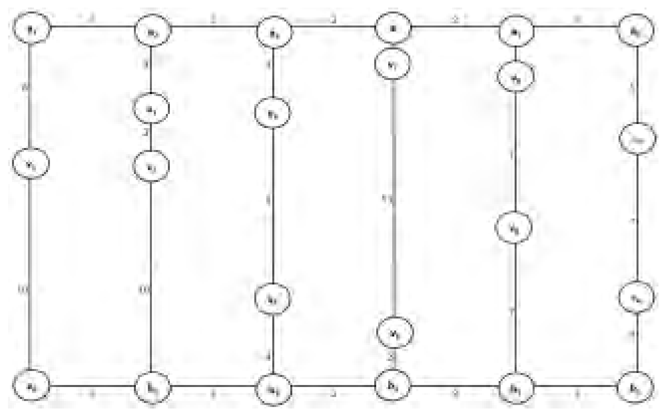

Figure 2. Graph representation of the OPP Instance

Roodbergen and de Koster [4] modified Ratliff and Rosenthal Algorithm for the two-block case, where a middle cross aisle exists in between, by introducing new connection types and equivalence classes. They also concluded that it is difficult to further extend this algorithm for more than two-block cases. For fishbone and V-shaped layouts, Çelik and Süral [5] introduced a linear-time algorithm. The relevant literature also contains several simple heuristics such as S-shape, return, midpoint and largest gap heuristics. For the details of these heuristics, the reader is referred to [3]. For a detailed review of warehouse order picking operations, the reader is referred to [6] and [7].

How can the orders be grouped for the pickers such that the total distance traveled by pickers is minimized? This is called batching and sorting problem, which is another important part of the warehouse operations. Here, partitioning is the main factor of the complexity, hence several linear-time heuristics, such as rule-based algorithms, seed algorithms, savings algorithms and metaheuristics are introduced. Also notice that sorting is required at the end of the picking process since the items picked should be sorted according to customer order or destination. For a detailed review of batching and sorting operations, the reader is referred to [6] and [8]. Since this study tries to balance the workload between pickers and force them to finish order picking process as soon as possible, it is a kind of way to meet the batching problem objective.

VRP, which is a generalization of TSP problem, determines the optimal routes to be traveled by the vehicles visiting a given set of nodes. There are exact and heuristic solution methods for this problem which aims to minimize the total overall distance traveled (MINSUM) including two-index VRP MTZ flow formulation. For a detailed review of VRP literature, the reader is referred to [1].

A VRP FORMULATION MINIMIZING THE TRAVEL DISTANCE OF THE LATEST PICKER

When two-index VRP MTZ flow formulation is used for the 2P-OPP problem, optimal overall distance traveled can be obtained, but this does not balance the workload of pickers partly due to nonexistence of capacity constraint for the pickers. Thus, for an uncapacitated 2-OPP problem, a model, which minimizes the travel distance of the latest picker, is required. To formulate the problem, we need to know the routes of each picker which forces us to use a three-index formulation where k is the index of the picker. In other words, three-index formulation should be used in order to clarify which picker is traversing each arc (i, j).

$$x_{ijk} = \begin{cases} 1, & \text{if } k^{th} \text{ picker is traversing over the arc } (i, j) \\ 0, & \text{otherwise} \end{cases}$$

One of the exact models developed by Toth and Vigo [1] is the three-index VRP MTZ flow formulation where the objective is to minimize the total overall distance traveled. Below, we suggest an extended version of this formulation with the objective of minimizing the maximum distance traveled by any one of the order pickers;

MINMAX: $\min \; L$

subject to

$$\sum_{\substack{i=0 \\ i\neq j}}^{n} \sum_{k=1}^{K} x_{ijk} = 1 \qquad \text{for } j = 1, \dots, n \qquad (1)$$

$$\sum_{\substack{j=0 \\ i\neq j}}^{n} \sum_{k=1}^{K} x_{ijk} = 1 \qquad \text{for } i = 1, \dots, n \qquad (2)$$

$$\sum_{j=1}^{n} x_{0jk} = 1 \qquad \text{for } k = 1, \dots, K \qquad (3)$$

$$\sum_{i=1}^{n} x_{i0k} = 1 \qquad \text{for } k = 1, \dots, K \qquad (4)$$

$$\sum_{\substack{i=0 \\ i\neq j}}^{n} x_{ijk} = \sum_{\substack{l=0 \\ j\neq l}}^{n} x_{jlk} \qquad \text{for } j = 1, \dots, n;\; k = 1, \dots, K \qquad (5)$$

$$u_j - u_i + n \sum_{k=1}^{K} x_{ijk} \leq n - 1 \qquad \text{for } i = 1, \dots, n;\; j = 1, \dots, n; i \neq j \qquad (6)$$

$$1 \leq u_i \leq n \qquad \text{for } i = 1, \dots, n \qquad (7)$$

$$\sum_{i=0}^{n} \sum_{j=0}^{n} c_{ij} x_{ijk} \leq L \qquad \text{for } k = 1, \dots, K \qquad (8)$$

$$x_{ijk} \text{ binary} \qquad \text{for } i = 1, \dots, n;\; j = 1, \dots, n; i \neq j \qquad (9)$$

In this extended formulation, the objective is to minimize the distance traveled by the latest picker. Constraints (1) and (2) state that each pick location is visited exactly once by one of the pickers. (3) and (4) state that exactly K pickers leave and return to the P&D point. (5) guarantees a tour for each picker. The additional variable u_i indicates the load of a picker after picking the *ith* item. (6) is the subtour elimination constraint since a contradiction ($u_i > u_j > \dots > u_i$) occurs when there is a subtour $(i, j, \dots, i)$ not containing the P&D point. (7) states that capacity of a picker cannot be more than total number of ordered items. Capacitated version can be obtained by modifying this and the previous constraints. (8) ensures that the distance traveled by each picker cannot be more than the latest tour, L, which is to be minimized in the objective function.

A MODIFIED DYNAMIC PROGRAMMING ALGORITHM

Since, the VRP problem is NP-hard, we develop a dynamic programming algorithm by modifying the single picker-single block algorithm given by Ratliff and Rosenthal [2] to reach a polynomial-time heuristic solution. We here try to balance the workload of two pickers while forcing them to use the minimum routes possible. This algorithm gets a near optimum solution *at most* at $O\ (m^2 + n)$ time where m is the number of picking aisles and n is the number of ordered items. Moreover, the solution time reduces down to $O\ (2m + n)$ if a class based storage policy, where fast-moving items are stored in the region closest to P&D point, is applied.

The algorithm consists of m *stages* where m is the number of pick aisles. Two substages for each aisle to focus are subgraph L_j^- and subgraph L_j^+. Subgraph L_j^- contains the nodes a_j and b_j, front and back of the picking aisle j, together with all nodes and minimum tour construction edges of graph G at the left of these two nodes. Subgraph L_j^+ additionally contains all nodes and minimum tour construction edges of picking aisle j of G. Then an L_j exists when $L_j = L_j^-$ or $L_j = L_j^+$. A PTS is a subgraph T_j of L_j where a completion exists with nodes and edges not included in L_j, such that union of T_j and completion forms a feasible order picking tour. Each substage has a number of equal *states* called equivalence classes, which can be represented by their (i) degree parity at a_j, (ii) degree parity at b_j and (iii) connectivity. Degree parities can be zero *(0),* even *(E)* or odd *(U),* while connectivity can be *0C*, *1C* or *2C*. Also, remember that the P&D point is assumed to be at the very right bottom corner. Then, any L_j PTS can be represented by any one of the equivalence classes $(U, U, 1C)$, $(E, 0, 1C)$, $(0, E, 1C)$, $(E, E, 1C)$, $(E, E, 2C)$ and $(0, 0, 1C)$. These states are updated through stages using the possible *connections* between states called connection types. There are two different connection types; connection types within an aisle (Figure 3(a)) and connection types between two neighboring aisles (Figure 3(b)).

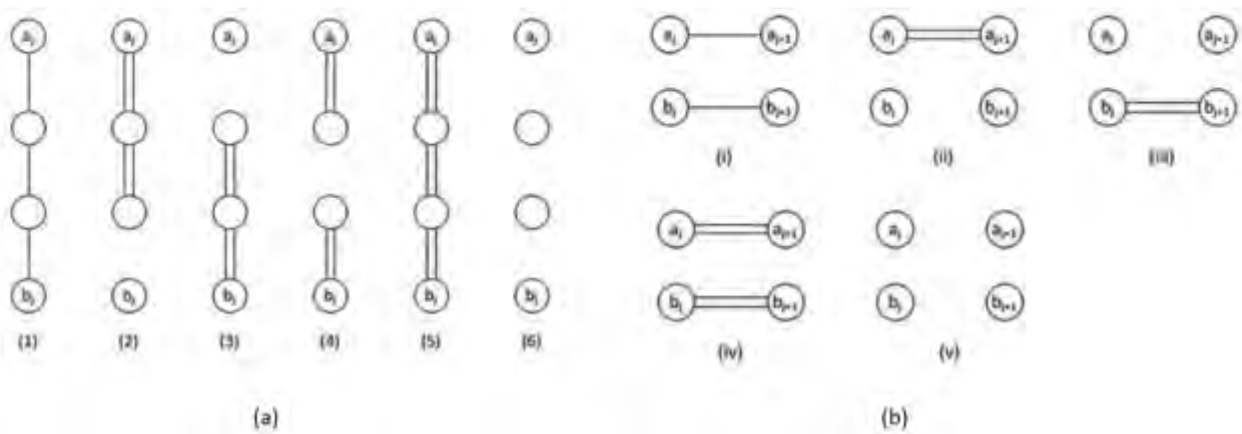

Figure 3. (a) Possible Connection Types within an Aisle, (b) Possible Connection Types Between Two Neighboring Aisles

At substage L_j^-, minimum tour lengths for each state are found by adding the possible connection types in Figure 3(b) to the minimum tour lengths of substage L_{j-1}^+ using the transition Table 2. At substage L_j^+, minimum tour lengths for each state are found by adding the possible connection types in Figure 3(a) to the minimum tour lengths of substage L_j^- using the transition Table 1.

Table 1. The L_j^+ Equivalence Classes that Result from Adding Each of the Connection Types in Figure 3(a) to the L_j^- Equivalence Classes

L_j^- equivalence classes	Intra-aisle connection types in Figure 3(a)					
	(1)	(2)	(3)	(4)	(5)	(6)
(U,U,1C)	(E,E,1C)	(U,U,1C)	(U,U,1C)	(U,U,1C)	(U,U,1C)	(U,U,1C)
(E,0,1C)	(U,U,1C)	(E,0,1C)	(E,E,2C)	(E,E,2C)	(E,E,1C)	(E,0,1C)
(0,E,1C)	(U,U,1C)	(E,E,2C)	(0,E,1C)	(E,E,2C)	(E,E,1C)	(0,E,1C)
(E,E,1C)	(U,U,1C)	(E,E,1C)	(E,E,1C)	(E,E,1C)	(E,E,1C)	(E,E,1C)
(E,E,2C)	(U,U,1C)	(E,E,2C)	(E,E,2C)	(E,E,2C)	(E,E,1C)	(E,E,2C)
(0,0,1C)	–	–	–	–	–	(0,0,1C)

Table 2. The L_{j+1}^- Equivalence Classes that Result from Adding Each of the Connection Types in Figure 3(b) to the PTSs in the L_j^+ Equivalence Classes

L_j^+ equivalence classes	Inter-aisle connection types in Figure 3(b)				
	(i)	(ii)	(iii)	(iv)	(v)
(U,U,1C)	(U,U,1C)	–	–	–	–
(E,0,1C)	–	(E,0,1C)	–	(E,E,2C)	(0,0,1C)
(0,E,1C)	–	–	(0,E,1C)	(E,E,2C)	(0,0,1C)
(E,E,1C)	–	(E,0,1C)	(0,E,1C)	(E,E,1C)	(0,0,1C)
(E,E,2C)	–	–	–	(E,E,2C)	–
(0,0,1C)	–	–	–	–	(0,0,1C)

Next, the first aisle is assigned to the first picker, the rest of the aisles are assigned to the second picker and minimum tour length for each picker is found. Then, first two aisles are assigned to the first picker, the rest is assigned to the second picker and minimum tour lengths are found. This loop continues until minimum tour length of the first picker becomes greater than the one of the second picker. This is the stopping criteria of the algorithm. The maximum distance traveled at the last loop, where the minimum tour length of the first picker becomes greater than the one of the second picker, and the previous loop is compared and the smaller one of these two maximums is found. This is the solution of the algorithm. So, we find a near optimal minmax solution for 2P-OPP problem while balancing the workload of the pickers and forcing them to use the minimum routes. The pseudo-code of the algorithm is depicted in the appendix.

NUMERICAL EXAMPLE

For the example given in Figure 2, we demonstrate the solutions of the model MINSUM and the proposed model MINMAX, implemented in AMPL. The solution of the proposed algorithm is encoded in C++ using Microsoft Visual Studio 2015. Figure 4(a), (b) and (c) demonstrates the resulting tours of the solution methods respectively.

MINSUM model minimizes the total distance traveled and finds 112 distance units, however the difference between pickers' traveled distances is large and the P&D point is active for 92 distance units. The proposed MINMAX model minimizes the maximum distance traveled and finds 58 distance units. Thus P&D point is active only for 58 distance units. Moreover, the difference between pickers is only 2 distance units. However, note that the solution time will increase drastically with the increase in the number of ordered items. On the other hand, the proposed algorithm tries to find a near optimal solution for the MINMAX problem, and finds 62 distance units. The difference between pickers is only 10 distance units and the solution time linearly depends on the number of aisles and solution time will increase only slightly with the increase in the number of ordered items. The solution approach is shown on Table 3.

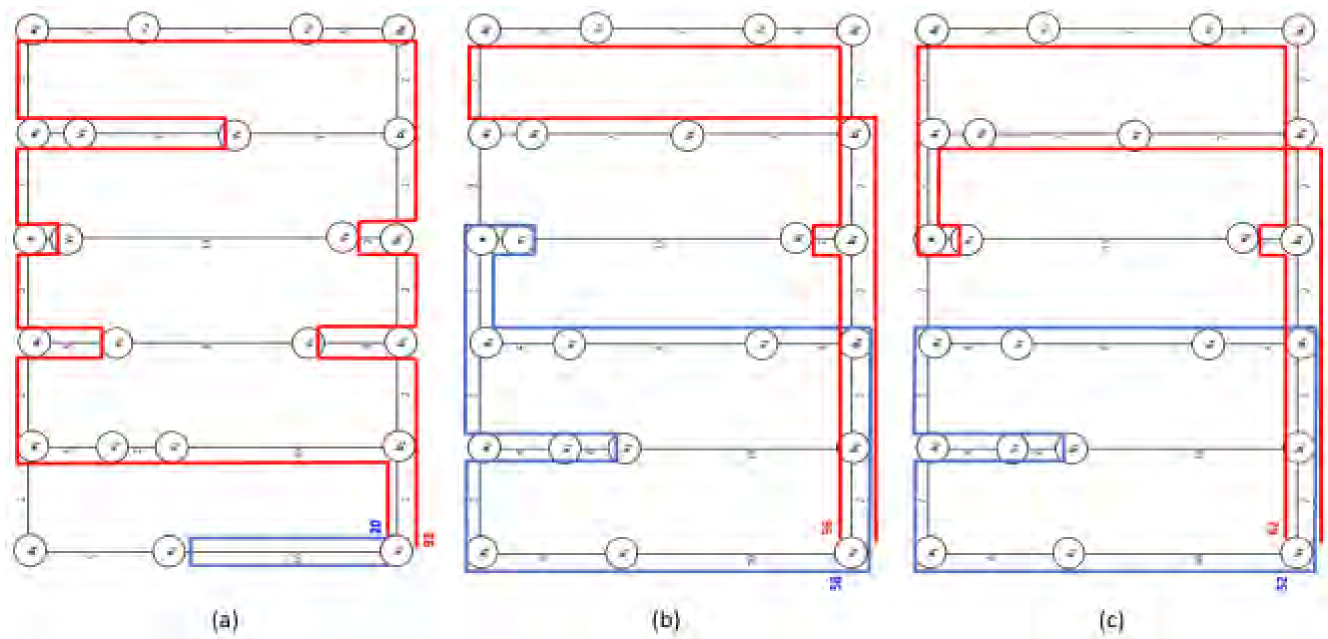

Figure 4. The minimum distance solutions of (a) MINSUM, (b) MINMAX and (c) the algorithm for the example in Figure 2

Table 3. The solution approach of the proposed algorithm

Picker 1		Picker 2			
Aisles Assigned	Minimum Tour Length	Aisles Assigned	Minimum Tour Length	Absolute Difference	
{}	0	{1, 2, 3, 4, 5, 6}	104*	104	*Minimum Tour Length for 1P-OPP
{1}	20	{2, 3, 4, 5, 6}	92	72	
{1, 2}	36	{3, 4, 5, 6}	76	40	
{1, 2, 3}	52	{4, 5, 6}	62**	10	**Aproximate Solution for MINMAX 2P-OPP
{1, 2, 3, 4}	66	{5, 6}	52	14	

COMPUTATIONAL EXPERIMENTS

In this section, the performance of the heuristic algorithm is tested on a small number of randomly generated instances. We aim to test the performance of the algorithm by finding the optimality gap of the heuristic algorithm. The summary of the results is given on Table 4. MINSUM solution, Z^*_{MINSUM}, represents the optimal distance traveled for single-picker OPP. MINMAX solution, Z^*_{MINMAX}, represents the optimal travel distance of the latest picker for 2P-OPP. Heuristic algorithm solution, Z_H, represents the travel distance of the latest picker in the solution of the algorithm. We denote by GAP the travel distance gap of the algorithm solution from the optimal MINMAX solution. In other words, $GAP = \frac{Z_H - Z^*_{MINMAX}}{Z^*_{MINMAX}}$. Savings represent the percent distance savings when two pickers are used instead of one picker. So, decision maker can choose to go with either a single picker or two pickers by comparing the results. The results in Table 4 show that using the proposed polynomial-time algorithm leads to either no gap or small gaps when compared to the MINMAX model.

Table 4. Summary of the computational experiments

				Solutions				Savings	
Aisles	Length	Items	Instance	MINSUM	MINMAX	Algorithm	GAP	MINMAX	Algorithm
7	10	10	1	66	44	44	0.0%	33.3%	33.3%
7	10	10	2	60	40	40	0.0%	33.3%	33.3%
7	10	10	3	54	36	36	0.0%	33.3%	33.3%
7	20	10	1	104	68	70	2.9%	34.6%	32.7%
7	20	10	2	106	60	60	0.0%	43.4%	43.4%
7	20	10	3	104	64	68	6.3%	38.5%	34.6%
15	10	10	1	112	80	82	2.5%	28.6%	26.8%
15	10	10	2	88	72	72	0.0%	18.2%	18.2%
15	10	10	3	112	76	78	2.6%	32.1%	30.4%
15	20	10	1	160	96	102	6.3%	40.0%	36.3%
15	20	10	2	100	88	88	0.0%	12.0%	12.0%
15	20	10	3	136	96	96	0.0%	29.4%	29.4%

CONCLUSION AND FUTURE WORK

This study is a part of an ongoing work aiming to find exact and heuristic algorithms for NP-hard problems regarding warehouse operations. Using the proposed algorithm for each picker, we find a near optimal minmax solution in polynomial time for the 2P-OPP problem while balancing the workload of the pickers and forcing them to use the minimum routes. The next extension of this paper is to test the performance of this heuristic approach on a large set of randomly generated instances and compare the results by finding the integrality gaps between the algorithm and the optimal solutions of MINMAX problem. Also notice that the difference between optimal MINMAX solution and the solution of the algorithm lies on the fact that the algorithm dos not consider splitting an aisle into both pickers. Such an extension will lead to an exact algorithm for the 2P-OPP problem. By focusing on minimizing the latest tour, the interaction between batching and routing is also automatically taken into account. It is also an advantage of the algorithm that it will terminate much faster when class based storage policy is applied. A parallel programming version of this algorithm may reduce the solution time significantly, since comparisons in the algorithm are independent of each other. The heuristics proposed by Hall [3] can also be applied for 2P-OPP problem using the algorithm suggested in this paper. It also seems that for an n-picker order picking problem the solution time will increase to $O(m^m + n)$.

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Appendix. Pseudo-code for the Dynamic Programming Algorithm

Input: data containing location of the picking items, number of picking aisles, length of cross aisle between two neighboring picking aisles. P&D point is the very right bottom corner.

for picking aisles $j = 1\ to\ m$ **do**

- compute the lengths of possible connection types within each aisle j using Figure 3.

end for

for equivalence classes $i = 1\ to\ 6$

do

-compute the length ${L_1}^+$ of class i.

end for

for picking aisles $j = 1\ to\ m$ **do**

for picking aisles $k = 2\ to\ j$ **do**

for equivalence classes $i = 1\ to\ 6$ **do**

-compute and determine the ${L_{k-1}}^-$ and ${L_k}^+$ PTSs of class i with the minimum length sum using tables 2 and 3.

end for

end for

-out of classes 2, 3, 4 and 6; determine "the ${L_j}^+$ PTS with the minimum length sum"

for equivalence classes $i = 1\ to\ 6$ **do**

-compute the length ${L_{j+1}}^+$ of class i (also take the P&D point into account)

end for

for picking aisles $l = j + 2\ to\ m$

do

for equivalence classes $i = 1\ to\ 6$ **do**

-compute and determine the ${L_{l-1}}^-$ and ${L_l}^+$ PTS of class i with the minimum length sum using Tables 2 and 3.

end for

end for

-out of classes 2, 3, 4 and 6; determine "the ${L_m}^+$ PTS with the minimum length sum"

-compute "the maximum for aisle j" by comparing "the ${L_j}^+$ PTS with the minimum length sum" and "the ${L_m}^+$ PTS with the minimum length sum" for aisle j

if

"the ${L_m}^+$ PTS with the minimum length sum" is **less than or equal to** "the ${L_j}^+$ PTS with the minimum length sum"

break

if

-the "the maximum for aisle j" is **less than** the "the maximum for aisle $j - 1$"

-set the MinMax to "the maximum for aisle j"

else

-set the MinMax to "the maximum for aisle $j - 1$"

ANT COLONY METAHEURISTIC FOR QUAY CRANE SEQUENCING IN CONTAINER TERMINALS

Fahrettin Eldemir [1], Mustafa E. Taner [2]

Abstract *− The worldwide container transportation shows a considerable growth in recent years. Therefore, efficiency and optimization is an indispensable need for the container terminals which are the gates of countries opening to the world. Terminal efficiency is developed by the effective usage of the cranes at berths and storage area, and of transporters between these areas. In this paper, the focus is on the quay crane operations in non-automated container terminals. For this purpose, a novel methodology that comprises the employment of the ant colony optimization metaheuristic is proposed to sequence and schedule the quay crane operations. In order to test the proposed methodology, various scenario analyses in different sizes are taken from the literature and the results obtained from these tests are analyzed statistically. The process completion time is used as the performance measure. It has been observed that the methodology can provide results that can be applied in container terminals.*

Keywords − Ant Colony Optimization, Container Terminal Operations, Quay Crane Scheduling,

INTRODUCTION

In international trade, exports and imports are increasing on a global scale and an important share of world trade is carried out via container vessels. Since the middle of the 20th century, many types of cargos are being containerized. Due to the technological developments in maritime industry, the vessels have been faster and higher capacity. Therefore, improving the efficiency of container shipping processes especially container terminal operations has the importance than ever.

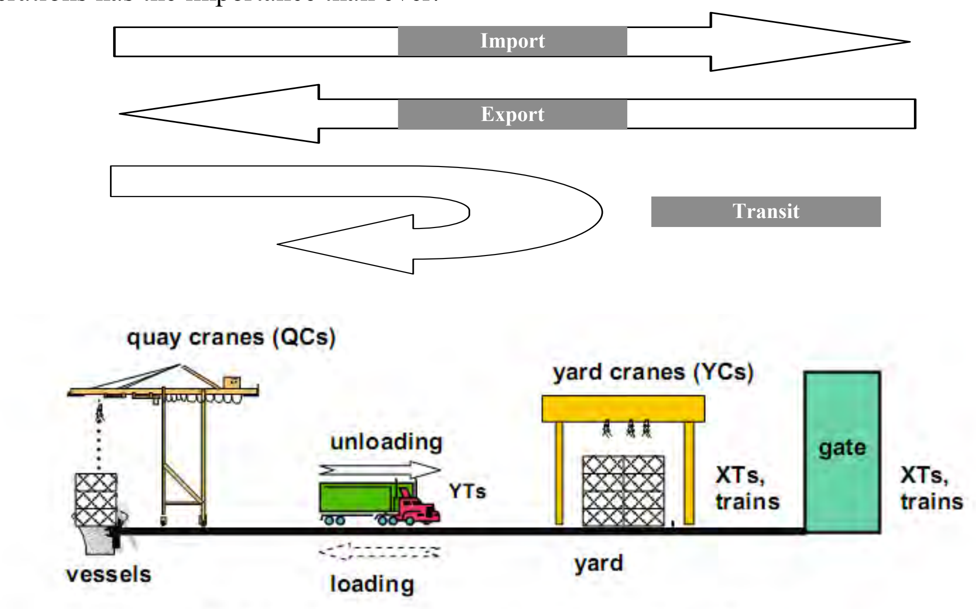

Figure 1. Terminal Services and Equipment [1]

In seaports, container terminals are the places where the container vessels are loaded and unloaded, and where the containerized cargo is temporarily stored while awaiting a future transportation. There are three types of services such as import, export and transit are executed according to the container trade types in container terminals. One of these services is for import during which containers come by vessel and exit from gate; the other one is for export during which containers come by external transporters (XTs) and exit from berth by vessel; the last one is for transit during which containers come by vessel and exit by another vessel.

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Different equipment are used while these services are being executed. In figure 1, services executed in a container terminal, transportation and handling operations and the equipment used during the operations are shown. Three types of equipment are used in terminals. These equipment are; firstly quay cranes used for unloading/loading the container from/to vessel, secondly yard cranes used for stacking containers at yards for unloading/loading the container from/to transport vehicle, and lastly the transport vehicles such as yard trucks (YTs) especially preferred in non-automated container terminals used for transport operations between berth and yard.

In this paper, the focus is on quay crane operations in non-automated container terminals. For this purpose, a novel methodology that comprises the employment of the ant colony optimization metaheuristic is proposed to sequence and schedule the quay crane operations.

Quay crane operations are the pacemaker process in a container terminal. While the handling operations on the vessel bays are being executed, the reshuffle containers are going to be unloaded from vessel in minimum number and of course temporary handle in the current bay of the vessel by the help of the proposed model. In this way, there is a significant saving in terms of total process count and process time.

Quay crane scheduling problem can be considered as Travelling Salesman Problem if there is only one operating crane. Since there are more than one operating quay cranes, the problem is very similar to Vehicle Routing Problem which is NP-hard. The only difference is that the cranes may interact with each other since only one crane can operate in a specific bay. Therefore for large problems, it is impossible to solve in reasonable times. Because of that, it is advisable to use heuristics in solving these problems. In this paper, the ant colony metaheuristic will be used for the solution. In the next section, relevant literature is summarized briefly. The proposed model is presented in Section 3 and the solution methodology is given in Section 4. Finally, the results obtained from tests are investigated and the study is concluded.

LITERATURE REVIEW

The quay crane scheduling problem is the trendy topic in scientific maritime literature. A mixed integer programming model has formulated by [2] that deals with various constraints associated with the quay crane schedules. The model is solved with Branch and bound algorithm. In addition, a greedy heurist algorithm called GRASP is proposed. In another study Branch and Cut algorithm is proposed as an alternative [3].The interferences of the cranes are introduced to the models by [4]. Later a fast heuristic for crane interference that utilizes Branch and Bound at its core is applied [5]. Availabilities of the vessels are restricted in certain time windows by [6]. As the number of studies grew and the number of models for the quay crane scheduling problem increased, a unified approach is needed to evaluate different models and this evaluation is done by [7]. Later a more comprehensive model that deals with parameters such as safety requirements, due dates, ready times and service rates is introduced by [8]. The problem has been addressed also as partitioning problem to distribute the container handling of the cranes evenly and solution procedures and heuristics are provided [9]. Recently, metaheuristic solutions to the quay crane scheduling problem started to be proposed by researchers. Genetic Algorithms solutions are provided by [10-12]. Hybrid models that combine Genetic Algorithms, Genetic Programming and Local Search are also proposed by [13]. Work load balancing model of the quay cranes schedules are also solved by Genetic Algorithms [14]. A hybrid estimation of distribution algorithm is propped by [15] for the quay crane scheduling problem. Constrain Programming [16] and Unidirectional Scheduling [17] models are developed in addition to the existing models.

Especially in huge container terminals, quay cranes are assigned to the vessel and quay crane operations are scheduled after the vessel is assigned to alternative quayside. Therefore, berth allocation problem and quay crane scheduling problem have to be solved simultaneously. Many studies in the literature are focused on this integrated problem. [18-21] are the most important studies. Lagrangean relaxation, genetic algorithm, simulation-optimization and branch and cut algorithm are used to solve the problem in these studies.

In this study, we focus on the quay crane scheduling problem. Double-cycle rule and temporary handling on vessel strategies are the unique from the other studies. Besides, the problem is firstly considered with ant colony optimization under these rules and strategies.

MODEL DESCRIPTION

In this study, the aim is to find the optimum job scheduling configuration which provides the minimum total process times of quay cranes (Figure 2). The sets, indices, parameters, decision variables, objective function and constraints of the model are given below:

Sets:

$\mathbf{N} = \{\mathbf{1}, \mathbf{2}, \dots, \mathbf{n}\}$	: the set of container jobs
$\mathbf{Q} = \{\mathbf{1}, \mathbf{2}, \dots, \mathbf{q}\}$	: the set of quay cranes
$\mathbf{B} = \{\mathbf{1}, \mathbf{2}, \dots, \mathbf{b}\}$	: the set of bays
$\mathbf{R} = \{\mathbf{1}, \mathbf{2}, \dots, \mathbf{r}\}$	: the set of positions

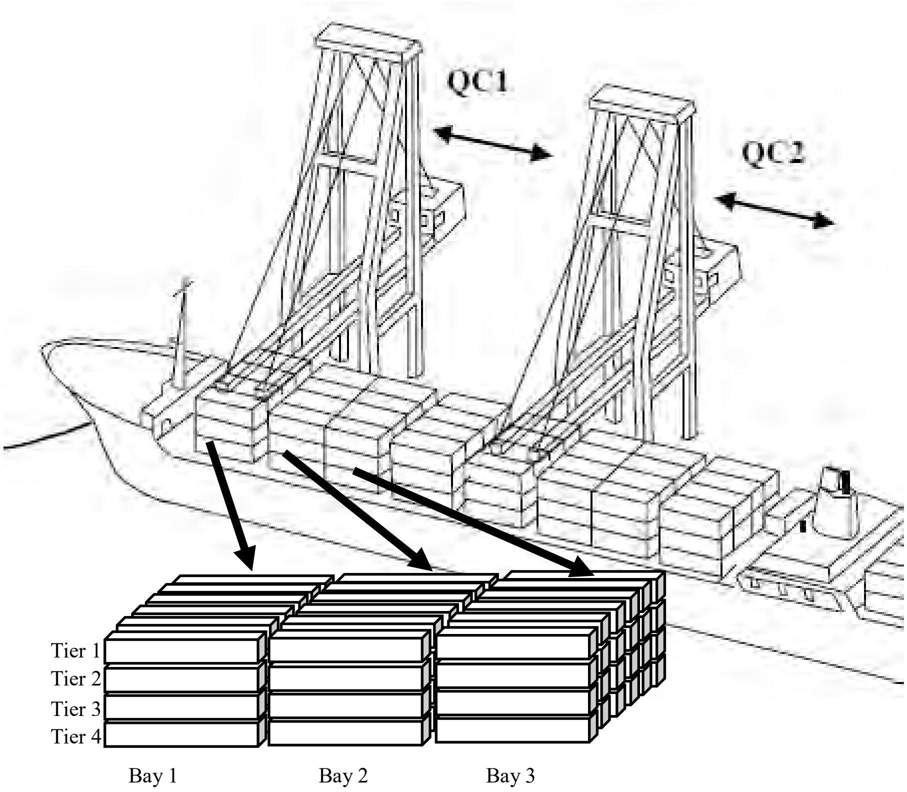

Figure 2. Ship Loading/Unloading and Quay Cranes (adapted from [2])

Indices:

$\mathbf{i}, \mathbf{j} \in \mathbf{N}$	: jobs
$\mathbf{s} \in \mathbf{N}$	: job sequence
$\mathbf{q} \in \mathbf{Q}$	: quay cranes
$\mathbf{b} \in \mathbf{B}$	: bay number
$\mathbf{r} \in \mathbf{R}$	: position number
$\boldsymbol{n}$	: number of container jobs
$\boldsymbol{q}$	: number of quay cranes
$\mathbf{b}$	: number of bays
$\boldsymbol{vqx_q}$	: the operation speed of q^{th} quay crane in x coordinate
$\boldsymbol{vqy_q}$	: operation speed of q^{th} quay crane in y coordinate
$\boldsymbol{dqx_{qi}}$	: travel distance of q^{th} quay crane in x coordinate for i^{th} job
$\boldsymbol{dqy_{qi}}$	: travel distance of q^{th} quay crane in y coordinate for i^{th} job
$\boldsymbol{dqx_{qirt}}$	: travel distance of q^{th} quay crane from r^{th} position to t^{th} position in x coordinate for i^{th} re-handled container job
$\boldsymbol{dqy_{qirt}}$	: travel distance of q^{th} quay crane from r^{th} position to t^{th} position in y coordinate for i^{th} re-handled container job
$\boldsymbol{J_{bb1}}$	: required distance between two quay cranes
$\boldsymbol{e_{iq}}$	: it shows which jobs can be done by which quay crane (if i^{th} job can be done by q^{th} quay crane, it is equal to 1; otherwise it is 0)

w_{ib}	: it shows which job is on which bay (if i[th] job is on b[th] bay, it is one; otherwise it is 0)
R_r	: it shows which job is on which berth position or on which ship (if a re-handled container on r[th] position has a target location on ship, it is 1; otherwise it is 0)
G_{ijqq1}	: security distance between two quay cranes
B_i	: bay of i[th] job
St_q	: transit time of quay crane between two bays (setup time)
D_i	: if the job is incoming job, 1; if the job is outgoing, it is 0.
QR	: extra handling time of quay cranes
PTQ_q	: duration of the quay crane which has the greatest completion time
S_q	: starting time of the first job of q[th] quay crane
F_q	: finishing time of the last job of q[th] quay crane
s_{qi}	: starting time of i[th] job of q[th] quay crane
f_{qi}	: finishing time of i[th] job of q[th] quay crane
x_{isq}	: if the i[th] job in s[th] order is assigned to q[th] quay crane, it is 1; otherwise, it is 0.
Z_{ij}	: if there is j[th] job after finishing i[th] job, 1; otherwise, 0.

Objective Function:

The first aim of the problem is to minimize the process time of the quay crane which has the maximum finishing time on berth.

$$Min\ Z = PTQ_q \quad \textbf{(1)}$$

The second aim of the problem is to minimize extra handling time of quay cranes.

$$Min\ Z = QR \quad \textbf{(2)}$$

Constraints:

The starting times of the jobs have to start after time 0 and (3) is for to guarantee this requirement. (4) is for to calculate the starting times of all jobs for quay cranes. If there is any bay difference, a setup time is added to the equation. The finishing times of all jobs for quay cranes are shown in (5). While (6) is about to calculate the starting time of first job for quay crane, in (7) the finishing time of the last job of quay cranes is calculated. On the other hand, (8) is about to find the finishing time of the last job for the quay crane which has the greatest completion time. (9) guarantees that the completion time of the next job is greater then the completion time of the previous job, for the cranes. Also, (10) guarantees that the starting time of the next job is greater than the starting time of the previous job. In (11), at any given quay crane, no more than one job assignment is allowed in any order. (12) guarantees the assignment of all the jobs to a quay crane in any order. (13) assigns every job to a quay crane which is capable of operating that particular job. (14) is for to guarantee that all the jobs to be scheduled that quay cranes are assigned in consecutive order so that there is no space in the sequence. (15) allows quay cranes to travel one way between jobs and thus eliminates sub-tours. (16-19) guarantee the security distance between quay cranes.

$$s_{qi} \geq 0\ , \forall\ i, q \quad \textbf{(3)}$$

$$s_{qi} = \left(f_{qi} + \left[\left(B_i - B_j\right) \cdot St_q\right]\right) \cdot Z_{ij}\ , \forall\ q, i\ and\ i \neq j \quad \textbf{(4)}$$

$$f_{qi} = s_{qi} + \left(dqx_{qi}/vqx_q\right) + \left(dqy_{qi}/vqy_q\right) + \sum r\left[R_r \cdot \left(\left(dqx_{qirt}/vqx_q\right) + \left(dqy_{qirt}/vqy_q\right)\right)\right], \forall\, q, i \quad (5)$$

$$s_q = min\{s_{qi}\}, \forall\, q, i \quad (6)$$

$$F_q = max\{f_{qi}\}, \forall\, q, i \quad (7)$$

$$PTQ_q = max\{F_q, S_q\}, \forall\, q \quad (8)$$

$$f_{qi} - \left[\left(dqx_{qi}/vqx_q\right) + \left(dqy_{qi}/vqy_q\right) + \sum r\left[R_r \cdot \left(\left(dqx_{qirt}/vqx_q\right) + \left(dqy_{qirt}/vqy_q\right)\right)\right]\right] + M \cdot Z_{ij} \geq f_{qi}, \forall\, q, i, j \quad (9)$$

$$s_{qi} + \left[\left(dqx_{qi}/vqx_q\right) + \left(dqy_{qi}/vqy_q\right) + \sum r\left[R_r \cdot \left(\left(dqx_{qirt}/vqx_q\right) + \left(dqy_{qirt}/vqy_q\right)\right)\right]\right] \leq s_{qj} + M \cdot Z_{ij}, \forall\, q, i, j \quad (10)$$

$$\sum_i x_{isq} \leq 1, \forall\, s, q \quad (11)$$

$$\sum s \sum_q x_{isq} = 1, \forall\, i \quad (12)$$

$$e_{iq} + w_{ib} \geq 2 \cdot x_{isq}, \forall\, i, s, q, b \quad (13)$$

$$\sum_j x_{jsq} - \sum_i x_{i\,s-1\,q} \leq 0, \forall\, s > 1, q \quad (14)$$

$$x_{jsq} + x_{i\,s-1\,q} \leq 1, \forall\, i, s, q \quad (15)$$

$$G_{ijqq1} = B_i - B_j + J_{bb1}, q < q_1 \quad (16)$$

$$G_{ijqq1} = B_j - B_i + J_{bb1}, q > q_1 \quad (17)$$

$$G_{ijqq1} + f_{qi} + \left(dqx_{qi}/vqx_q\right) + \left(\frac{dqy_{qi}}{vqy_q} + \sum r\left[R_r \cdot \left(\left(dqx_{qirt}/vqx_q\right) + \left(dqy_{qirt}/vqy_q\right)\right)\right]\right) - f_{qj} \leq M \cdot \left(3 - Z_{ij} - \sum_i xq_{isq} + \sum_j xq_{jsq_1}\right), \forall\, i, q, j, q_1, i \neq j \quad (18)$$

$$G_{ijqq1} + f_{qj} + \left(dqx_{qi}/vqx_q\right) + \left(\frac{dqy_{qi}}{vqy_q} + \sum r\left[R_r \cdot \left(\left(dqx_{qirt}/vqx_q\right) + \left(dqy_{qirt}/vqy_q\right)\right)\right]\right) - f_{qi} \leq M \cdot \left(3 - Z_{ji} - \sum_i xq_{isq} + \sum_j xq_{jsq_1}\right), \forall\, i, q, j, q_1, i \neq j \quad (19)$$

For the all quay cranes, sum of the times of re-handling and non-double-cycling movements are calculated. Thus, it is aimed to reduce the duration of ineffective operations of the quay crane, which is critical on makespan, as well as of non-critical quay crane.

$$QR = \sum_q \left((F_q - S_q) - \left(\sum_q \sum_i \left((dqx_{qi}/vqx_q) + (dqy_{qi}/vqy_q) \right) - \sum_i (s_{qi} - z_{ti}) \right) \right) \quad \textbf{(20)}$$

The last two constraints are non-negativity constraints.

$$Z_{ij}, x_{isq} \in \{0,1\}, \forall\, i, j, s, q \; ve \; i \neq j \quad \textbf{(21)}$$

$$s_{qi}, f_{qi}, S_q, F_q \geq 1, \forall\, i, q \quad \textbf{(22)}$$

ANT COLONY OPTIMIZATION AND NUMERICAL EXAMPLE

Because of the complexity of the problem it is very hard to solve this problem with traditional optimization methods. Therefore, as mentioned earlier heuristics are applied in the literature. In this section the ant colony optimization (ACO) which is proposed by Dorigo[22] is applied to the crane scheduling problem. The ACOs are metaheuristics that are inspired by the collective behavior of the real ants in the nature. The ACO is a multiagent algorithm and each agent imitates the behavior of real ant. The ACO has been found useful in combinatorial optimization problems such as; production scheduling, assignment and vehicle routing. It has been observed by Goss et al[23] in an experiment shown in figure 3 that the simple behaviors of the ants perform a complex task. In the experiment each ant tries different route reach the food. On the path, each ant leaves some scent called pheromone. The ants those found shorter route completes more trips in a certain time period therefore these ants leave more pheromone. The pheromones guide the behavior of the ants.

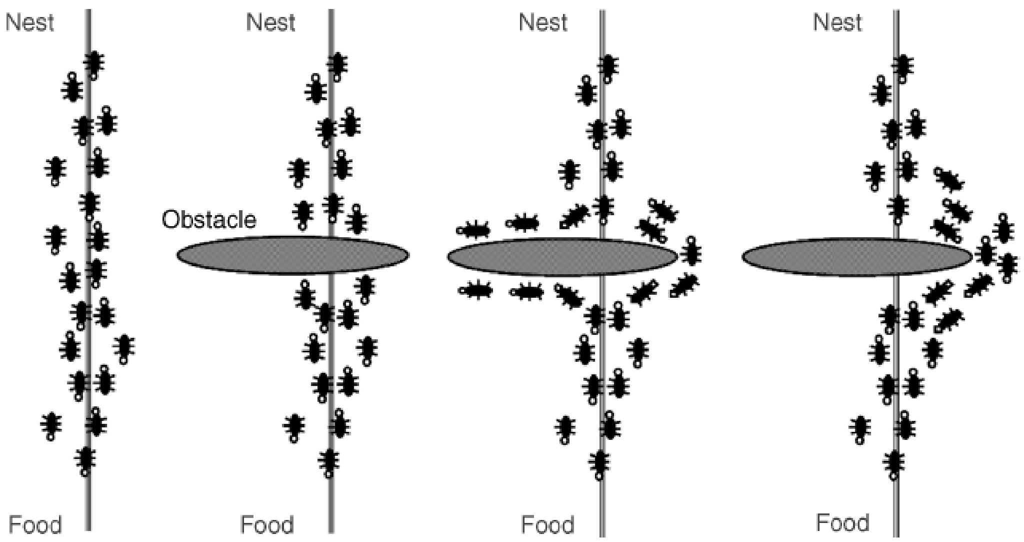

Figure 3. Ant Colony Food Search Patern [24]

The ant colony algorithm for the best solution or a set of good solutions is given below.

- Determine stopping criteria (For example: Stop if no improvement)
- Define pheromone matrix
- Initialize the pheromone matrix
- Give directives to the ants to construct solutions using the pheromone matrix
- Find the ant with the best solution
- Reinforce the pheromone values with the information from the best ant.
- Evaporate the pheromone values that are not used in best solution
- Check if the stopping criteria is met

To clarify the methodology, an example of quay crane scheduling problem is given. Let the number of bays be 25, number of columns be 12 and number of tiers be 6. Let us assume that there are 40 jobs for 2 cranes. 25 of these jobs are unloading and remaining 15 jobs are loading tasks. The task list is given in table 1. The first column is the task number. The last column states whether the task is loading or unloading job that will be performed by the quay crane. For unloading tasks; column 2, 3 and 4 of table 1 state the position of container that should be taken. There might be some containers on top of that specific container. Therefore those containers that are on top should be moved before reaching the target container. The fifth column shows the number of containers that should be moved before reaching the target container. At the end, the quay crane either dwell on the yard side which is shown by “0” in column six or dwells on ship deck. The time that is required to perform a specific task depends on the position of target container and the number of containers that should be moved before reaching the target container. This time is given in seventh column in table 1.

Table 1. The task list to be performed on an example vessel

Task	Bay	Col	Tier	Over	EndCol	Time	Type
1	7	1	6	3	1	78	Unloading
2	18	9	4	3	9	146	Unloading
3	17	5	2	1	5	30	Unloading
…	…	…	…	…	…	…	…
24	21	3	1	0	0	5	Unloading
25	19	6	6	4	6	172	Unloading
26	17	2	1		2	3	Loading
27	13	2	3		2	5	Loading
…	…	…	…	…	…	…	…
39	20	7	3		7	10	Loading
40	5	2	6		2	8	Loading

At the beginning of the scheduling, let’s assume that the quay cranes are dwelling at different corners of the dock. To simplify the problem, it is assumed that the quay cranes move from one bay to another bay in unit time (*t*) and the cranes have the same speed (1 unit length/ unit time) in all three dimensions for the cases both loading and unloading operations. The aim is to minimize the process finish time of the quay crane which has the maximum finishing time on berth. To do this, 40 jobs will be separated to 2 cranes and the sequence of them will be decided. For the ACO algorithms the number of ants usually selected a number between 50 and 200. For this problem 100 ants are included in the algorithm.

Step 1. Generate a 42*42 pheromone matrix in which all the numbers are 1.

Step 2. For ant *a* = 1 to 100 do {

- Choose a random number *u* from discrete uniform distribution U~[1..39],
- Set $n_1 = u$ and $n_2 = 40 - u$
- Generate an unassigned jobs set S = [1,…40]
- Form work order for first crane from S based on pheromone matrix which will have n_1 members (W_1)
  - For i = 1 to n_1 Select w_i, $S = S - \{w_i\}$
- Form work order for second crane from S based on pheromone matrix which will have n_2 members (W_2)
  - $W_a = W_1 + W_2$
- Calculate TC_a completion time for ant *a*.
- If $TC_a < TC_{min}$ then
  - $W_{min} = W_a$
  - $TC_{min} = TC_a$
  - Update pheromone matrix

} End of ant loop

Step 3. Check if the stopping criteria is met

- If yes stop
- If not go to step 2.

Pheromone matrix represents the desirability of performing jobs one after another. In starting point of the algorithm, all the numbers are 1. After one iteration, all the coefficients are changed. If the sequence is used by the best solution provided by ants the coefficient are increased by Δ amount. If the sequences are not in the optimal solution the coefficients are decreased to (1-ρ) times of their values. For example, if $\Delta=1$ and $\rho=0.2$ are taken and in the solution if we need to follow a sequence like 3-6-5-10, the probability of choosing this pattern becomes two-fold for the next stage of the algorithm. Thus, the necessary elements of the matrix become 2, and the others become 0.8. These stages can be called reinforcement and evaporation phases of the algorithm which helps to update pheromone matrix.

Numerical Results: The algorithm satisfied the stopping criteria after 25th iteration. Algorithm stopped because there were no huge differences between the completion times of two successive iterations (smaller than % 0.5). The final optimum result for the specific problem above is 803(t) which found by the algorithm. To compare the results 100 randomly solutions are generated and their completion times are calculated. The best of randomly obtained solutions turned to be 1109(t). And in addition a heuristic, (that is the crane goes to the nearest adjacent job after finishing any job), is applied and the solution would be 892(t).

CONCLUSION

Although different metaheuristics have been employed to address quay crane scheduling problem, the ant colony optimization algorithm has been first time applied to this problem. The representation steps and improvement steps were successfully coded. As expected the ant colony algorithm emerged to a better solution than random solutions. The algorithm also performed better than the simple heuristic that is developed for this problem. Therefore it can be concluded that the ant colony optimization metaheuristic is a good candidate to obtain better results in quay crane scheduling problems.

However the performance of the algorithm should not be limited to one example. It should be tested with the other examples from the literature. There is also one other important task to be completed that is the parameter tuning of the algorithm. The appropriate sizes of the ant colonies, appropriate reinforcement and evaporation rates and stopping criteria should be addressed. The performance of the algorithm should also be compared with other algorithms including metaheuristics and especially the optimum value when it is available.

From the managerial perspective, the algorithm that is proposed here can provide time savings therefore decrease in the operation costs. These algorithms should be integrated with "Container Terminals Operating Systems" as a decision support system. The efficiency of the terminals is expected to increase as these systems are integrated with the other information technologies that are used at the container terminals.

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PERCEPTIONS AND BARRIERS IN IMPLEMENTING INDUSTRY 4.0 CONCEPTIONS IN CONTAINER TERMINALS

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Abstract **–** *Industry 4.0 is a kind of IT-enabled mass and the goal of the conception is to perform flexible and customized business processes, to use resources efficiently and eventually to achieve lean systems. Seaports are nodal points in the whole supply chain and they play vital role in enhancing seamless flow of the systems. Through applying the principles of cyber-physical systems (CPS), Internet of Things (IoT) and future-oriented technologies, which involve self-governed systems, at container terminals; digital improvements in terms of operational efficiency, cost reduction and quality assurance may be achieved. Successful application of such systems require an understanding of how Industry 4.0 is perceived, what constitute well-managed systems and the barriers to implementation. This paper firstly aims to analyze port manager's perceptions toward Industry 4.0 in Turkey and then an attempt has been made towards identifying the barriers affecting the digitization and linking of all operational processes at container terminals. Finally, ways of increasing network-linked intelligent systems which realize self-regulating applications at Turkish container terminals will be addressed.*

Keywords – Industry 4.0, barriers, container terminals, port efficiency

INTRODUCTION

In the 21st century, customers have become more demanding and fulfilling their requirements is much more complex today. For being competitive, enterprises predominantly try to create greater value for the customers in terms of cycle times, product or service availability, reliability and they implement different types of innovations such as technical, technological, organizational, etc. In this respect, the latest solution Industry 4.0 generate advantages to develop logistics and supply chain systems [5, 28].

Hofmann and Rüsch [7] define Industry 4.0 as "the digital connectivity that enables an automated and self-optimized systems including the delivering without human interventions (self-adapting systems based on transparency and predictive power)." They note that the internet and other intelligent applications connect the all processes and participants of the system consistently; and the system elements perform autonomous and decentralized decision making. Industry 4.0 integrate the digital and real world by highly technological applications and create several advantages for supply chain systems. For achieving sustainable logistics and supply chain systems, digitization of the whole system is a necessity within the scope of Industy 4.0 solutions [8]. Digitization enables to use "smart" solutions and achieve efficient and reliable organizations in terms of shortened lead times, flexibility, and cost reduction. Internet of Things (IoT) provide an opportunity to digitalize the systems and they create disruptive innovation in the existing market [22, 7].

Together with the increasing trend in container shipping business, container terminals become much more critical nodal points as an interchange facility within the supply chain systems. In order to perform better operations in terms of time, efficiency, security, awareness for environment; container terminals started to implement automation technologies in their facilities for being a "smart port" within the scope of Industry 4.0 solutions [16]. Thus, they are able to achieve systematization and standardization in their business processes and to become much more competitive in the market.

This study aims to analyze port manager's perceptions toward Industry 4.0 in Turkey and summarizing barriers in implementing Industry 4.0 solutions in Turkish container terminals. In-depth and face-to-face interviews with participating managers were performed at container terminals in Istanbul, Kocaeli and Mersin. The paper also makes recommendations to enable and encourage greater use of Industry 4.0 conceptions in Turkish container terminals.

The paper is structured as follows: Section 2 provides information about Industry 4.0 conception and its major components. Section 3 discusses the effects of the technological developments on container terminals which are heavily located on the major shipping routes. Then, the major obstacles in implementing Industry 4.0

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applications in Turkish container terminals are given in six main categories. Finally, the ways of increasing network-linked intelligent systems which realize self-regulating applications in Turkish container terminals is discussed in recommendation and conclusion section.

INDUSTRY 4.0 CONCEPTION

In 2011, German federal government initiated a strategy, named as “Industry 4.0” to empower the country’s manufacturing competitiveness and strengthen the German economy [9, 19, 26]. The main objective of this initiative is to improve the existing processes of the various industries particularly comprising manufacturing, engineering and supply chain activities. This concept is widely used by academicians and practitioners in their recent studies [6].

At the end of 18th century, the 1st industrial revolution introduced mechanical production based on water and steam power. The 2nd industrial revolution started with mass production based on electrification and division of labor at the beginning of 20th century. The 3rd, also called “the digital revolution” began with the utilization of automatic machines based on electronics and internet technology in the 1970s. Industry 4.0 emphasize to use the cyber physical systems (CPS), based on heterogeneous data and knowledge integration. It is a move from centrally controlled systems to decentralized systems [3, 14, 5].

Industry 4.0 refers to *“technological evolution from embedded systems to cyber-physical systems.”* It requires transforming conventional centralized systems into decentralized autonomous systems by way of the real and virtual world interaction [15]. Virtuality, reality and the simulation of the processes have an important role in this conception [5]. These kind of systems aim to achieve efficiency, productivity, safety, security and realize automation within the operational activities [20, 13].

Cyber-physical systems (CPS) are vital component of Industry 4.0 and they act as a bridge between virtual-physical worlds and actualize networked world via Internet of Things (IoT) [1, 17]. Micro-controllers, sensors, actuators, RFID are the example for IoT applications. Information exchange is performed among embedded computer terminals, wireless applications, houses, or clouds [4, 11]. These kind of systems gigantic data set which is called “big data” and managing this data requires modern tools to turn data into actionable insights, which include early warning algorithms, predictive models and dashboards [28].

Interoperability and integration are key factors for achieving seamless operations across organizational boundaries. Within an integrated and interoperable networked organizations, all separate processes or functions exchange the data and share information [2]. Other fundamental features of Industry 4.0 are digitization, optimization, interoperability, integration, customization, adaptation, decentralization, self-regulation, service orientation [18, 23, 13]. Hermann, Pentek and Otto [6] indicate the design principles of Industry 4.0 as below;

Interconnection: Machines, devices, sensors and people are need to be entirely connected through IoT technologies. By doing so, the system aims to achieve joint *collaboration* between all participants. Connection between participants enables to have some specific modularized *standards* (such as lot-size) and these standards provide flexibility to meet the market demand. In addition; ensuring safety of stored data and achieving *cyber-security* of the system is vital.

Decentralized Decision: Interconnected process and information transparency lead the participants to autonomous decision-making system. CPS applications such as computers, sensor, etc. facilitate the decentralized decision-making style.

Technical Assistance: Highly multifaceted CPS systems require *virtual* or *physical assistance*. Particularly; for robotic devices it is essential to be in an active connection with humans and obtain their support. The object is to create collaboration between human and machine.

Information Transparency: The whole virtual and physical systems make information transparency essential. Data analytics and information provision are major elements of information transparency.

METHODOLOGY

Within the scope of this study, face-to-face, in-depth and semi-structured interviews were performed with five managers from four different container terminals in order to obtain the port manager's perception about Industry 4.0. The duration of our interviews ranged from 20 to 35 minutes. These interviews were actualized between the dates 11.07.2017 and 27.07.2017 and the details of the interviews are demonstrated in Table 1.

Table 1. Details of the Interviews Conducted

	Institution	Person Interviewed	Date	Type and Duration of the Interview
İstanbul	Marport Terminal Operators S.A.	Trade and Customer Relation Director	27.07.2017	face-to-face, 35 min.
Istanbul	Kumport Container Terminal	General Manager	27.07.2017	face-to-face, 20 min.
Kocaeli	Dp World Yarımca	Commercial Line Manager Finance Director	20.07.2017	face-to-face, 25 min.
Mersin	MIP Container Terminal	Sales and Marketing Senior Executive	15.07.2017	face-to-face, 35 min.
Kocaeli	Yılport Holding Inc.	Assistant General Manager	11.07.2017	face-to-face, 25 min.

REFLECTIONS OF INDUSTRY 4.0 ON CONTAINER TERMINALS

The Fourth Industrial Revolution, usually called "Industry 4.0" or "The Digital Industrial Revolution" is a process based on how technology, specifically; automation through softwares and machines, artificial intelligence, internet of things including the cloud system, is to transform the businesses as well as the Container Terminals in the foreseeable future [29]. Container terminals that are located on the major shipping routes with a relatively higher TEU handling capacity, have been more responsive on adapting themselves to the processes of the Industry 4.0.

According to Wang and Liu [27]; major ports in the world have gone through three development stages: *informationalized ports*, *digital ports*, and *intelligent ports*. What is known as smart ports focus on automation and internet of things concepts as how the terminals of the future expected to be hyper-connected via the means of Industry 4.0. In a way it is "big data" combined with automation and the Internet of Things (IoT) [29]. There is no doubt that the automated and smart ports will be the pioneers of this new trend for other shipping industries.

The key aspect of Industry 4.0, the industrial automation, consists the use of mechanic, hydraulic, pneumatic, electric - electronic and computerized elements or systems to control equipment and processes within the Container Terminals [16]. Containers, cranes, storage yard handling equipment, small devices, trucks and even infrastructure elements can be equipped to become intelligent. Container terminals are in a transformation towards unmanned operations, artificial intelligence management systems and self-controlled machines and devices [21].

Trends in CT Automation and the Levels of Automation: Fully and Semi-Automated

In automated container terminals, containers are transported from the marshalling yard to a ship and vice versa by automated vehicles. As defined by Xisong et. al. [30] the term "automated terminals" refers to *terminals that have automated their storage equipment and the interchange between subsystems*. In such terminals, crane-ship operations are still manual whilst the interaction between yard cranes and the inland transportation means of reception and delivery remain assisted by remote controllers. The general trend is headed for higher levels of automation that go beyond the borders of terminal yards to involve all operations. In general terms this wider development includes: the automation of gates, the automation of yards; and the automation of quay cranes.

Table 2. Advantages and Disadvantages of Automated Container Terminals [16]

	Advantages	Disadvantages
Operational Performance	• Increased operational productivity • Operating with allocations and high yard density: offering more capacity with the same space • Increased flexibility to adapt to demand peaks • More organized and methodical operations, reducing uncertainty in response times • Higher capacity to prioritize operational changes • Less affected by external factors and lack of stevedores • More efficient use of resources • More control of operations given the existence of continuous communication between control systems and the fleet of equipment, easing thereby the decision making process in real time • Less volume of shuffling operations required which can be planned in advance to be carried out without interfering with loading and unloading operations (housekeeping)	• Less flexibility for operational planning • New scenarios have to be previously planned • More difficulty to react when exceptions occur • Power cuts for electric devices • Any breakdown may cause overall operation failure or delay
Safety and Security	• Increase in safety in terminals given the reduction of risks to human resources • Incorporation of security systems	• Sensitivity for non-experienced problems
Environmental Sustainability	• Operating with electric equipment (less consumption, less emissions and less noise) • Best use of current spaces (fewer extensions)	• May generate labor conflicts (loss of job positions)
Economic and financial profitability	• Less variable operational costs • Less maintenance operational costs	• Requires a (higher) capital outlay • Requires a high initial cost

The Gates are automated by RFID (Radio-frequency Identification) and OCR (Optical Character Recognition) systems working with detector cameras positioned in terminal gates monitoring every truck, train and vehicle. A kind of a non-contact identification device using a short range wireless technology, can automatically identify barcode data through RF signal [16]. It is a low cost and efficient new technology changing the product tracking and recognizing. RFID is integrated with a central information system, to transmit the identification of the goods (products), and then to achieve information exchange and sharing through computer network. The system also works with low light and reads the container seal and detects if the container is in good condition.

Yard automation is the most common and obvious trend among CTs. Container Terminals whose yard operations are totally or partially automated, are the ones known as fully-automated or semi-automated terminals, respectively [16].

Table 3. List of Fully and Semi-Automated Container Terminals [16]

- ECT Delta Terminal (HPH) – Port of Rotterdam, The Netherlands- (from 1993) **(A)**
- London Thamesport (HPH) –Medway Ports, United Kingdom - (from 1994) **(S)**
- Hong Kong International Terminal 6-7 (HIT) (HPH) – Port of Hong Kong, Hong Kong- (from 1995) **(S)**
- Pasir Panjang Bridge Crane Terminal (PSA) – Port of Singapore, Republic of Singapore- (from 2000) **(S)**
- HHLA-CTA – Port of Hamburg, Germany- (from 2002) **(A)**
- Patrick Terminals –Port of Brisbane, Australia- (from 2005) **(A)**
- Tobishima Pier South Side Container Terminal (TCB) – Port of Nagoya, Japan- (from 2006) **(A)**
- Wan Hai –Port of Tokyo, Japan- (from 2006) **(S)**
- APM T erminals Virginia, Norfolk (APMT) –Portsmouth, United States - (from 2007) **(S)**
- Antwerp Gateway Terminal (DPW) – Port of Antwerp, Belgium- (from 2007) **(S)**
- Evergreen (EMC) – Port of Kaohsiung, Taiwan- (from 2007) **(S)**
- Euromax Terminal – Port of Rotterdam, The Netherlands - (from 2008) **(A)**
- TTI Algeciras (Hanjin) – Port of Algeciras Bay, Spain- (from 2010) **(S)**
- Pusan Newport International Terminal (PNIT) (PSA y Hanjin) – Port of Busan, South Korea (from 2010) **(S)**
- HHLA-CTB – Port of Hamburg, Germany - (from 2011) **(S)**
- Tercat (HPH) – Port of Barcelona, Spain- (from 2012) **(S)**
- Xiamen Yuanhai Container Terminal – Port of Xiamen, China- (from 2013) **(A)**
- TraPac Expansion – Port of Los Angeles, United States of America- (from 2013) **(A)**
- APM Terminals Maasvlakte 2 (APMT) – Port of Rotterdam, The Netherlands- (from 2014) **(A)**
- Rotterdam World Gateway (RWG) (DPW) – Port of Rotterdam, The Netherlands- (from 2014) **(A)**
- New Qianwan Container Terminal – Port of Qingdao, China – (from 2017) **(A)**
- Long Beach Container Terminal Pier E and F- Port of Long Beach, United States – (from 2017) **(A)**
- Yangshan Deepwater Port – Shanghai, China – (to be completed in December 2017) **(A)**

(A) Fully Automated Terminal; **(S)** Semi-automated terminal

The automated technology of storage and transfer equipment is similar and handles the automation of the inventory of the stock of containers located in the yard and the monitoring of handling equipment in real time. The automated storage and retrieval system is a new concept and the two major components of AS(automated storage)/RS are the storage and retrieval machine (SRM) and the storage racks. The AS/RS has the advantages of providing a high density storage capacity, high throughput rate, and random access for a target container, without re-handling operations [10]. There are equipment operating fully or partly automated in the stocking yard such as the ARTG and ARMG cranes, AGV (Automated Guided Vehicles), ALVs (Automated Lifting Vehicles) and ASCs (Automatic Stacking Crane). These equipment offer economic, environmental, and technical advantages compared to conventional transport fleets [21].

As automated systems demand high initial investment, they are mostly operated where labor costs or other operational costs are high. As indicated in the study of [25], if unmanned equipment like AGVs or ALVs for transportation and automated gantry cranes for stacking are used, a main task of the control system is to make sure containers arrive 'in-time' at the interfaces (of the equipment such as, e.g., cranes and AGVs) and the idle times (of the cranes) are minimized.

The number of automated and semi-automated terminals has been on the rise over the past years and increased investments being made in automation projects and the construction of new automated terminals in different countries [16]. The technology acquired in these terminals is disturbed heterogeneously although the way of operation seems alike.

The automatization of quay cranes is overdue, although it is predicted that they will have a leap of technology. To date efforts to automate quay cranes have resulted in minor automations which, implemented in factories at origin or by means of retrofitting, can mechanize some of the functions that until then depended on the ability of crane operators [32]. These are focused on the control of the movements of spreaders, both involuntary (sway and skew) as well as their pathway, and the connection between quay cranes and transfer equipment. In parallel, terminals and manufacturers are testing systems that would manifest a qualitative technological leap for the automation of STS cranes [16].

An intermediate solution between automated and manual terminals can be sustained by the human-machine collaboration ways such as partial automation or semi-automation in which operations are carried out by conventional equipment and controlled by humans, or vice-versa.

Intelligent Ports are a service system for port transportation based on modern electronic information technology, information services for port participants is based on the collection, processing, release, exchange, analysis, and usage of the relevant information [24]. IoT technology is the basis for the development of the Intelligent Ports. Sensor technology allows objects to have the "perception"; RFID technology make them "speak"; machine-to-machine (M2M) let them “exchange”; finally, IoT let all objects in the world interconnect. So, the handling equipment, ships, containers, vehicles, and instruments, which are widely distributed in the global ports, are connected to this "net" [12, 31]. Xisong [30] identifies similarly with Lu et. al. [12] the key technologies and products of IoT that are needed in the construction of Intelligent Ports whose performance requirements consist high security, reliability, high recognition rate and high stability.

As well as these systems, the Automatic Identification System (AIS) technology, Chart GIS technology, GPS, Electronic Data Interchange (EDI) technology, Smart Ship Management System helps creating the Joint Inspection Units at ports (Customs, CIQ, maritime, border, etc.) making it possible to understand the ships’ reporting and approval by the same system [30]. It enhances the real-time location and supervision of the ships. Thus it extends the capabilities of the automation and IoT systems of the modern container terminals.

FINDINGS

Considering all the ports operating in Turkey, there is not a fully-automated port currently in operation complying with Industry 4.0 practices (Rotterdam, Hamburg, Antwerp, etc.). Among the ports where the interviews are made, only in the DP World, Semi-automated handling equipment are being used. DP World is known as the most technology-bearing port in Turkey, benefiting in many of its business processes.

At present, many ports operating in our country are in the effort of renewing their technological infrastructure, trying to optimize many business processes. In order to meet the requirements of the Industry 4.0, it is necessary to integrate all the processes in a single system and to make sure the interoperability among them. The ports in our country can now automate only some of the major processes. To name a few; operations such as port entry procedures, crane operation processes etc. For example, Yılport, DP World and APM are performing automated, unmanned gate systems (new automated systems improve the gate performance). Current gate entrance-exit operations at these ports are carried out by OCR (Optical Character Recognition) and RFID systems. Thanks to these technologies, number of cameras that can read optical characters read the vehicle numbers, including vehicle plates, even at night; able to control the container seal and damage. In this case, higher efficiency is obtained compared to the gate operations performed manually as the incorrect data entries caused by human fault are eliminated. In MIP, Marport, Kumport and many other Turkish ports, these operations are carried out manually by hand-terminals. That’s why the manual auditing cause operational waste of time during a container’s entrance into the port. Many ports in our country make the necessary evaluations to transcend into these kind of systems.

Again in our country, only in the DP World the crane operation can be automatically managed from the computer screen in the planning office, without going out on the crane. Such semi-automated systems largely influence the, "level of qualification" and "working conditions" of the staff rather than the “number of staff”. However, since all operators will be working in a single office, the number of chief-officer per shift can be reduced thus the number of total staff available can be minimized.

The most important feature that such systems should have is the cyber-security. When a fully automated port faces a cyber-attack, it takes a long time to fully recover its usual activities. For example, during the

"Ransomware cyber-attack" to the APM Group's fully automated Maasvlakte Terminal located in the smart port of Rotterdam, the equipment had become "out of use" for some time and the terminal has faced disruptions. The semi-automated older terminal operating in the same port was able to continue its operations in a shorter period of time. APM has suffered major short-term losses in this case. The importance of cyber-security has been emphasized by the port managers when such systems are being established in our country.

In the light of the interviews performed with marina manager, fundamental barriers in implementing industry 4.0 conceptions in container terminals can be summarized as below.

Complex Business Processes

When it is assessed from the technical perspective, the current business processes in our country's ports cannot be considered as eligible for the transition towards Industry 4.0 applications where fully-automated systems are used. The human factor is very much in the foreground in our ports. Within the port areas there are physically present customers who are filling the documents manually, exchanging money and causing time consuming customs procedures. When we look at fully-automated terminals in the world, only container and handling equipment operations take place in the port areas.

However in the ports of our country, container stuffing and stripping operations (CFS operations) create a handicap for the transition process to the Industry 4.0. In order to be able to talk about full automation in the container movement, such detailed operations must be automated as well.

Difficulties in Customs Procedures

The current Customs Legislation of our country is a great obstacle for the implementation of Industry 4.0 practices. Especially in the declarations falling to the red line and subjected to the full count application, the control of the products is realized in the "Inspection Field" located within the port boundaries. During the goods' control; Customs Clearance Officer, Customs Consultant (with whom the cargo representative work together), and port business representative are present. Such physical control activities performed within the port area, is a huge obstacle in the transition process towards full automation.

Energy Supply Deficiencies

For the purpose of putting Industry 4.0 applications into practice, there is a need for large areas where fully automated equipment can move freely. However, the vast majority of the ports in our country have not such sufficient width. In addition, in bad weather conditions, electrical failures occur in many parts of our country, especially in industrial districts. Especially, ports in the Ambarlı Region stated that they frequently encounter electricity failures and that these interruptions disrupt their activities. Although such problems are partially overcome with generator systems, fully-automated systems under Industry 4.0 need to eliminate these problems altogether.

High Investment Costs

There is an intense competition among the ports that provide container services in our country (eg Istanbul Ambarlı Region, Kocaeli, Aliağa Nemrut Bay, Mersin-İskenderun ports, etc.). Businesses are striving to reduce costs and increase profitability while at the same time trying to fulfill customer demands and expectations in order to survive. Ports are passionate about eco-friendly investments to meet the expectations of both the customers and the community, especially about sustainability. However, in an environment of intense competition, it is not possible to provide return on high cost investments such as Industry 4.0 full automation systems. Although many ports continuously make technological investments on the basis of each business process in order to improve their service quality and increase customer satisfaction, the transition to fully automation systems requires undertaking much higher investment costs.

Supply Surplus

Especially in recent years, there has been a surplus of supply in the market with new container terminal investments and current capacity developments in existing terminals in our country. This is also on of the most important barriers in front of Industry 4.0 applications. Most of the existing ports already operate with an occupancy rate below their full capacity. To switch to automation systems would increase the efficiency of the ports, but for now, due to insufficient demand, there is no need to increase productivity in the existing market and to complete operations faster and in a shorter time.

Lack of Qualified Personnel

In order to switch to fully automated systems at the ports in our country, all port users and port employees must have enough qualification to use such technology. However, the port users and the port personnel at every level are not yet at the desired level of competence for using that technology.

RECOMMENDATIONS AND CONCLUSION

Nowadays, in order to implement Industry 4.0 applications in a sustainable way, which are mainly seen in manufacturing sectors, it is necessary to automate every business process so that all system participants can effectively adapt to the system. In order to switch to Industry 4.0 applications in the container terminals operating in our country, it is necessary to remove the barriers obtained as a result of interviews conducted within the scope of this study.

Port managers especially emphasize that, existing customs legislation must be made more appropriate for Industry 4.0 applications in order to harmonize the use of information technologies with fully-automated systems. In this context, it should be ensured that the actual audit activities should be carried out in areas outside the port areas, like in fully-automated ports abroad. To name an example, Mersin Port has been selected as the pilot region in a project aiming to extend the use of technology in the customs procedures. In this context, the license plate number of vehicles entering the port area, the declaration and the company information can be seen on the database of the Customs Directorate from the common software system at the port entrance gate. Thus, the Customs Department can also be able to cover the relevant declaration of burden unless an extra control is required.

If it is desired to switch to full automation in a container terminal in our country, the use of container freight station (CFS) service can be reduced which is an important barrier to switch to Industry 4.0 so as to concentrate on the transit freight operations. In addition, necessary precautions should be taken to address the source of distress for energy supply, both port-wide (e.g. port site lighting with solar energy to reduce energy costs) and nation-wide (e.g. accomplishing renewable energy plants).

Although there are some technical short-term struggle methods available for the current barriers, long-term strategies need to be developed in order to be able to sustain our competitive position as a country.

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SINGLE HUB CAPACITY ALLOCATION MODEL FOR AIR CARGO FIRMS

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Abstract − *Global and rapidly developing air freight operations constitute the largest share in cargo industry. Especially global competition forces the companies to use the quickest transportation alternatives with the most appropriate cost. Air cargo firms provide a reasonably basic transportation service for certain size of goods within a short time from the origin to the destination. With the current pricing strategies, air cargo firms face capacity allocation problems because the demand is generally higher than the offered capacity. In this study a mathematical programming based approach is presented for revenue maximization by allocating the capacity in air cargo operations under demand and capacity constraints. It is assumed that the air cargo network has a single hub and each link between hub and nodes has limited capacity. Because of its origin nodes (demands) and its destination nodes (supplies); this problem is structurally similar to transportation problem. However, unlike the transportation problem, the demand should be between specific origins and destinations. Therefore, the traditional transportation algorithms do not work for this particular problem. In addition; the large number of origins, destinations and time horizons make the problem more complicated. To address these issues, a heuristic solution is developed and compared with the optimal solution.*

Keywords − *Air Cargo, Capacity Allocation, Linear Programming, Revenue Management*

INTRODUCTION

With the development of world trade and the increase in cargo operations around the world, the air cargo industry and naturally air cargo firms, forwarders, shippers and airports have gained more importance. Also in today's economy, the air cargo industry is seen as the primary route of transportation for valuable goods and luxury goods [1]. At present, although the air cargo industry only fulfills a small part of the worldwide cargo transportation, its market share is expected to increase in the coming years. As exchange volume and monetary movement increase, air transport demand will increase. Boeing estimates that air cargo demand will grow by 4% over the next decade [2]. An air cargo firm with sufficient resources and expert staff can be a tremendous resource for monetary progress. Since 2008, the world's air cargo industry is facing an extreme decline, although it is expected to increase its market share in the coming years. While several air cargo carriers have disappeared from the market, others have reduced the amount of transport due to decreased interest [3]. Furthermore, numerous carriers and forwarders changed to less expensive methods for transport. On the other hand, air cargo companies that want to maintain and increase their current income are working on preparing and supervising management programs for revenue maximization [4].

When there are many ideas, strategies, practices and articles on revenue management in the passenger airline industry, there are few studies focusing on especially revenue management in the air cargo industry. Air cargo companies need to determine the most optimal strategy to take into account such factors as aircrafts, staff status, airport restrictions and capacity constraints in order to achieve maximum profit. The aim here is to maximize profits by producing timelines that optimally use the capacities of aircrafts. This complex plan and the decisions are taken as results of the capacity allocation problem. In this study, a mathematical model was developed that focuses on optimal capacity allocation and revenue maximization when there is a capacity constraint on the origins and destinations of single hub air cargo operations.

LITERATURE REVIEW

Capacity allocation for the air traveler industry has been studied well in the literature. But, the capacity allocation problems in the air cargo industry are very different from those in the air traveler area due to the distinctive characteristics of the air cargo. Revenue management of air cargo industry differs from revenue management of air passenger industry from various perspectives such as capacity estimation, network capacity allotment, and capacity booking conduct.

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Kasilingam talks about the importance of demand estimating, capacity estimating, capacity allotment, and overbooking in the general capacity allotment process [5]. A comparative review can be seen in Slager and Kapteijns, who talk about difficulties of a cargo revenue management, and a few noteworthy differences between revenue management in air cargo and air travelers industry [6].

Karaesmen formulates the basic version of the spot market allotment problem by a continuous linear programming model. She supposes that there is only one shipment type, and indicates that results of a sequence of linear models converge to an optimal solution of the continuous linear programming model, so do the offer costs, which can be processed by an estimation calculation. Her outcome is hypothetically intriguing however cannot be stretched out to catch allocation necessities [7].

Pak and Dekker showed a dynamic programming (DP) problem to allocate capacity for the air cargo industry. The model is constrained with flight capacity in both weight and volume. They approached the worth function by a standard knapsack problem, which is also approached by an ordering algorithm that efficiently produces a set of bid-prices [8].

Popescu studies a spot market allotment problem with accumulation and positive lead time. She separates the demand into two sets and purposes a diverse model and algorithm for each set. She also considers the conditions of the model with one and two time lags, and indicates that the optimal allotment, if exists, is a deterministic stationary allotment. Her hypothesis and models are developed for revenue management of traditional network for travelers, and demand correlation is not considered [9].

Amaruchkul et al. suggests a few heuristics to decompose and approximate the value function of a dynamic programming for the air cargo market. The dynamic program that they model is like to the traditional passenger revenue management problem with multiple classes. They experimentally demonstrate that their heuristics perform well [10]. References [8] and [10] show the short-term allotment problem using dynamic programing to build a superior allotment strategy. But, extending the model to catch allocations outstandingly escalates the complexity of the problem.

Gupta works on the uncompleted carrier–forwarder contract case, in which the extent of requests are decided due to the forwarder’s endeavor level [11].

Luo et al. study the spot market allotment problem in weight and capacity while calculating damage and offload expenses. They analyze the model in terms of booking receiving regions, that could be rectangular or circular. But, their model is single-leg, and the offered controls are difficult to apply and store in an information system [12].

Amaruchkul et al. examine a capacity contract, which regulates the allotment level, unit cost for the used capacity, and unit discount rate for the unused capacity. They expressed the expected offering, as a separate benefit function of a carrier and forwarder. The benefit functions are then united to create a stochastic optimization model that maximizes the total offering subject to an encouragement compatibility constraint and a forwarder offering lower bound [13].

Hellermann et al. proposes an option contract that considers the overbooking of forwarders. A numerical study further is provided as an analysis about the impact of overbooking on contract parameters and profitability [14].

HUB AND SPOKE NETWORK REPRESENTATION

Most of air cargo firms use hub and spoke network to routes for their plane traffic. The words "hub" and "spoke" create a pretty bright image of how this system works (Figure 1). A hub is a central airport that flights are routed through, and spokes are the routes that planes take out of the hub airport. Most major air cargo firms use multiple hubs.

A good example of a hub and spoke system is that of Turkish Airlines, which has its hub at Istanbul Ataturk Airport, IST. To give an example, let us assume the cargo will depart from Tahran, IKA, and it needs to be transferred to Atlanta, ATL. There is probably not sufficient demand between Tahran and Atlanta to dedicate a direct flight from Tahran to Atlanta. In this situation the airline flies the cargo from Tahran to Istanbul first, and then from Istanbul to Atlanta via a connecting flight.

The purpose of the hub-and-spoke systems are to reduce costs and give passengers better routes to destinations. Airplanes are an airline's most valuable commodity, and every flight has certain set costs. Each seat and each cargo tonnage on the plane represents a portion of the total flight cost. For each seat that is filled by a passenger or load capacity used by the cargo, airlines lower their break-even prices, which are the seat prices or cargo carrying prices per ton at which an airline stops losing money or and begins to show a profit on the flight. Therefore it is best to maximize the usage of cargo capacity.

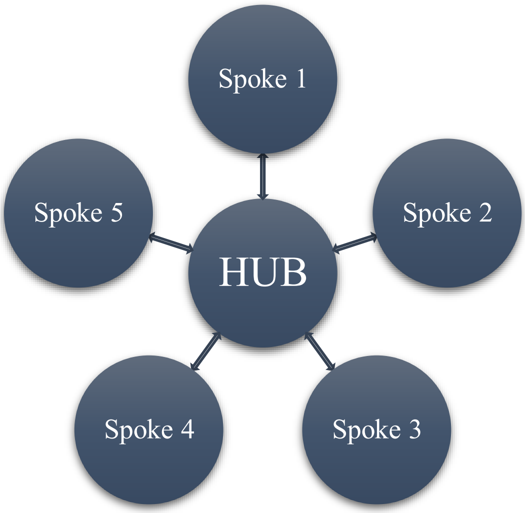

Figure 1. Hub and Spoke Structure.

MATHEMATICAL MODEL

To maximize the cargo revenues under the capacity and demand constraint, a mathematical model is needed. In this section a linear programming model (LP) is proposed that will give the optimum assignment of the cargo capacities to the cities. The following set of parameters are used in the LP model:

N : the number of airports
T : the number of periods
i: indices for origins [1..N]
j: indices for destinations [1..N]
t: indices for periods [1..T]
Cap_{jt} : Cargo weight capacity of destination j in period t.
Cap_{it} : Cargo weight capacity of origin i in period t.
D_{ijt} : Demanded cargo weight from origin i to destination j in period t.
P_{ijt} : Price per ton of the cargo from origin i to destination j requested in period t.

Decision variables :

X_{ijt} : Cargo weight to be transported in period t from origin i to destination j requested in period t.
$X1_{ijt}$: Cargo weight to be transported in period t+1 from origin i to destination j requested in period t.
$X2_{ijt}$: Cargo weight to be transported in period t+2 from origin i to destination j requested in period t.

The formulation is given as follows :

$$\text{Max } Z = \sum_i \sum_j \sum_t (X_{ijt} + X1_{ijt} + X2_{ijt}) \cdot P_{ijt} \quad (1)$$

s.t. $$X_{ijt} + X1_{ijt} + X2_{ijt} \leq D_{ijt} \qquad \forall\ i, j, t \quad (2)$$

$$\sum_i (X_{ijt}) + \sum_i (X1_{ij(t-1)}) + \sum_i (X2_{ij(t-2)}) \leq Cap_{jt} \quad (3)$$

$$\sum_j (X_{ijt}) + \sum_j (X1_{ij(t-1)}) + \sum_j (X2_{ij(t-2)}) \leq Cap_{it} \quad (4)$$

$$X_{ijt}, X1_{ijt}, X2_{ijt}, \in R^+ \quad (5)$$

In the model it has been created that the demand that are not fulfilled at the existing period can be transferred up to two periods ahead. In this formulation, the objective function (1) is the maximization of revenue. The first constraint (eq. 2) indicates that the amount to be sent in period t, period t+1 and period t+2 for the cargo that belongs to period t cannot exceed the amount of the demand for that period. Constraint (3) indicates the amount of cargo leaving origin i cannot exceed the output capacity of that origin. Constraint (4) indicates the amount of cargo entering destination j cannot exceed the entry capacity of that destination. Constraints in (5) are the domain constraints.

SCENARIOS

To test the performance of the mathematical model, three different empirical scenarios are created. First one has five origins and five destinations and the goods can be transported in the present period or can be delayed until the next two periods if the capacity is not available. Second scenario has 50 origins and 10 destinations and goods can be delayed until the next period. Third and the last one has 100 origins and 15 destinations but goods are not allowed to be transported in later periods. In all cases, capacities and demands are created randomly.

First Scenario (Five Origins & Five Destinations)

Table 1. Parameter Values of First Scenario

	D_{ij1}					
	D1	**D2**	**D3**	**D4**	**D5**	**Cap_{i1}**
O1	33080	5272	4822	29399	9854	12000
O2	19140	19383	14412	9288	27148	14000
O3	29273	25965	34387	23496	6922	40000
O4	30407	26000	16964	11529	10980	15000
O5	21667	15970	20764	12665	6429	45000
Cap_{j1}	10000	30000	10000	25000	55000	

	D_{ij2}					
	D1	**D2**	**D3**	**D4**	**D5**	**Cap_{i2}**
O1	4111	34001	20187	11007	11008	12000
O2	21736	23220	3233	27241	21549	14000
O3	5792	31803	3423	22456	34121	40000
O4	1873	19829	27374	33842	2049	15000
O5	24544	10044	22772	20697	10851	45000
Cap_{j2}	10000	30000	10000	25000	55000	

	D_{ij3}					
	D1	**D2**	**D3**	**D4**	**D5**	**Cap_{i3}**
O1	33478	17859	16303	11096	10099	12000
O2	9433	20591	2687	27522	34932	14000
O3	33762	32705	27412	21984	8059	40000
O4	23564	32813	21218	26796	14951	15000
O5	29014	30505	4004	2545	24840	45000
Cap_{j3}	10000	30000	10000	25000	55000	

	D_{ij4}					
	D1	**D2**	**D3**	**D4**	**D5**	**Cap_{i4}**
O1	16026	23907	31747	30265	4098	12000
O2	27824	14403	3043	28628	26573	14000
O3	9104	32103	9225	17313	15228	40000
O4	32127	3667	9104	3890	26770	15000
O5	23246	21154	14329	29162	28223	45000
Cap_{j4}	10000	30000	10000	25000	55000	

	D_{ij5}					
	D1	**D2**	**D3**	**D4**	**D5**	**Cap_{i5}**
O1	10460	13861	24900	21392	27254	12000
O2	5980	21207	30351	24864	16873	14000
O3	34003	2386	19668	23013	9857	40000
O4	20509	16773	10584	23262	5134	15000
O5	7020	22444	32009	4354	12741	45000
Cap_{j5}	10000	30000	10000	25000	55000	

	D_{ij6}					
	D1	**D2**	**D3**	**D4**	**D5**	**Cap_{i6}**
O1	15275	16952	10130	14904	2275	12000
O2	30048	10776	28882	24488	1530	14000
O3	29729	20116	26696	3277	2372	40000
O4	9919	6070	32556	23916	31138	15000
O5	29052	17354	8362	10919	9700	45000
Cap_{j6}	10000	30000	10000	25000	55000	

In this scenario the parameter values specified in Table 1 are used. The period is assessed as six periods and the demands that are not fulfilled at the existing period can be transferred up to two periods ahead. The prices are fixed to 1 $/ton. When the mathematical model is solved with MATLAB Optimization Toolbox 94500 variables are used and $753185 is given as a solution.

Second Scenario (50 Origins & 10 Destinations)

In the second scenario the number of origins and the number of destinations are increased and parameters are changed. The period is assessed as six periods and the demands that are not fulfilled at the existing period can be transferred to the next period. The prices are fixed to 1 $/ton. The capacities and demand values are varying from period to period. However only some of first period demand and capacity values are given in table 2.

Table 2. First Period Demand and Capacity Values of Second Scenario

	D_{ij1}										
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**Cap_{i1}**
O1	10744	11291	4063	6004	7018	6520	4335	3826	8652	7859	5441
O2	6365	11704	4790	5480	6586	8916	4987	5930	13890	4617	33054
O3	12520	7961	12972	4685	7139	3146	3632	4538	12871	5271	36478
O4	12609	12563	7388	5003	10932	6504	3472	8567	7502	13885	12500
O5	6345	10389	13070	8829	12711	14963	10322	7980	10075	11605	39089
O6	10057	4689	11330	7997	3386	13677	12823	12753	4319	8842	26137
O7	7147	3280	6657	11197	12465	14743	11021	4594	3575	10511	19494
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
O45	12716	12291	4000	4915	11144	9181	8936	13635	9891	8596	47886
O46	4957	7918	11208	6515	3557	11031	6980	12367	12883	12979	27391
O47	3656	3968	9949	9606	9638	9115	4630	11202	5673	7842	6148
O48	5164	11968	5896	7396	14851	14974	5649	12637	3050	14294	20646
O49	11138	3396	4621	14024	9639	7024	10932	10902	9069	5322	47347
O50	4789	12845	9504	13142	13176	9129	7280	6583	3554	12552	32812
Cap_{j2}	45770	48695	35786	21760	33283	9383	30379	16378	16186	15175	

When the mathematical model is solved with MATLAB Optimization Toolbox 20,160,000 variables are used and $1,581,843 is given as a solution.

Third Scenario (100 Origins & 15 Destinations)

In the third scenario the six periods are selected. However in this scenario the goods are not allowed to transfer to the future periods. Then price matrix is created with randomly changing values between 1 and 50. In this scenario the number of origins has been kept large, 100 origins. The number of destinations is increased to 15. The number of periods that has been studied kept at six periods. In table 3, only some of demand and capacity values that are belonging to the first period have been shown.

When the third scenario is solved using this new matrix and with LP model, the result is $117,894,193. However the number of variables and the number of constraints forces this problem to be solved by heuristics instead of solving by simplex or other optimal solutions. The heuristic that is advised here would be as follows:

Starting from the northwestern corner of the matrix to the right to complete the line capacity to complete the request to meet the demand on that line with the last cell added to the demand capacity of the cell to reduce the capacity corresponding to passing. Once the capacity is met, the remaining cells in the line will be zero. Then go through the next row and start from the leftmost cell. Repeat the same steps. To check whether the cell capacity of that cell has been exceeded in passing each cell on the right. If it is exceeded, reduce the value of the cell so that it corresponds to the capacity. Once the capacity is met, the remaining cells in the column will be zero.

Table 3. First Period Demand and Capacity Values of Third Case

	Dij1															
	D1	**D2**	**D3**	**D4**	**D5**	**D6**	**D7**	**D8**	**D9**	**D10**	**D11**	**D12**	**D13**	**D14**	**D15**	
O1	4160	9548	9183	6261	12173	5292	10057	7996	6399	10847	6197	10546	11378	3123	10569	39066
O2	14780	12223	6976	12256	13964	5695	9339	3544	8346	14551	7713	8503	9224	5001	9943	45566
O3	4324	8319	6157	14999	6288	9133	3790	6021	13245	9395	14414	11352	9208	13353	8793	13210
O4	5528	12839	10274	4618	13084	3294	8014	12516	9195	8827	9050	9045	3283	12508	9080	33298
O5	13160	12917	5451	10370	8293	5218	4091	10508	12228	4315	10294	13426	5690	6829	5424	45608
O6	11719	6196	9785	4656	6832	9722	10245	7621	6624	3127	5391	4597	14740	4420	8103	31898
O7	6016	7919	11003	3221	14585	12160	6980	10655	7152	10900	6827	4971	10069	9571	8247	27077
⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮	⋮
O94	9140	8199	8441	10440	14276	13152	7098	8564	13709	5035	4417	5870	14663	7443	5780	49721
O95	8543	4834	8604	8276	7361	8473	3007	4813	11617	9826	8103	10371	10058	13904	9524	14648
O96	5826	11596	9188	13897	4981	12194	9501	7864	8268	4572	11395	4114	3155	14190	13788	37340
O97	12868	5688	6261	7616	12923	6554	12719	9037	11540	10190	10192	10665	10139	9255	14162	43124
O98	7369	5899	4704	7387	11047	3435	4051	4948	14555	8854	8987	11058	14232	10397	8248	45250
O99	14745	14685	14826	9143	12662	13991	14724	4760	12465	5973	3462	5611	13357	7971	4931	16692
O100	12392	5117	4095	11774	4609	9312	6204	3028	4823	12297	3516	6965	11647	9415	13261	40572
Capj6	16067	48118	35959	10406	18620	13379	10793	49571	31073	45903	48377	40638	5214	47972	49553	

Then, in the price matrix, the sum of prices are sorted from top to bottom and left to right. After the variables in the third scenario are sorted according to the sorted price matrix, the problem solved with heuristic and the result is $71,878,984. Finally, in the third scenario, each period O&D cell was multiplied by its corresponding value in the price matrix. The resultant matrices are summed up from top to bottom and from left to right in ascending order, when the final matrices solved with the heuristic the result is $70,108,246.

CONCLUSION

In this study, a mathematical model was developed that focuses on optimal capacity allocation and revenue maximization when there is a capacity constraint on the origins and destinations of single hub air cargo operations. First, the model was solved on a scenario that goods transferred from 5 origins to 5 destinations in 6 periods. And allows the transfer of the request that cannot be carried in that period up to next 2 periods. Although the O&D dimension was small, 94500 variables were used in the solution. When looking at the result of the first scenario, it was seen that the model used the input and output capacities at the maximum level to maximize profit. In the latter scenario goods transferred from 50 origins to 10 destinations in 6 periods. and the demand that are not fulfilled at the existing period could be transferred to the next period. In this scenario, the variable amount of 20,160,000 that occurred, both the person who prepared the model and the solution program, faced a very complicated and hard structure. Nevertheless, the model maximized revenue using capacities at the optimum level. In the last scenario there were 100 origin and 15 destinations but goods not allowed to transfer next periods. In this scenario, the variable amount of 81,000,000 that occurred. The heuristic solution is turned to be inevitable.

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A LOGISTICS ALLOCATION MODEL FOR FREIGHT VILLAGES: A CASE STUDY FOR TURKEY

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Abstract *– Freight villages have numerous benefits for improving the quality of life for residents of the regions where they have constructed. By reducing the unnecessary movements of vehicles, they alleviate urban traffic congestion which leads to less environmental and noise pollution. Therefore, allocation in freight villages is a crucial issue. In this study, an allocation model for freight village is proposed. This model has two objectives: i) transportation cost minimization and ii) transportation time minimization. It is applied to Turkey case. In order to solve this problem, linear physical programming is used since it eliminates the weights determination phase from the decision process.*

Keywords – Allocation Model, Freight Village, Logistics, Linear Physical Programming

INTRODUCTION

A freight village can be defined as a specific commercial site where various logistics-oriented companies provide their specialized logistics services and related accompanying services. The "freight village" concept first introduced in early 1960s to cope with the growing logistics activities [1]. After the establishment of initial freight village in France, many others are instituted rapidly in a number of countries around the world.

Freight villages are also known as logistics villages, logistics centers, distribution parks and various other names depending on the services provided. Since a freight village is essentially an intermodal terminal, it encourages interaction between rail-ways, motorways, waterways and airways.

Freight villages have numerous benefits for improving the quality of life for residents of the regions where they have constructed. By reducing the unnecessary movements of vehicles, they alleviate urban traffic congestion which leads to less environmental and noise pollution. The synergy between the firms in freight village improves the efficiency of logistics processes. A freight village is also an important opportunity for both customers and logistics firms in terms of competitiveness and economic growth.

There are numerous studies in the literature about designing a freight village and factors to consider when designing a freight village. Logistics village is an interesting issue for the development of a logistics plan. Thus, some of the studies deal with selecting the logistics village locations. One of them is conducted by [2]. While evaluating the logistics village location alternatives, they use geographic information system (GIS) based multi-criteria decision making model. Moreover, [1] study about the evaluation of effects of intermodal freight villages by using multi-criteria analysis. Reference [3] has another study about evaluation of freight villages considering financial dimension of investments for a freight village. Furthermore, there is another study about location and allocation of a logistics center by [4]. They propose a robust optimization model about location and allocation of logistics centers. They also make their analysis under stochastic environment. Afandizadeh and Moayedfar [5] have a study about the feasibility of creating a freight village in special economic zone of Shahid Rajaie port in Hormozgan Province. They also make a sensitivity analysis and depict its results.

Apart from the studies about location selection of freight villages, there is another group of studies about freight village design which are multi-criteria methods applied. For instance, in the study of Ballis et al. [6], three alternative designs for freight villages are evaluated by the method of PROMETHEE.

Similarly, a study related to an implementation of freight villages is conducted in Turkey [7]. This study makes an analysis about freight villages and its contributions to Turkish State Railways (TCDD). For this reason, 12 alternatives locations are assessed while considering distances covered and freight capacities (ton-km) transferred to freight villages. They design a mathematical model which reveals that 5 of 12 freight villages should be opened.

In this study, we focused on a logistic network which is constituted from seaports, Freight Villages (FVs) and Organized Industrial Zones (OIZs). Among those nodes railway or road transportation modes may be used. An exception is that only the road transportation mode may be used for direct shipments from seaports to

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OIZs. Main idea of the study is considering the tradeoff between transportation cost and transportation time by facilitating from the freight villages having railway connections.

METHODOLOGY

Linear Physical Programming

Most of the optimization problems focus on solving real world problems. While solving optimization problems, decision makers judge alternatives and effectiveness of the solutions. To handle an optimization model, mathematical programming models require constructing an objective function that is subjected to constraints. At the problem formulation stage, decision makers need precise statements for the objectives. However, most real world decision-making problems are multi-objective and exist in an imprecise environment.

Goal programming is a mainly used methodology in multi-objective environments and generally applied to linear problems thus deals with the achievement of pre-scribed goals or targets. The original approach reported by Charnes and Cooper [8], [9], is known as the Archimedean approach and goals are comparable and differ by numerical weights. A utility function is used to represent these goals. The major advantage of using a utility function depends on the correct assessment and usage only then it will practically ensure the most satisfactory solution. Unfortunately, Messac et al. [10] stated in their study that there was no practical approach exists for forming utility functions in a multi-objective setting.

In literature, fuzzy problem formulations used to overcome the difficulties associated with setting weights and goals. Fuzzy sets, which are defined by Zadeh [11], are used in the development of fuzzy goal programming approaches. However, these approaches need a scalar goal for each criterion as well.

In 1996, Linear Physical Programming (LPP) was firstly proposed by [10] as a new methodology to decision-making problems which are mostly multi-objective. Methodology provides an optimization method in which specific algorithms is used for obtaining the weights of multiple objectives. According to method, after determination of the weights, these weights are used in the optimization process to obtain optimal results [12].

Within the physical programming procedure, the decision maker expresses preferences for each criterion using four different classes. Each class comprises two cases, hard and soft, referring to the sharpness of the preference. McAllister et al. [13] declined that LPP provides specificity and flexibility to express the preferences for each criterion, which is better than simply saying minimize, maximize, greater than, less than, or equal to. Two main classes and their sub-classes are characterized as follows [10];

Soft Classes:

Class 1S Smaller-is-better
Class 2S Larger-is-better
Class 3S Value-is-better
Class 4S Range-is-better

Hard Classes:

Class 1H Must be smaller
Class 2H Must be larger
Class 3H Must be equal
Class 4H Within range

In LPP, decision maker doesn't need to specify optimization weights in the problem formulation stage. Rather, he/she specifies ranges of different degrees of desirability for each objective. The parameters/targets $\boldsymbol{t_{i1}}^{+}$ through $\boldsymbol{t_{i5}}^{+}$ are physically meaningful values that are specified by the decision maker associated with the i[th] criterion. Decision variable vectors are denoted as x, and the i[th] generic criterion as$g_i(x)$. The value of the criterion is categorized according to the preference ranges shown on the horizontal axis. These are defined as follows;

- Ideal range($\boldsymbol{g_i} \leq \boldsymbol{t_{i1}}^{+}$): an acceptable range with a minimal additional value.
- Desirable range($\boldsymbol{t_{i1}}^{+} \leq \boldsymbol{g_i} \leq \boldsymbol{t_{i2}}^{+}$)**:** an acceptable range that is desirable.
- Tolerable range($\boldsymbol{t_{i2}}^{+} \leq \boldsymbol{g_i} \leq \boldsymbol{t_{i3}}^{+}$)**:** an acceptable, tolerable range.
- Undesirable range($\boldsymbol{t_{i3}}^{+} \leq \boldsymbol{g_i} \leq \boldsymbol{t_{i4}}^{+}$)**:** a range that, while acceptable, is undesirable.

- Highly undesirable range($t_{i4}^+ \leq g_i \leq t_{i5}^+$)**:** a range that, while still acceptable, is highly undesirable.
- Unacceptable range($g_i \geq t_{i5}^+$)**:** the range of values that the generic objective must not take.

In Figure 1, soft class functions for the LPP method is presented. Class-functions are used to map design metrics into non-dimensional, strictly positive, real numbers. This mapping, in effect, transforms design metrics with disparate units and physical meaning onto a dimensionless scale through a unimodal function.

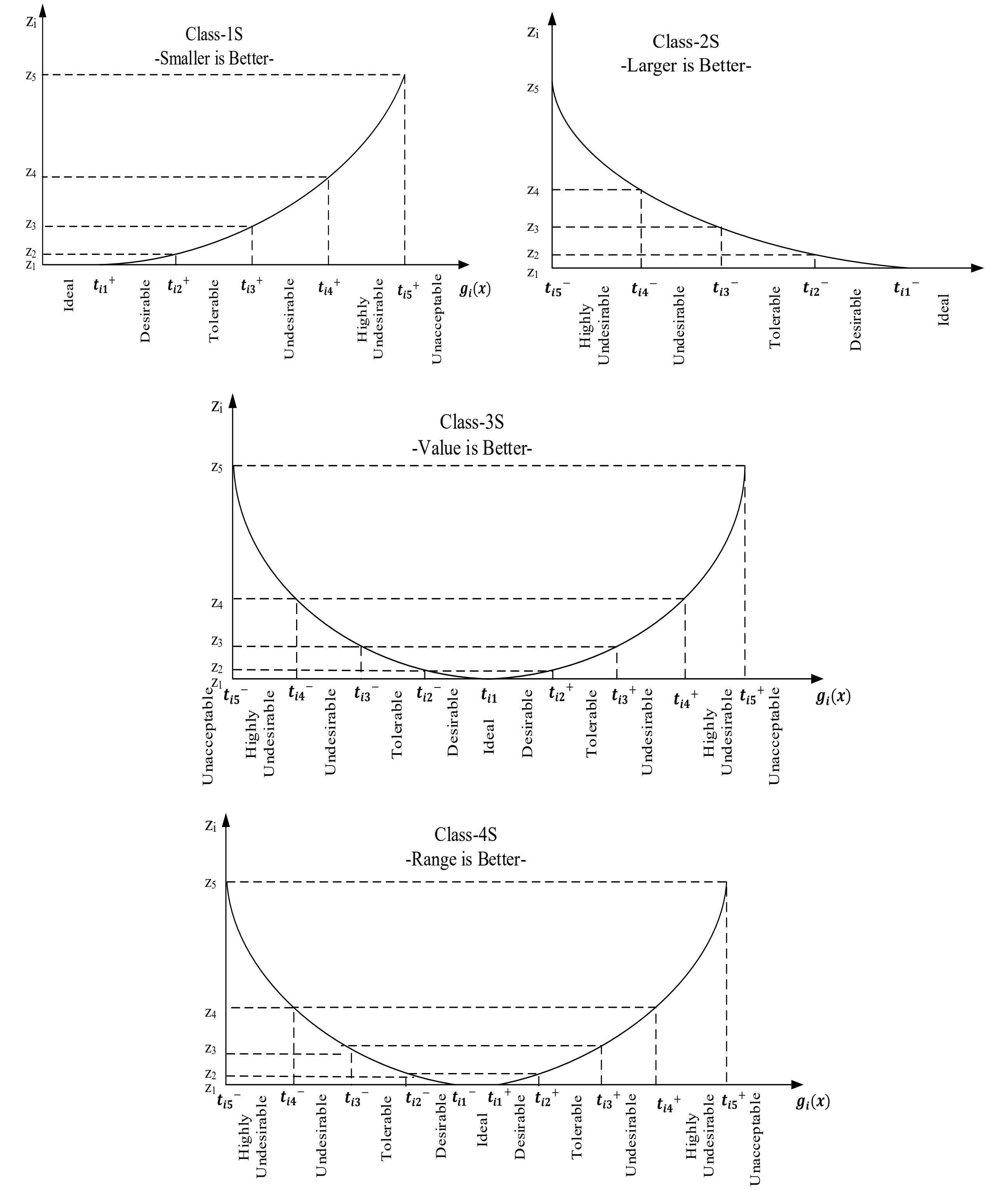

Figure 1. Soft class functions for physical programming (Adapted from [10])

The application of physical programming employs a flexible and natural problem formulation framework. Generally following four steps followed in the LPP [10];

1. One of the four classes is specified by decision maker for each criterion
2. Limits of the ranges are defined for each criterion by decision maker $t_{is}{}^{+}, t_{is}{}^{-}$
3. LPP weight algorithm is used as follows after preferences of decision maker is defined (Step 1&2) ;
   a) $\beta = 1.1$; $w_{i1}^{+} = 0, w_{i1}^{-} = 0$; $\tilde{z}^{2}$ = small positive number
      $i = 0$; $s = 1, n_{sc}$ = # of soft criteria
      (β will be used as a convexity parameter; n_{sc} denotes the number of soft criteria)
   b) Set i = i+1 "i" denote criterion number.
   c) Set s = s+1 "s" denote a generic range-intersection
      Evaluate in sequence, $\tilde{z}^{s}, \tilde{t}_{is}{}^{+}, \tilde{t}_{is}{}^{-}, w_{is}{}^{+}, w_{is}{}^{-}, \widetilde{w}_{is}{}^{+}, \widetilde{w}_{is}{}^{-}, \widetilde{w}_{min}$
      If $\widetilde{w}_{min}$ is less than some chosen small positive number then increase β an go Step 2
   d) If s ≠ 5, go to Step 3
   e) If i ≠ n_{sc}, go to Step 2
4. With using the weights obtained from the above algorithm, it is possible to write mathematical expressions for the piecewise linear class function of each criterion. Total score for each alternative is calculated as follows [14];
   $$\min_{d_{is}^{-}, d_{is}^{+}, x} J = \sum_{i=1}^{n_{sc}} \sum_{s=2}^{5} (\widetilde{w}_{is}{}^{-} d_{is}^{-} + \widetilde{w}_{is}{}^{+} d_{is}^{+})$$

All soft class functions should be minimizing at the total objective function. In cases where decision maker only cares to stay within some limits, hard classes should apply. For a hard criterion, only two ranges are defined, acceptable and unacceptable. All of the hard class functions should appear as constraints. Kongar and Gupta [15] stated the properties of class functions. According to the study, (i) a lower value of a class function is preferred over a higher value, (ii) class function is strictly positive, continuous, piecewise linear and convex and (iii) the value of a class function z_i at a given ranges-intersection is the same for any class type.

Different from goal programming and fuzzy goal programming techniques, LPP uses the satisfaction levels. Kongar and Gupta [16] stated that LPP distinguishes itself from the other techniques by removing the decision maker from the weight determination process. LPP method uses crisp numbers, but objective function is piecewise linear thus model allow decision makers to denote their desirability degrees. Moreover, LPP intends to be a simple and user-friendly optimization method and employs a flexible and natural problem formulation framework. Since design problems have a multi-objective nature, in other terms conflicting objectives directly affect the search, LPP provides a more flexible and deterministic solution approach to achieve the best solution.

Allocation Model

The model is designed for transportation cost and transportation time minimization considering the material flows among seaports, FVs and OIZs. There are two alternative transportation modes: road and railway. Basically, model choses direct or indirect shipment. In direct shipping alternative, materials are sent from seaport to OIZ directly. And the second alternative is using the FVs as transshipment points. Used indices, parameters, decision variables and the formulation of the objective functions and constraints are detailed below.

Indices:

i: Seaports

j: Freight villages

k: Organized industrial zones

Parameters:

c_{ijm}: cost of transportation from seaport *i* to freight village *j* with mode *m*

c_{jkm}: cost of transportation from freight village *j* to OIZ *i* with mode *m*

c_{ikm}: cost of transportation from seaport *i* to OIZ *k* with mode *m*

t_{ijm}: transportation time from seaport *i* to freight village *j* with mode *m*

t_{jkm}: transportation time from freight village *j* to OIZ *i* with mode *m*

t_{ikm}: transportation time from seaport i to OIZ k with mode m
cap_i: freight handling capacity of seaport i
cap_j: freight handling capacity of freight village j
D_k: demand of OIZ k

Decision variables:

x_{ijm}: transported quantity from seaport i to freight village j with mode m
x_{jkm}: transported quantity from freight village j to OIZ i with mode m
x_{ikm}: transported quantity from seaport i to OIZ k with mode m

i. *Piecewise linear Archimedian aggregate function can be given as follows:*

$$\min J = \sum_{i=1}^{n_{sc}} \sum_{s=2}^{5} \left(\widetilde{w}_{is}^{-} d_{is}^{-} + \widetilde{w}_{is}^{+} d_{is}^{+} \right) \quad (1)$$

ii. *Criteria (Soft Constraints):*

The model includes two Class-1S criteria which are subject to minimization. There is no Class 2S, Class 3S and Class 4S criteria in the model.

$$g_1 = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{m=1}^{M} c_{ijm} x_{ijm} + \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{M} c_{jkm} x_{jkm} + \sum_{i=1}^{I} \sum_{k=1}^{K} \sum_{m=1}^{M} c_{ikm} x_{ikm} \quad (2)$$

$$g_2 = \sum_{i=1}^{I} \sum_{j=1}^{J} \sum_{m=1}^{M} t_{ijm} x_{ijm} + \sum_{j=1}^{J} \sum_{k=1}^{K} \sum_{m=1}^{M} t_{jkm} x_{jkm} + \sum_{i=1}^{I} \sum_{k=1}^{K} \sum_{m=1}^{M} t_{ikm} x_{ikm} \quad (3)$$

2 and 3 try to minimize the total transportation cost and transportation time respectively.

iii. *Goal Constraints:*

These constraints try to minimize deviations (d_{is}) from target values. If the final value of the performance criteria is in the ideal range, the total deviation will be zero Eq.4-5.

$$g_i - d_{is}^{+} \le t_{i(s-1)}^{+};\quad g_i \le t_{i5}^{+};\quad d_{is}^{+} \ge 0 \quad \text{(for all } i \text{ in classes 1S, 3S, 4S, } i = 1,\ldots,n_{sc};\ s = 2,\ldots 5) \quad (4)$$

$$g_i + d_{is}^{-} \ge t_{i(s-1)}^{-};\quad g_i \ge t_{i5}^{-};\quad d_{is}^{-} \ge 0 \quad \text{(for all } i \text{ in classes 2S, 3S, 4S, } i = 1,\ldots,n_{sc};\ s = 2,\ldots 5) \quad (5)$$

As aforementioned, this model includes two 1S performance criteria.

iv. *System Constraints (Hard constraints):*

Below given equations denoted as hard constraints which are related with the main problem.

$$\sum_{j=1}^{J} x_{ijm} + \sum_{k=1}^{K} x_{ikm} \le cap_i \quad \forall i \in I \quad (6)$$

$$\sum_{i=1}^{I} \sum_{m=1}^{M} x_{ijm} \le cap_j \quad \forall j \in J \quad (7)$$

$$\sum_{i=1}^{I} x_{ikm} + \sum_{j=1}^{J} x_{jkm} \ge D_k \quad \forall k \in K \quad (8)$$

$$\sum_{i=1}^{I} \sum_{m=1}^{M} x_{ijm} \ge \sum_{k=1}^{K} \sum_{m=1}^{M} x_{jkm} \quad \forall j \in J \quad (9)$$

$$x_{ijm}, x_{jkm}, x_{ikm} \ge 0 \quad \forall i \in I, \forall j \in J, \forall m \in M \quad (10)$$

6-7 ensure not to exceed the capacity of seaports and FVs respectively. 8 provide to satisfy the demand of each OIZ. 9 is the constraint that balances the delivering and shipping quantities for each FV. And 10 is the non-negativity constraint.

CASE STUDY

The case is designed for the shipments of the some OIZs in Turkey that have rail connections. These OIZs are (1) Torbalı, (2) Manisa, (3) Kemalpaşa, (4) Tire, (5) Ankara 1., (6) Erzincan, (7) Malatya, (8) Elazığ, (9) Diyarbakır, (10) Gaziantep. The supplies of the networks are ten seaports having railway connections. The chosen seaports are (1) Tekirdağ, (2) Haydarpaşa, (3) Yılport, (4) Gübretaş, (5) Bandırma, (6) Kozlu, (7) Samsun, (8) İzmir, (9) Mersin, (10) İskenderun. Between seaports and OIZs, some of the TCDD FVs may be used as transshipment points. The list of the FVs is (1) Halkali-Istanbul, (2) Köseköy-Izmit, (3) Hasanbey-Eskişehir, (4) Gökköy-Balikesir, (5) Uşak, (6) Kaklik- Denizli, (7) Gelemen-Samsun.

Demand quantities of the OIZs are produced considering the statistical data from Turkish Statistical Institute (Table 1). The supply quantities of the seaports are obtained by proportioning the total demand into the total capacities of the seaports (Table 2). The capacities of the FVs are assumed as 5000 tones, since there is not a capacity problem in TCDD FVs.

Table 1. Demands of OIZs (in tones)

Torbalı OIZ	Manisa OIZ	K.paşa OIZ	Tire OIZ	Ankara 1. OIZ	Erzincan OIZ	Malatya OIZ	Elazığ OIZ	D.bakır OIZ	G.antep OIZ
1000	2000	1250	500	4000	750	1000	500	1000	1500

Table 2. Supply of the Seaports (in tones)

Port1	Port2	Port3	Port4	Port5	Port6	Port7	Port8	Port9	Port10
277	197	3853	491	393	295	723	1903	4549	830

The transportation costs and transportation times are derived from the distances between nodes of the network. Distances in km are multiplied by the values given in Table 3. These coefficients are obtained from the logistics sector experts. In the case, road transportation mode may be used for all shipments but railway alternative is not applicable for direct shipments between Seaports and OIZ.

Table 3. Unit transportation costs (TL) and times (Hour)

Unit transportation cost per tone*km		Unit transportation time per km	
Road	Railway	Road	Railway
0,224	0,137	0,018	0,025

First, the model is solved for cost and time minimization objectives separately by using LINGO solver. The results are found as the ideal solution values for each objective. Then, the obtained decision variable values for cost minimization problem are used in time minimization problem to find the unacceptable value of it. Same calculations are repeated to obtain the unacceptable value of cost minimization objective. For the remaining target values of LPP formulation, preferences of the logistics sector experts are asked. These desirability degrees are given in Table 4.

Table 4. Desirability degrees concerned objectives (Target values)

	g_1 Class 1S (Minimization)	**g_2 Class 1S (Minimization)**
Ideal	<877.878,48	<86.575,17
Desirable	877.878,48 - 937.728,91	86.575,17 - 99.292,20
Tolerable	937.728,91 - 997.579,33	99.292,20 - 105.650,72
Undesirable	997.579,33 - 1.057.429,76	105.650,72 - 112.009,24
Highly undesirable	1.057.429,76 - 1.077.379,90	112.009,24 - 118.367,75
Unacceptable	>1.077.379,90	>118.367,75

To obtain the normalized weight deviations, LPP weighting algorithm is run by using data shown in Table 4. The final weight deviations of performance criteria are shown in Table 5.

Table 5. The final weight deviations of performance criteria

	$\tilde{w}_{12}^{+}$	$\tilde{w}_{13}^{+}$	$\tilde{w}_{14}^{+}$	$\tilde{w}_{15}^{+}$
g_1	0,029	0,029	0,469	0,472
	$\tilde{w}_{22}^{+}$	$\tilde{w}_{23}^{+}$	$\tilde{w}_{24}^{+}$	$\tilde{w}_{25}^{+}$
g_2	0,156	0,453	0,187	0,203

After completing the above mentioned calculations and using the weights obtained with weighting algorithm, LPP model is solved and the results of the objective functions are represented in Table 6.

Table 6. Objective value results for LPP model

Transportation cost minimization (g_1)		Transportation time minimization(g_2)	
Numerical Results	Preference Degree	Numerical Results	Preference Degree
931.599,32	Desirable	99.292,18	Desirable

In Table 7-9 the shipped quantities are shown. From Seaport 3, 4, 5 and 7 to FV 2, 4 and 7 5460 tons of materials are shipped. For all shipments between seaports and FVs railway mode is chosen.

Table 7. Shipped quantities from seaports to FVs

	Mode	FV2	FV4	FV7
Seaport 3	**Railway**	3853	0	0
Seaport 4	**Railway**	491	0	0
Seaport 5	**Railway**	0	393	0
Seaport 7	**Railway**	0	0	723

And those materials are shipped from FVs to OIZ 1, 2, 3, 5 and 6. On that stage, again railway is chosen, except from Seaport 3 to OIZ 5. Choosing of the railway mode mostly may be explained by the effect of cost minimization.

Table 8. Shipped quantities from FVs to OIZs

	Mode	OIZ1	OIZ2	OIZ3	OIZ5	OIZ6
FV2	**Road**	0	0	0	841	0
FV2	**Railway**	174	1803	3	1523	0
FV4	**Railway**	393	0	0	0	0
FV7	**Railway**	0	0	0	0	723

Remaining quantities are shipped from Seaports to OIZs because of the time pressure. The main highlighted point is that the four FVs are chosen to use as transshipment points and the reason of this is cost minimization objective.

Table 9. Shipped quantities from seaports to OIZs

	OIZ1	OIZ2	OIZ3	OIZ4	OIZ5	OIZ6	OIZ7	OIZ8	OIZ9
Seaport1	0	0	0	277	0	0	0	0	0
Seaport2	0	197	0	0	0	0	0	0	0
Seaport6	0	0	0	0	295	0	0	0	0
Seaport7	0	0	0	0	0	0	0	0	0
Seaport8	433	0	1247	223	0	0	0	0	0
Seaport9	0	0	0	0	1341	27	1000	500	170
Seaport10	0	0	0	0	0	0	0	0	830

CONCLUSION

The “freight village” concept firstly emerged in early 1960s after that its application rapidly spread and today, there are more than 60 freight villages in Europe. Also, construction of several freight villages is planned. One of the main functions of these freight villages which are operated at national/ international state is distribution from the one center, smart warehousing systems and easier customs transactions. Freight villages are integrated to all transportation systems and help lower costs and increase efficiency of logistic networks.
In today’s globalized business environment, infrastructure of the transportation and related policies gained importance day by day. These villages are an integral part of the logistics chain. From this point of view,

freight villages have a critical role in the competition among countries. In Turkey, construction of freight villages provide several advantages as following,

- Gaining advantage in the globalized market, simplifying to gather and distribute process of goods.
- Take advantage of Turkey's geostrategic location close to Asia and Europe.
- Creating connection to many organized industry areas through logistics routes.
- Develop combined transportation via connecting railroads, airports and seaports.
- Utilizes Turkey's transportation infrastructure.
- Save money from storage. Enable companies to save time and money.

In this study, an allocation model is constructed to show the benefits of the freights villages in logistics networks. As it is seen from the case study results, from Seaport 3, 4, 5 and 7 to FV 2, 4 and 75460 tons of materials are shipped and those materials are shipped from FVs to OIZ 1, 2, 3, 5 and 6. The most important sides of FVs are consolidation opportunities and railway usage. According to results, for all shipments between seaports and FVs and between FVs and OIZ, railway is chosen, except from Seaport 3 to OIZ 5. Choosing of the railway mode mostly may be explained by the effect of cost minimization. Study highlighted that; FVs contributed to cost minimization when they are used as transshipment points in allocation model.
In future studies, problem can be extended in many ways. Adding handling operations in the FVs may bring more accurate results. What is more, stope industry is very important for railway usage and important mining locations may be considered as supply points to extend the problem.

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