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CONTENT


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A MODEL FOR SUPPLIER SELECTION UNDER ENVIRONMENTAL CONSIDERATIONS

Ahmet Selçuk Yalçın[1], Hüseyin Selçuk Kılıç[2]

Abstract− *In this study, two robust multi-attribute decision making techniques (MCDM), Intuitionistic Fuzzy Analytic Hierarchy Process (IF-AHP) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) are utilized in combination to better address this selection problem. The criteria importance weights are determined via IF-AHP, then the obtained importance weights are used in the PROMETHEE method for the best ranking of the alternative suppliers. An application in air filter industry is performed to demonstrate the validation of the proposed methodology.*

Keywords− Greenness, IF-AHP, PROMETHEE, supplier selection

INTRODUCTION

Green supply chain management (GSCM) has fascinated a lot of interest from scholars and practitioners as it has environmental objectives such as reducing waste, protecting product, raw materials and natural resources, and providing sustainability (Fortes, 2009). The supplier selection decision is one of the most basic and significant decisions made by purchasers and enterprises (Bai and Sarkis, 2010). Hazardous substances present in the raw materials supplied by suppliers can leave a negative environmental impression on the supply chain (Lee et al., 2009). Therefore, cooperating with appropriate environmental suppliers is a quite crucial issue (Akman, 2012).

Green supplier selection can be regarded as the MCDM problem comprising of conflicting criteria, alternatives and decision makers (Bali and Guresen, 2013). However, the blend of quantitative and qualitative criteria and the wideness and variety of suppliers make the supplier selection and assessment process more complicated (Bananeian et al., 2016). Various decision-making methodologies for green supplier selection have been utilized such as AHP, ANP, TOPSIS, VIKOR, DEMATEL, fuzzy set theory, and their hybrid ones.

The most frequently used methodology is AHP followed by ANP, DEA, and other techniques. AHP does not only deal with the ambiguity and impression of the human decision making process, but also it can ensure the requisite strength and flexibility to for decision makers to comprehend the problem (Govindan et al., 2015).

Green supplier selection problem shows uncertainty because decision makers (DMs) may be unwilling or unsuccessful in assigning crisp evaluation values due to limited knowledge or subjectivity of qualitative assessment criteria (Bali and Güresen, 2013; Liao and Xu, 2014). In the last years, intuitionistic fuzzy logic was regarded as a strong tool to deal with the uncertainty in decision making process. Therefore, in this paper, intuitionistic fuzzy AHP is used to calculate criteria weights. IF-AHP method is a considerable way to overcome the ambiguity occurring from individual's qualitative judgment (Liao and Xu, 2014). Afterwards, PROMETHEE II method is utilized to rank the alternatives taking the criteria weights into consideration.

The organization of this paper is as follows: Section 2 defines intuitionistic fuzzy logic and the proposed model. Section 3 provides an application in filtration industry on how the model can be implemented using IF-AHP and PROMETHEE II. The last section presents the conclusion.

IF-AHP AND PROMETHEE II

The integrated model aims to determine the most appropriate green supplier considering environmental and traditional criteria. Firstly, IF-AHP is used to compute the criteria weights, the weights is used as an input for

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PROMETHEE II. Then, the suppliers are ranked by using PROMETHEE II. The fundamental steps of integrated methodology are demonstrated in Figure 1.

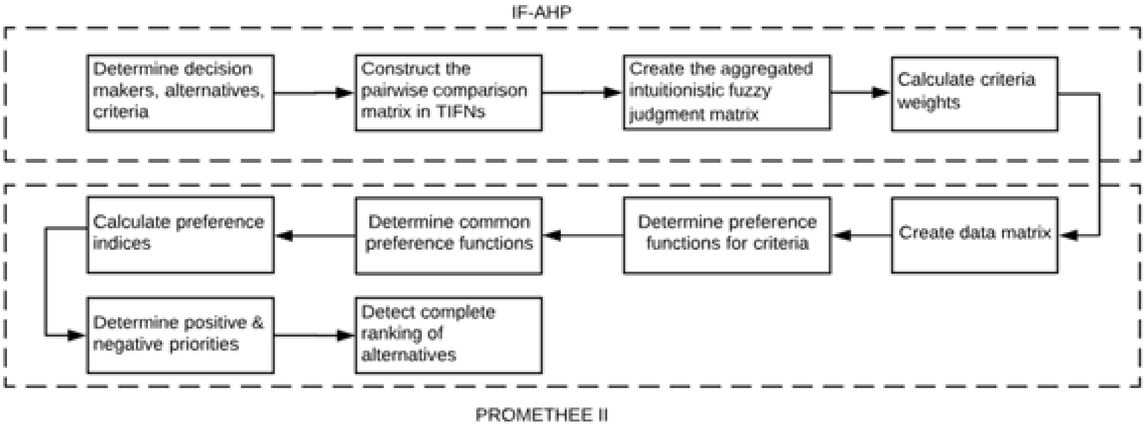

Figure 1. Framework of the Model

IF-AHP

AHP developed by Saaty (1980) is a MCDM technique that performs a pairwise comparison in a hierarchical manner and produces weight as output. However, IF-AHP is more superior and effective than the other AHP models in the process of removing the uncertainties that emerge from the decision maker (Xu and Liao, 2014). Due to the hesitation function, more current results could be effectively obtained in this technique. IF-AHP procedure can be summarized by following steps (Abdullah and Najib, 2016; Büyüközkan et al., 2017):

Step 1: Create the structure of the hierarchy for the assessment of the problem. Define the objective, criteria and alternatives to solve the problem

Step 2: Transform data to TIFNs and construct the pairwise comparison matrix. DMs are requested to define grading using 'nine' AHP linguistic scale, which is from ' equally important' to 'extremely more important' regarding the considerations related to MCDM problems. The transformation of AHP crisp number to TIFN is demonstrated in Table 1.

Table 1: Transformation of the AHP Preference Number to TIFNs (Büyüközkan et al., 2017)

Preference on Pairwise Comparison	AHP Preference Number	Reciprocal AHP Number	TIFN	Reciprocal TIFNs
Equally important (E)	1	1	(0.02, 0.18, 0.80)	(0.02, 0.18, 0.80)
Intermediate value (IV)	2	1/2	(0.06, 0.23, 0.70)	(0.23, 0.06, 0.70)
Weakly more important (WMI)	3	1/3	(0.13, 0.27, 0.60)	(0.27, 0.13, 0.60)
Intermediate value (IV)	4	1/4	(0.22, 0.28, 0.50)	(0.28, 0.22, 0.50)
Strongly more important (SMI)	5	1/5	(0.33, 0.27, 0.40)	(0.27, 0.33, 0.40)
Intermediate value (IV)	6	1/6	(0.47, 0.23, 0.30)	(0.23, 0.47, 0.30)
Very strong more important (VSMI)	7	1/7	(0.62, 0.18, 0.20)	(0.18, 0.62, 0.20)
Intermediate value (IV)	8	1/8	(0.80, 0.10, 0.10)	(0.10, 0.80, 0.10)
Extremely more important (AMI)	9	1/9	(1.0, 0, 0)	(0, 1.0, 0)

Step 3: Determine the weights of DMs. The significance of DMs is evaluated as linguistic factors. The linguistic factors for decision makers are demonstrated in Table 2. The Equation (1) proposed by Boran et al. (2009) is utilized to determine the weight of a decision maker weight. It is assumed that $D = (\mu_k, v_k, \pi_k)$ is the intuitionistic fuzzy number of kth DM.

Table 2: Linguistic Factors for the Significance of DMs (Boran et al., 2009)

Linguistic Factors	TIFN	Linguistic Factors	TIFN
Very important	(0.90, 0.05, 0.05)	Unimportant	(0.25, 0.60, 0.15)
Important	(0.75, 0.20, 0.05)	Very unimportant	(0.10, 0.80, 0.10)
Medium	(0.50, 0.40, 0.10)		

$$\lambda_k = \frac{\left(\mu_k + \pi_k \cdot \left(\frac{\mu_k}{\mu_k + v_k}\right)\right)}{\sum_{k=1}^{m}\left(\mu_k + \pi_k \cdot \left(\frac{\mu_k}{\mu_k + v_k}\right)\right)} \quad (1)$$

Step 4: Create the aggregated intuitionistic fuzzy judgement matrix based on DMs. Every separate view must be integrated to form an aggregated intuitionistic fuzzy decision matrix by implementing IFWA. It is assumed that $R^{(k)} = (r_{ij}^{k})_{mxn}$intuitionistic fuzzy decision matrix of k[th] DM and $\lambda = \{\lambda_1, \lambda_2, \dots, \lambda_n\}$ denotes the whole weights of decision makers and $\sum_{m=1}^{t} \lambda = 1$. The related formulation proposed by Xu (2007) is provided in (2).

$$r_{ij} = IFWA_\lambda \left(r_{ij}^{(1)}, r_{ij}^{(2)}, \dots, r_{ij}^{(t)}\right) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus \dots \oplus \lambda_t r_{ij}^{(t)} =$$
$$= \left[1 - \prod_{k=1}^{t}\left(1 - \mu_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{t}\left(v_{ij}^{(k)}\right)^{\lambda_k}, \prod_{k=1}^{t}\left(1 - \mu_{ij}^{(k)}\right)^{\lambda_k} - \prod_{k=1}^{t}\left(v_{ij}^{(k)}\right)^{\lambda_k}\right] \quad (2)$$

Step 5: Compute the consistency ratio of the aggregated intuitionistic fuzzy judgement matrix. The consistency ratio could be computed by (3).

$$\mathrm{C.R} = \frac{((\lambda_{\max} - n)/(n-1))}{\mathrm{R.I}} \quad (3)$$

in which it is supposed that $(\lambda_{\max} - n)$ is the mean valuation of hesitation degree of the criteria and n denotes the dimension of matrix in the study. The valuation of random indices (RI) proposed by Saaty (1980) is demonstrated on Table 3. CR can be accepted if it does not pass 0.10.

Table 3: Random Indices of Sizes of Matrices

n	1-2	3	4	5	6	7	8	9
RI	0.0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

Step 6: Compute the intuitionistic fuzzy weight of the aggregated intuitionistic fuzzy judgement matrix. The Equation (4) is used to calculate the entropy weight of each criterion's aggregated value.

$$\bar{\bar{w}}_i = -\frac{1}{n \ln 2}[\mu_i \ln \mu_i + v_i \ln v_i - (1 - \pi_i)\ln(1 - \pi_i) - \pi_i \ln 2] \quad (4)$$

Final entropy weights of every criterion could be calculated by using (5) in case of $\sum_{i}^{n} w_i = 1$.

$$w_i = \frac{1 - \bar{\bar{w}}_i}{n - \sum_{j=1}^{n} \bar{\bar{w}}_i} \quad (5)$$

PROMETHEE II

PROMETHEE is a multiple decision making method developed by Jean-Pierre Brans. This method is based on superiority. The steps of the PROMETHEE II method are provided as follows (Brans and Mareschal, 2005):

Step 1: Create the data matrix. The data matrix is constructed by weights and alternatives evaluated by criteria.

Step 2: Determine the preference functions for criteria. Preference functions are determined to show the structure and internal relations of the identified evaluation factors. They are demonstrated in Table 4.

Step 3: The common preference functions for the pair of alternatives based on preference functions are determined. The calculation of common preference function is indicated in (6).

$$P(a,b) = \begin{cases} 0, f(a) \le f(b) \\ p[f(a) - f(b)], f(a) > f(b) \end{cases} \quad (6)$$

Table 4: Preference Functions (Brans and Mareschal, 2005).

Type	Parameter	Function	Type	Parameter	Function
First Type	-	$p(d) = \begin{cases} 0, d \le 0 \\ 1, d > 0 \end{cases}$	Fourth Type	a,b	$p(d) = \begin{cases} 0, d \le a \\ 1/2, a < d \le b \\ 1, d > b \end{cases}$
Second Type	m	$p(d) = \begin{cases} 0, d \le m \\ 1, d > m \end{cases}$	Fifth Type	c,e	$p(d) = \begin{cases} 0, d \le c \\ c < d \le e \\ 1, d > e \end{cases}$
Third Type	k	$p(d) = \begin{cases} d/k, d \le k \\ 1, d > k \end{cases}$	Sixth Type	σ	$P(d) = \begin{cases} 0, d \le 0 \\ 1 - e^{\frac{d^2}{2\sigma^2}}, d > 0 \end{cases}$

Step 4: The preference index for every pair of alternative is detected. The calculation of preference index for any a and b alternatives evaluated with respect to k criterion is done by (7).

$$\pi(a,b) = \frac{\sum_{i=1}^{k} W_i * P_i(a,b)}{\sum_{i=1}^{k} W_i} \quad (7)$$

Step 5: Determine positive and negative superiorities of alternatives. The positive and negative priorities for any a alternative could be computed by utilizing (8) and (9) respectively.

$$\Phi^+(a) = \frac{1}{n-1} \sum_{i=1}^{n} \pi(a,b) \quad (8)$$

$$\Phi^-(a) = \frac{1}{n-1} \sum_{i=1}^{n} \pi(b,a) \quad (9)$$

Step 6: Determine complete priorities of alternatives with PROMETHEE II. Complete priority of every alternative is calculated by the aid of (10)-(12). After calculating the complete priority values, the alternatives can be ranked on the same ground.

$$\Phi(a) = \Phi^+(a) - \Phi^-(a) \quad (10)$$

If $\Phi(a) > \Phi(b)$ alternative a is more superior. (11)

If $\Phi(a) = \Phi(b)$ alternatives a and b are same. (12)

APPLICATION IN AIR FILTER INDUSTRY

In this section, an application in filtration industry is proposed to demonstrate how the model works. The suppliers in the application provide HEPA air filtration media. Those suppliers are called as A1, A2, A3, A4 and A5. As a result of an elaborative literature review on green and traditional supplier selection criteria and based on the suggestions of experts and academic scientists, the related criteria were determined. Quality (C1), price (C2), delivery (C3) and performance history (C4) were identified as the traditional criteria and greenness (C5) as the green criterion.

IF-AHP Methodology for Determining the Weights of the Criteria

Three decision makers who are executives from department of quality, production and research and development participated in assessment process. They have reconciled on pair-wise comparisons of the criteria by using AHP scales ranging from 'equally important' to 'extremely more important'. Due to compromise assessment, there was no need to be fused the decision makers' ideas. Table 5 presents a pair-wise comparison of the criteria in TIFNs based on compromise evaluation. Table 6 presents aggregated matrix of the criteria, while its consistency ratio is 0.04. At last, Table 7 shows the entropy weights and final entropy weights that are considered as an input for PROMETHEE II.

Table 5. Pairwise Comparison of the Criteria

Main Criteria	C1	C2	C3	C4	C5
C1	(0.02, 0.18, 0.80)	(0.33, 0.27, 0.40)	(0.27, 0.33, 0.40)	(0.62, 0.18, 0.20)	(0.18, 0.62, 0.20)
C2	(0.27, 0.33, 0.40)	(0.02, 0.18, 0.80)	(0.18, 0.62, 0.20)	(0.33, 0.27, 0.40)	(0, 1.0, 0)
C3	(0.33, 0.27, 0.40)	(0.62, 0.18, 0.20)	(0.02, 0.18, 0.80)	(1.0, 0, 0)	(0.27, 0.33, 0.40)
C4	(0.18, 0.62 0.20)	(0.27, 0.33, 0.40)	(0, 1.0, 0)	(0.02, 0.18, 0.80)	(0, 1.0, 0)
C5	(0.62, 0.18, 0.20)	(1.0, 0, 0)	(0.33, 0.27, 0.40)	(1.0, 0, 0)	(0.02, 0.18, 0.80)

Table 6. Aggregated Matrix of Main Criteria in TIFNs

Main Criteria	C1	C2	C3	C4	C5	Aggregated matrix
C1	(0.02, 0.18, 0.80)	(0.33, 0.27, 0.40)	(0.27, 0.33, 0.40)	(0.62, 0.18, 0.20)	(0.18, 0.62, 0.20)	(0.851, 0.002, 0.147)
C2	(0.27, 0.33, 0.40)	(0.02, 0.18, 0.80)	(0.18, 0.62, 0.20)	(0.33, 0.27, 0.40)	(0, 1.0, 0)	(0.607, 0.010, 0.383)
C3	(0.33, 0.27, 0.40)	(0.62, 0.18, 0.20)	(0.02, 0.18, 0.80)	(1.0, 0, 0)	(0.27, 0.33, 0.40)	(1.0, 0, 0)
C4	(0.18, 0.62, 0.20)	(0.27, 0.33, 0.40)	(0, 1.0, 0)	(0.02, 0.18, 0.80)	(0, 1.0, 0)	(0.414, 0.036, 0.550)
C5	(0.62, 0.18, 0.20)	(1.0, 0, 0)	(0.33, 0.27, 0.40)	(1.0, 0, 0)	(0.02, 0.18, 0.80)	(1.0, 0, 0)

Table 7. Final entropy weights of the criteria

Criteria	Aggregated matrix	Entropy weights	Final entropy weight
Quality	(0.851,0.002,0,147)	0,033	0,2044
Delivery	(0.607,0.010,0.383)	0,091	0,1921
Price	(1,0,0)	0	0,2114
Performance History	(0.414,0.036,0.550)	0,146	0,1805
Greenness	(1,0,0)	0	0,2114

Using PROMETHEE for Ranking Suppliers

PROMETHEE method is utilized to obtain the final ranking of the alternatives. Firstly, the data matrix for the alternatives is constructed by compromise evaluation among decision makers via a ten-point Likert type scale as shown in Table 8. Then, the fifth type (linear) preference function is determined for all criteria. The parameters for the criteria of quality, delivery, price, performance history and greenness are (3,5), (3,5), (2,4), (1,3), (2,4) respectively. Next, preference index for every pair of alternative is detected. The obtained results are illustrated in Table 9. Positive and negative priorities are calculated for the alternative suppliers and the obtained results are shown in Table 10.

Table 8. Data Matrix

	Criteria				
Alt.	Quality (max)	Delivery (max)	Price (max)	Performance History (max)	Greenness (max)
A	5	2	4	4	8
B	3	5	8	3	6
C	4	3	4	6	7
D	8	4	7	3	4
E	7	7	5	3	9
Weight	0,2044	0,1921	0,2114	0,1805	0,2114

Table 9. Calculated Preference Indices for Alternative Suppliers

	A	B	C	D	E
A	-	0	0	0,2114	0
B	0,2114	-	0,2114	0	0,1057
C	0,0902	0,1805	-	0,2862	0,1805
D	0,1057	0,2044	0,2079	-	0
E	0,1921	0,2079	0,096	0,2114	-

Table 10. Positive and Negative Priorities for Alternative Suppliers

Alt.	A	B	C	D	E
Φ^+	0,2114	0,5285	0,7374	0,518	0,7074
Φ^-	0,5954	0,5928	0,5153	0,709	0,2862

Eventually, the complete ranking is determined by PROMETHEE II method. As a result of the complete ranking, supplier E is identified as the best one with 0,4212. Other suppliers are listed as C-B-D-A.

CONCLUSION

MCDM problems have ambiguity and uncertainty because of human judgments and subjectivity. However, it is quite difficult to perceive the decision maker's linguistic evaluations by exact numbers. Thus, in recent years, intuitionistic fuzzy methods are preferred in a number of researches to deal with the uncertainty of evaluations. This paper proposes an integrated model for green supplier selection. IF-AHP is considered as an appropriate method to weigh the criteria. At first, IF-AHP is applied to determine the criteria weights. Afterwards, PROMETHEE which is regarded as a proper and practical outranking method, is applied to rank the alternative suppliers considering the criteria weights. Eventually, an application is presented for the validation and detailed analysis of the proposed method. The application is carried out in HEPA filtration industry which is never studied in the literature. The methodology is accomplished in choosing the most appropriate green supplier. In further studies, decision maker tools such as AHP and TOPSIS can be enhanced by neutrosophic sets which are capable to deal with inconsistent and indeterminate information.

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HEURISTIC APPROACH FOR TWO-ECHELON VEHICLE ROUTING PROBLEM WITH SIMULTANEOUS PICKUP AND DELIVERY

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Abstract *– In recent years multi echelon distribution systems are widespread with hierarchical level strategies in distribution systems. Especially two-echelon distribution systems have positive effects on environment and traffic congestion. In this study two-echelon vehicle routing problem with simultaneous pickup and delivery (2E-VRPSPD) is considered. In this problem simultaneous pickup and delivery activities are conducted simultaneously only in the first echelon. First, we propose a node-based mathematical model and adapt four valid inequalities strengthen the formulation. Since the 2E-VRPSPD is an NP-hard problem, a heuristic approach based on variable neighborhood descent (VND) and local search (LS), called VND_LS, is developed. An experimental study is conducted to demonstrate the effect of the valid inequalities and performance of VND_LS. According to the computational results, valid inequalities have effect to strengthen the mathematical formulation and VND_LS is also efficient to obtain good solution for the problem.*

Keywords – Metaheuristics, Simultaneous Pickup and Delivery, Two-Echelon Vehicle Routing Problem

INTRODUCTION

In today's highly competitive world companies prefer different distribution strategies due to legal restrictions and environmental considerations. These strategies are in the field of distribution type, vehicle usage and hierarchical level. As a hierarchical level strategy, in multi-echelon systems the goods are transported from the depot to the customers through intermediate points (Sitek and Wikarek, 2014). Applications of multi-echelon distribution systems can be encountered in logistics and cargo services, hypermarket products distribution, automotive spare parts distribution, e-commerce and home delivery services and city logistics. Simultaneous pickup and delivery operations are one kind of the VRP and delivery and pickup activities are considered 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 delivery (2E-VRPSPD) is considered which a new variant of two-echelon VRP. The considered distribution system has simultaneous pickup and deliveries in the first echelon. A node-based two-index formulation is used to model the system and valid inequalities are utilized to strengthen the model. Since the NP-hardness of the 2E-VRPSPD, we develop a hybrid heuristic algorithm based on Variable Neighborhood Descent (VND) and Local Search (LS), called VND_LS, to find a solution for the medium- and large-instances of the problem. A two-stage experimental study is carried out to investigate the effect of the valid inequalities and the performance of the hybrid heuristic algorithm on test problems. While the first stage investigates the effects of the valid inequalities in the mathematical model, the second stage evaluates the performance of the proposed VND_LS.

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. Studies on different type of 2E-VRP can be classified as exact algorithms, heuristic algorithms, matheuristics and others according to the solution approaches. Branch and cut algorithm (Jepsen et al 2013; Perboli, 2010), decomposition algorithms with side constraints (Baldacci et al 2013), branch and price algorithm

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(Ahmadizar et al, 2015) are heuristic approaches used to solve the problem. Perboli et al (2011) used matheuristics for 2E-VRP. Finally, In the field of other studies we can mention introducing the mathematical model (Crainic et al, 2004) and analyzing the impact of cost types (Crainic et al, 2012).

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. Ncontains 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 Aconsists of the set of arcs between depot and satellites $(A_1 = \{i, j\}, i \neq jvei, j \in N_0 \cup N_D)$ and the set of arcs between satellites and customers$(A_1 = \{l, m\}, l \neq mvel, m \in N_C \cup N_D)$. 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, each satellite has delivery demand D_i and pickup demand P_i. Delivery 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 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 (2004). The decision variables used to formulate the model are as follows:

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

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

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

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 $(\forall l \in N_C)$; and V_i, pickup load on vehicle just before having serviced satellite i $(\forall i \in N_D)$.

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

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

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

$$U_j - U_i + CV_1 x_{ij} \leq CV_1 - D_j \qquad \forall i,j \in N_D \qquad (4)$$
$$D_i \leq U_i \leq CV_1 \qquad \forall i \in N_D \qquad (5)$$
$$V_i - V_j + CV_1 x_{ij} \leq CV_1 - P_j \qquad \forall i,j \in N_D \qquad (6)$$
$$P_i \leq V_i \leq CV_1 \qquad \forall i \in N_D \qquad (7)$$
$$U_i + V_i - D_i \leq CV_1 \qquad \forall i \in N_D \qquad (8)$$
$$D_i = \sum_{l \in N_C} z_{li} D_i \qquad \forall i \in N_D \qquad (9)$$
$$\sum_{m \in N} y_{lm} = 1 \qquad \forall l \in N_C \qquad (10)$$
$$\sum_{m \in N} y_{lm} = \sum_{m \in N} y_{ml} \qquad \forall l \in N \qquad (11)$$
$$\sum_{i \in N_D} z_{li} = 1 \qquad \forall l \in N_C \qquad (12)$$
$$y_{li} \leq z_{li} \qquad \forall i \in N_D, \forall l \in N_C \qquad (13)$$
$$y_{il} \leq z_{il} \qquad \forall i \in N_D, \forall l \in N_C \qquad (14)$$
$$y_{lm} + z_{li} + \sum_{s \in N_D, s \neq i} z_{ms} \leq 2 \qquad \forall l,m \in N_C, l \neq m, \forall i \in N_D \qquad (15)$$
$$U_m - U_l + CV_2 y_{lm} + (CV_2 - D_l - D_m) y_{ml} \leq CV_2 - D_l \qquad \forall l,m \in N_C \qquad (16)$$
$$D_l + \sum_{m \in N_C} y_{lm} D_m \leq U_l \leq CV_2 - (CV_2 - D_l) y_{li} \qquad \forall i \in N_D, \forall l \in N_C \qquad (17)$$
$$x_{ij} \in \{0,1\}, y_{lm} \in \{0,1\} \qquad \forall i,j \in N, \forall l,m \in N \qquad (18)$$
$$z_{il} \in \{0,1\} \qquad \forall i, \in N_D, \forall l \in N_C \qquad (19)$$
$$U_i, V_i, U_l \geq 0 \qquad \forall i,l \in N \qquad (20)$$

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 delivery demands of the each satellite are equal or lower than the capacity of each satellite. Constraint set (10) ensures that each customer must be visited exactly once and constraint set (11) guarantees that entering and leaving arcs to each node are equal. Constraint set (12) ensures that each customer must be assigned to only one depot. Constraint sets (13) – (15) prevent the illegal routes, i.e. starting and ending at the different depots. Constraint set (16) eliminates sub tours for delivery tours in the second echelon. Constraint set (17) is lower and upper bounds of the additional variable U_l. Constraint sets (18) to (20) 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.

$$\sum_{k \in N_D} \sum_{m \in N_C} y_{km} \geq r_{2E-VRPSPD}(N_C) \qquad (21)$$

where $r_{2E-VRPSPD}(N_C) = \lceil max(\sum_{m \in N_C} d_m ; \sum_{m \in N_C} p_m) / CV_2 \rceil$ and $\lceil \bullet \rceil$ is the smallest integer bigger than •. This valid inequality is firstly used by Achutan et al (2003) 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 (Karaoglan et al, 2011).

$$\sum_{k \in N_D} \sum_{m \in N_C} y_{km} \geq \lceil \sum_{m \in N_C} d_m / CV_2 \rceil \qquad (22)$$

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 (Gouveia, 1995).

$$y_{mn} + y_{nm} \leq 1 \qquad \forall m,n \in N_C \qquad (23)$$

Third valid inequality is adopted for 2E-VRPSPD from a generalized large multi-star (GLM) inequality for VRP (Gouveia, 1995; Letchford and Salazar-Gonzalez, 2006).

$$\sum_{m\in S}\sum_{n\in N_C/S} y_{mn} \geq (1/CV_2)\left(\sum_{m\in S} d_m + \sum_{m\in S}\sum_{n\in N_C/S} d_m(y_{mn}+y_{nm})\right)\forall S \subseteq N_C, S \neq \emptyset \quad (24)$$

Last valid inequality is derived from capacity and sub tour elimination constraint for VRP (Laporte et al, 1983). This constraint ensures that the number of vehicles visiting a set of customers (S) is not less than the lower bound.

$$\sum_{(m,n)\in S} y_{mn} \leq |S| - r_{2E-VRPSPD}(S) \qquad \forall s \subseteq N_C, S \geq 2 \quad (25)$$

where, $r_{2E-VRPSPD}(S)$ is calculated as given in (21).

A HYBRID HEURISTIC APPROACH FOR 2E-VRPSPD

Because of the NP-hardness of the 2E-VRPSPD, it is difficult to obtain optimal solutions especially for medium-size and large-size problems by using mathematical model. Thus, a heuristic approach is implemented to find solutions quickly for this kind of problems. This study proposes a hybrid heuristic approach based on variable neighborhood descent (VND) and local search (LS), called VND_LS, to solve medium and large-size 2E-VRPSPD instances. The hybrid heuristic approach obtains a feasible solution by VND and then improves it by using LS. This successive usage of VND and LS continues until stopping criteria are met. In the VND_LS, a 3(|N_C|+|N_D|) matrix consisting of two parts is used to represent a solution. The first and second parts of the matrix are devoted to second and first echelon of the 2E-VRPSPD, respectively. While the first part consists of the first |N_C| columns of the matrix, the second part includes remaining |N_D| columns. Let consider the first part of the matrix. The first row gives the sequence of customers. While the second row represents routes that customers are assigned and the third row represents the satellites that routes and also customers are assigned. Similar explanation can be given for the second part of the matrix. While the first row in the second part gives the sequences of satellites, the second row represents routes that satellites are assigned and third row is for main depots that routes and also satellites are assigned.

An initial solution is implemented to start the algorithm. The VND_LS uses following approach to obtain an initial solution. In this approach, firstly, customers are assigned to satellites in the second echelon and then routes are constructed. After the pickup and delivery demands of each satellite are determined based on the assigned customers to the corresponding satellite, routes of the first echelon are obtained. While assigning the customers to satellites, the distance between customer and satellite is considered and customers are assigned the nearest satellite. If the capacity of the satellite is exceeded, the customer is assigned to the second nearest satellite. To obtain the routes in both echelons, Nearest Neighborhood Heuristic (NNH) is used.

After obtaining a feasible initial solution, it is improved using VND_LS. To improve solutions, nine different neighborhood mechanisms are used. These mechanisms are *Shift (1,0)*, *Shift (2,0)*, *Swap (1,1)*, *Swap (2,1)*, *Exchange*, *2-Opt*, *Insertion*, *Satellite Change* and *Satellite Swap*. *Shift (1,0)* removes a customer *c* from its current route r_1 and relocates it at the best position in route r_2 in the same or different satellites. In *Shift (2,0)* mechanism customers c_1 and c_2 are removed from their current route r_1 and are relocated at the best position in route r_2 in the same or different satellites. In *Swap (1,1)* mechanism two randomly selected customers c_1 and c_2 which are in two different routes (r_1 and r_2) are exchanged in the same or different satellites. In *Swap (2,1)* mechanism randomly selected consecutive customers c_1 and c_2 in route r_1 and other randomly selected customer in route r_2 are exchanged in the same or different satellites. In *Exchange* mechanism two randomly selected customers c_1 and c_2, which are in the same route (r_1), are exchanged. In *2-Opt* mechanism two non-consecutive arcs (i.e. *i*, *j* and *m*, *n*), which are in the same route (r_1), are deleted. Then two new arcs are created (i.e. *i*,*m* and *j*,*n*) and the path lying between the created arc pair is reversed. In *Insertion* mechanism randomly selected customer c_1 is located in a different position in the same route. In *Satellite Change* mechanism randomly selected route r_1 belonging to satellite *j* is moved to another satellite *k*. In *Satellite Swap* mechanism two different routes r_1 and r_2 are exchanged belonging to different satellites.

The VND_LS starts with an initial solution and the best solution, obtained by VND in each iteration, is improved by LS. The improved solution is used as an initial solution for VND algorithm and the successive application of VND and LS continues until reaching stopping criteria. In each iteration of VND, one of the neighborhood mechanisms is selected randomly except for *Swap (1,1)* and *Exchange*. The selected neighborhood mechanism generates new solutions randomly. Each generated solution is feasible, i.e. vehicle capacity constraint is satisfied. Firstly, selected neighborhood structure is applied in the second echelon. After that the NNH is used to obtain a solution for the first echelon. When the termination condition is met for VND, the obtained best solution is improved by LS. In LS phase, *Swap (1,1)* and *Exchange* neighborhood mechanism are used to obtain an improved solution. The LS phase generates feasible solutions randomly by using each neighborhood mechanism and then the best solution among neighbors is selected. If the best solution improves the current solution, then this solution is considered as current solution and the search among new neighbors continues. If the best solution found by LS is not improved in successive *nui_ls* steps, LS is stopped and its best solution is considered as an initial solution for the VND_LS. If the best solution found by the VND_LS is not improved in *nui_vndls* successive applications of VND and LS, then the VND_LS is stopped and the best solution is reported. The *nui_ls* and *nui_vndls* are set to 10 and 50 for LS and VND_LS, respectively, based on our previous studies.

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 VND_LS 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 composed of 6 sets. These sets were derived from the sets generated for 2E-VRP Christofides and Eilon (1969), Crainic et al (2010), Hemmelmayr et al (2012) and Baldacci et al (2013). 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 (1999) and Angelelli and Mansini (2002) (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.

According to the results in Table 1 valid inequalities have individual effects on the mathematical model to obtain tight bounds. Average LB gap is 25,63% for original model. By adding valid inequalities (23), (25), (26) and (27) separately to the mathematical model, the gap reduces to 25,00%; 13,09%; 25,30% and 15,11% respectively. The valid inequality (25) causes the highest reduction in LB gap.

Performance of VND_LS Algorithm

To investigate the performance of the proposed VND_LS, percentage gap (Gap) and CPU Time are used as performance measures. The gap is calculated as $[(UB - LB)/UB]x100$ where UB is the upper bound obtained by CPLEX for mathematical formulation and the best solution obtained by VND_LS for the heuristic. 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 1. Individual Effects of Valid Inequalities

Problem Parameters	Parameter Value	# of Problems	Original	(21)	(23)	(24)	(25)
# of Satellites and Customers	2-12	132	25,19	25,15	12,13	23,83	4,23
	2-21	48	23,75	23,75	8,71	23,69	5,16
	2-32	48	26,52	26,52	8,63	26,51	7,13
	2-50	120	23,24	20,89	5,62	23,23	17,32
	3-50	72	17,48	16,95	17,47	17,47	16,87
	4-50	16	9,56	9,16	4,15	9,56	4,65
	5-50	76	29,77	29,49	13,97	29,74	28,53
	6-50	4	20,12	20,12	12,60	20,12	11,84
	4-75	4	20,32	20,32	11,59	20,32	11,41
	5-75	4	24,62	24,62	16,69	24,62	14,13
	6-75	4	30,24	30,24	21,24	30,24	21,96
	4-100	4	35,10	34,93	30,11	35,10	28,36
	5-100	16	47,61	47,60	41,46	47,61	39,38
	6-100	4	46,26	46,26	41,03	46,26	41,02
	10-100	12	65,42	65,34	57,51	65,42	57,96
Average			**25,63**	**25,00**	**13,09**	**25,30**	**15,11**
DSS	W-Z	348	25,31	24,55	14,01	24,78	13,13
	X-Y	216	26,14	25,73	11,60	26,14	18,31
Average			**25,63**	**25,00**	**13,09**	**25,30**	**15,11**

Table 2 shows the performance of VND_LS compared with mathematical formulation according to the number of satellites and customers, and DSS. According to the results in the table, gap and CPU time of mathematical formulation and the VND_LS usually increase according to number of satellites and number of customers. Average gap of mathematical formulation is 6,35% and average CPU time is 3648,61 seconds. These values are 5,48% and 16,55 seconds for VND_LS. According to these results, VND_LS outperforms the mathematical formulation in gap and solution time. The problems with AM demand separation strategy have higher gap in mathematical formulation and VND_LS.

Table 2. Performance of VND_LS Compared to Mathematical Formulation

Problem Parameters	Parameter Value	# of Problems	Mathematical Formulation		VND_LS	
			Gap	CPU Time	Gap	CPU Time
# of Satellites and Customers	2-12	132	0,00	3,05	0,00	0,68
	2-21	48	0,74	1248,80	0,74	1,35
	2-32	48	4,03	5612,88	4,03	3,11
	2-50	120	4,59	5060,56	4,59	12,76
	3-50	72	1,94	3431,43	1,94	6,86
	4-50	16	3,03	5355,56	3,03	12,49
	5-50	76	7,87	5465,89	7,41	21,88
	6-50	4	4,07	6756,27	3,90	15,34
	4-75	4	6,01	7200,00	5,95	46,53
	5-75	4	20,38	7200,00	15,17	49,27
	6-75	4	24,58	7200,00	20,00	47,29
	4-100	4	34,88	7200,00	21,77	51,47
	5-100	16	47,38	7200,00	37,31	119,65
	6-100	4	45,78	7200,00	37,35	40,76
	10-100	12	59,42	7200,00	45,71	185,61
Average (Total)			**6,35**	**3648,61**	**5,48**	**16,55**
DSS	W-Z	348	5,81	3416,40	5,27	16,04
	X-Y	216	7,22	4022,72	5,83	17,37
Average (Total)			**6,35**	**3648,61**	**5,48**	**16,55**

CONCLUSION

This paper introduces two-echelon vehicle routing problem with simultaneous pickup and delivery, which is a new variant of 2E-VRP. A mathematical model for the problem has been proposed and it has been strengthened using valid inequalities. Because of the NP-hardness of the 2E-VRPSPD, a hybrid heuristic algorithm-based variable neighborhood descent (VND) and local search (LS), called VND_LS, has been proposed. Experimental studies have been conducted to investigate the effect of the valid inequalities and the performance of the VND_LS on test problems obtained from the literature. Totally 504 instances have been considered for the assessments. The experimental analysis show that the lower bounds are improved when the valid inequalities are added to mathematical model and also the hybrid heuristic approach, VND_LS, is an effective and efficient to find good solutions for the 2E-VRPSPD.

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SUPPLIER EVALUATION WITH ARTIFICIAL NEURAL NETWORK

Irmak Daldır[1], Nedret Tosun[2], Ömür Tosun[3]

Abstract *– Supplier evaluation problem has received a great deal of attention from practitioners and researchers, because this decision has an important impact on achieving the target of the enterprises. Besides, the problem itself is complex and involves various criteria. This paper presents a 2-phase decision making methodology using artificial neural network which groups suppliers into 3 categories. At the first step evaluation criteria will be determined by decision makers and then the importance of the criteria and the rank of the suppliers' are determined. The model uses the decision makers' judgments as input and divides the suppliers in to three group which are good, neutral and bad. The proposed rule based model can be used as a decision support system while classifying suppliers according to their performance.*

Keywords – Classification, Decision Support System, Neural Network, Supplier Evaluation

INTRODUCTION

Supplier evaluation and selection problem has been studied extensively in the literature. The reason behind this, the impact of the decision affects whole supply chain members. Making right decisions would directly affect the success of the supply chain. For example, right suppliers can lead to shortening product development cycle, improvement on quality, reduce inventory levels, decrease on production costs, increase on flexibility, and increased satisfaction at customer expectations. In other words, choosing the most suitable supplier for businesses is key to achieving business goals and increasing productivity.

The supplier topic in the literature are mainly focus on supplier selection, evaluation and development. Supplier selection is made to select the suitable supplier in between alternative suppliers accordingly to business's short and long term plans. Supplier evaluation is defined as measuring the performance of the suppliers at a specified time interval and it depends on the selected criteria. In the case of supplier development, it is aimed to improve the incomplete aspects of suppliers and to increase the efficiency of the supply chain by making it more useful for the vendee. The terms evaluation and selection can be used interchangeably while defining the selecting the criteria during this paper, however the main focus of this paper making an evaluation and categorizing the suppliers according to their status into three category.

This paper propose a machine learning method, artificial neural network (ANN), in order to learn the decision makers approach and with the help of this learned model it categorize the suppliers into three group. With the help of this model decision process of executives is aimed to ease. The paper firstly gives brief information on evaluation criteria, afterwards the method is introduced and finally model and results are given.

SUPPLIER EVALUATION CRITERIA

As implied before the topic has received a lot attention in the literature. Therefore, there are a lot of different criteria in the literature for supplier evaluation process. Some of these are summarized in Table 1 according to their used frequency and some criteria are removed because of the low preference. Among the 20 studies, the delivery criterion was the most preferred criterion. The ranking of criteria goes on as cost, quality, technical capability and financial situation.

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Table 1. Supplier Evaluation Criteria and Their Frequency

Criterion	How many times used in articles	Reference
Delivery	18	(Chen, 2011) (Narasimhan, et al., 2001)(Araz and Ozkarahan, 2007) (Bruno, et al., 2012) (Çelebi and Bayraktar, 2008) (Pi and Low, 2006) (Özgen and et al., 2008) (Wang, 2010) (Tahiriri and et al.,2008) (Wu and Blackhurst, 2009) (Lima-Junior and Carpinetti, 2016) (Liou and et al.,2014) (Osiro and et al.,2014) (Keskin, 2014) (Tavana and et al., 2016) (Singh, 2014) (Van and et al., 2018) (Hashemian and et al., 2014)
Price/Cost	17	(Chen, 2011)(Narasimhan, et al., 2001)(Akarte, et al., 2001)(Bruno, et al., 2012)(Çelebi and Bayraktar, 2008)(Pi and Low, 2006) (Özgen and et al., 2008) (Wang, 2010)(Tahiriri and et al.,2008)(Wu and Blackhurst, 2009)(Lima-Junior and Carpinetti, 2016) (Liou and et al.,2014)(Keskin, 2014)(Tavana and et al., 2016) (Singh, 2014)(Van and et al., 2018)(Hashemian and et al., 2014)
Quality	17	(Chen, 2011)(Chen, et al., 2006) (Narasimhan, et al., 2001) (Araz and Ozkarahan, 2007) (Akarte, et al., 2001) (Bruno, et al., 2012) (Çelebi and Bayraktar, 2008) (Pi and Low, 2006) (Wang, 2010) (Tahiriri and et al.,2008) (Wu and Blackhurst, 2009) (Liou and et al.,2014) (Osiro and et al.,2014) (Keskin, 2014) (Singh, 2014) (Van and et al., 2018) (Hashemian and et al., 2014)
Technical Capability	12	(Chen, 2011) (Chen, et al., 2006) (Narasimhan, et al., 2001) (Araz and Ozkarahan, 2007) (Akarte, et al., 2001) (Bruno, et al., 2012) (Tahiriri and et al.,2008) (Osiro and et al.,2014) (Keskin, 2014) (Tavana and et al., 2016) (Van and et al., 2018) (Hashemian and et al., 2014)
Financial Situation	9	(Chen, 2011) (Chen, et al., 2006) (Araz and Ozkarahan, 2007) (Bruno, et al., 2012) (Özgen and et al., 2008) (Wang, 2010) (Tahiriri and et al.,2008) (Osiro and et al.,2014) (Van and et al., 2018)
Service	5	(Chen, 2011) (Çelebi and Bayraktar, 2008) (Pi and Low, 2006)(Wang, 2010) (Osiro and et al.,2014)
Business Relations	5	(Chen, 2011) (Chen, et al., 2006) (Tahiriri and et al.,2008)(Liou and et al.,2014) (Keskin, 2014)
Environmental Responsiveness	5	(Özgen and et al., 2008) (Tahiriri and et al.,2008) (Osiro and et al.,2014) (Van and et al., 2018)
Management and Organization	4	(Chen, 2011) (Narasimhan, et al., 2001) (Tahiriri and et al.,2008)
Communication System	4	(Chen, 2011) (Araz and Ozkarahan, 2007) (Osiro and et al.,2014) (Keskin, 2014)
Equipment and Capability	3	(Chen, 2011) (Narasimhan, et al., 2001)
Reputation	3	(Chen, 2011) (Van and et al., 2018) (Hashemian and et al., 2014)
Employment Relations	3	(Chen, 2011) (Osiro and et al.,2014) (Van and et al., 2018)

As a result of detailed discussions with the supplier procurement specialist, it was decided that the use of these five criteria, which are frequently used in the literature, is in accordance with their supplier evaluation system. The selected criteria are used in some studies with sub criteria and in others studies in the same way as they are added to list. In order to be clear about their meaning the sub-criteria are given. In other words when delivery criterion is mentioned it contains the meaning of delivery on time (timeliness), response to company's specific request (quantity or time), and order fulfillment rate, the followings are given in Table 2.

Table 2. Supplier Evaluation Criteria and It's Meaning for the Paper

Criterion	Content
Delivery	Delivery on time (timeliness), response to company's specific request (quantity or time), order fulfillment rate
Price/Cost	Product price, Freight cost, Tariff and custom duties, Compliance with sectorial price behavior
Quality	Quality-related certificates, Rejection rate of the product, Remedy for quality problems
Technical Capability	Technology level, Capability of R&D, Capability of design
Financial Situation	Financial Status

ARTIFICIAL NEURAL NETWORK

Researchers used various method to solve this multi-criteria problem which are data envelopment analysis (DEA) (Liu, 2000) (Garfamy, 2006) (Narasimhan, 2001), linear programming (Ng, 2008), analytic hierarchy process (AHP)(Bruno and et al.,2012), case-based reasoning (Faez and et al., 2009), analytic network process (Pang and Bai, 2013), fuzzy set theory (Chen and et al., 2006), and genetic algorithm (Sadeghieh and et al.,2012). Moreover, there are hybrid approaches too. Some of the similar integrated approaches to this study are Genetic Algorithm (GA), AHP, DEA and artificial neural network methods. For AHP, DEA and ANN studies of Ha and Krishnan (2008) and Kuo et al. (2010) can be given. Lau et al. (2006) and Golmohammadi et al. (2009) studied the topic with GA and ANN. This paper proposes only ANN method to solve the evaluation problem with evaluations of procurement specialist. Before the implementation phase the method is introduced.

ANN is one of machine learning approach. In classical programming, it is a necessity to program every situation, however in machine learning the inputs and outcomes are given and the rules are determined by the developed model. In other words, instead of dealing with every kind of situation and developing a rule for them like classical programming, machine learning develops its own rules. ANN approach is based on working principle of neural structure of the brain.

There are different kinds of structures for ANN. Multi-layered perceptron (MLP) is preferred for this problem and it is trained with back propagation learning algorithm which is usually preferred (Gandomi, Alavi 2011). As seen at Figure 1 there are minimum three layers at a MLP network. The first layer is for inputs, the second layer is hidden layer (sometimes more can be used) and the third layer is for output(s). ANNs consist of a set of processing elements called neurons or nodes.

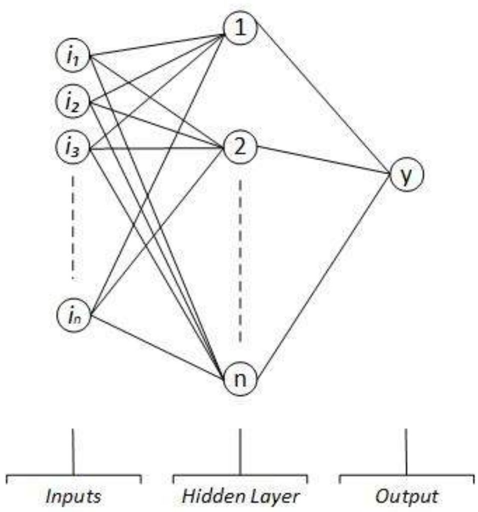

Figure 1. Basic Elements of an Artificial Neural Network

Each neuron is connected to all nodes in the adjacent layer and this connection has weight. The input value and the weight of that layer is computed at each node. A bias is added to this calculation and then usually a nonlinear activation function (also called transfer function) is applied. The input signal propagates forward on a layer-by-layer basis through the network. This process is carried out by applying a training algorithm to adjust the weights, which is the “learning” part of the algorithm and it results when the lower error criteria is met (Faris and et al. 2016).

MODEL DEVELOPMENT

The feed forward artificial neural network which is based on the back-propagation learning algorithm was proposed for the problem. Model was developed with Python version 3.7.0. The views of a supply chain and logistic specialist’s are gathered for the predetermined 5 criteria. Different combinations of the criteria were asked to the specialist thus the suppliers are evaluated and grouped as good, neutral and bad. Table 3 is given as example.

Table 2. Specialist Evaluation Example

Quality	Delivery	Cost	Manufacturing Capability	Service	Status
96	30	20	25	14	1
51	55	60	51	85	2
48	56	28	28	8	1
74	88	90	51	77	3

1= Bad, 2= Neutral, 3=Bad
The highest rank of an criteria is 100, the lowest 0

Total 175 evaluation is made and model developed accordingly. 70 percent of inputs are used for train and the remaining are for test the model. One hidden layer is preferred and as an activation function logistic and rectified linear unit (ReLU) and hyperbolic functions are tried out. Logistic (sigmoid) activation function is usually used for predicting the probability output with the range of 0 and 1. ReLU activation function turns to zero if it receives negative input and for any positive value it return the value back and it is mostly preferred for neural networks. Hyperbolic tangent activation function’s range is between -1 to 1 and mainly used classification between two classes. Every three function is tried with different hidden layer neuron combination (3, 4, 5 and 6) with 10 run to compare results. In order to compare results different statistical indicators are used, which are F1-score, precision, recall, log loss and Cohen Kappa Score. F1-score shows how precise the classifier which actually the weighted average of precision and recall. They are based on confusion matrix. Precision is a ratio that correctly predicted observations to the total predicted positive observations. Recall in other words sensitivity is a ratio of correctly predicted positive observations to the all observations. Log loss function is another multi class classification performance indicator. It measures the accuracy of a classifier by penalizing false classifications, so minimizing the function results means better accuracy of the classifier. While Cohen Kappa Score evaluation Table 3 is used (Landis and Koch, 1977)

Table 3. Cohen Kappa Score Interpretation

Score	Meaning
0	Agreement equivalent to chance.
0.1 – 0.20	Slight agreement
0.21 – 0.40	Fair agreement
0.41 – 0.60	Moderate agreement
0.61 – 0.80	Substantial agreement
0.81 – 0.99	Near perfect agreement
1	Perfect agreement

According to given statistics and 10 trials for each activation function with different hidden layer, it is determined that logistic activation function with a hidden layer with 3 neurons is the best for this classification model and the results given at Table 4.

Table 4. Results of the Best Alternative

	1	2	3	4	5	6	7	8	9	10
Precision	0,81	0,81	0,75	0,81	0,75	0,81	0,75	0,68	0,81	0,81
Recall	0,81	0,81	0,75	0,81	0,74	0,81	0,75	0,68	0,81	0,81
F1-Score	0,81	0,81	0,75	0,81	0,74	0,81	0,75	0,68	0,81	0,81
Log Loss	3,160	3,17	3,425	3,433	2,297	3,408	3,424	2,644	3,408	3,512
Cohen Kappa	0,684	0,684	0,592	0,684	0,555	0,684	0,592	0,462	0,684	0,684

The developed classifier results show that classifier performs well enough with the structured way and can be used as decision support system.

CONCULUSION

Machine learning methods are emerging as more frequently used methods and it becoming an alternative to the methods used as decision support system. The most important advantage of machine learning compared to other methods is that it can learn from past experiences and the ability to improve results with the learned experience. In this study, artificial neural network model is used to support decision making process at evaluation process of suppliers. In order to achieve this objective supply chain and logistic specialist's views are gathered and artificial neural network model is developed. The results of the model was satisfactory and it can be used as decision support system. For future studies it is thought that multiple expert opinion can be used to get better results and more classification groups can be studied. Such as for determination of suppliers which can included to supplier development process. Thus it can be more useful for the firms.

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MULTI-CRITERIA SORTING OF THIRD-PARTY REVERSE LOGISTICS PROVIDERS

Mehmet Ali Ilgın[1], Muhammet Enes Akpınar[2]

Abstract *– Increasing environmental problems and the rise in electronic commerce have forced many firms to focus on the issues associated with reverse logistics which involves all the activities required for the collection and either recovery or disposal of products returned for any reason (e.g., warranty, end-of-life). If a firm builds its own reverse logistics network, it has to deal with various problems including the high fixed costs associated with sophisticated material handling equipment and the cost of the dedicated workforce required for the operation and maintenance of collection and product recovery facilities. Hence, an increasing number of companies avoid those problems by outsourcing reverse logistics operations to third-party reverse logistics providers. Evaluation and selection of third-party reverse logistics providers is an active research area. However, to the best of our knowledge, there is no study on the sorting of third-party reverse logistics providers. We fill this research gap by using a multi-criteria analysis technique called VIKOR for the sorting of third-party reverse logistics providers.*

Keywords – Third Party Reverse Logistics Provider, Multi-Criteria Analysis, Sorting, VIKOR

INTRODUCTION

Reverse logistics (RL) involves all the activities required for the collection and either disposal or recovery of products returned for various reasons (e.g., warranty, end-of-life). Increasing environmental problems and the rise in electronic commerce have forced many firms to focus on the issues associated with RL.

Construction of a RL network requires the acquisition of sophisticated material handling equipment. A dedicated workforce is also needed. Hence, an increasing number of companies outsource their RL operations to third-party reverse logistics providers (3PRLPs) in order to avoid the equipment and workforce costs associated with RL.

Evaluation and selection of 3PRLPs is an active research area. Efendigil et al. (2008) integrated fuzzy AHP (Analytical Hierarchy Process) and artificial neural networks for the determination of the most suitable 3PRLP.Kannan (2009) used AHP and Fuzzy AHP in order to evaluate 3PRLPs. Fuzzy extent analysis was employed in Kannan & Murugesan (2011) for the evaluation 3PRLPs in battery industry. Kannan et al. (2009a) developed a fuzzy TOPSIS approach in order determine the most suitable 3PRLP. Kannan et al. (2009b) evaluated 3PRLPs by integrating Interpretive Structural Modeling and fuzzy TOPSIS. Mavi et al. (2017) integrated fuzzy SWARA (Stepwise Weight Assessment Ratio Analysis) and fuzzy MOORA (Multi-Objective Optimization on the Basis of Ratio Analysis) in order to evaluate 3PRLPs in plastic sector. Zarbakhshnia et al. (2018) proposed a two-step approach. First, 3PRLP evaluation criteria are weighted using fuzzy SWARA. Then, 3PRLPs are ranked using fuzzy COPRAS (Complex Proportional Assessment).

Although there are many papers on the evaluation and selection of 3PRLPs, to the best of our knowledge, there is no study on the sorting of 3PRLPs. This study fills this research gap by sorting 3PRLPs into predefined classes. The rest of the paper is organized as follows. Section 2 provides details on the application of a VIKOR-based sorting methodology for the classification of 3PRLPs. Conclusions and future research directions are presented in Section 3.

SORTING OF THIRD PARTY REVERSE LOGISTICS PROVIDERS USING VIKORSORT

A case example is provided in this section in order to present the use of VIKOR (Opricovic & Tzeng, 2004) in multi criteria sorting of 3PRLPs. The sorting methodology employed in this study is called as VIKORSORT

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and this methodology was originally proposed by Araz et al. (2016) and Demir et al. (2018). Alternative 3PRLPs are sorted into three classes following the steps of VIKORSORT as follows:

Step 1: 3PRLP Evaluation criteria and criteria weights are determined as presented in Table 1.

Table 1. 3PRLP Evaluation Criteria and Criteria Weights

3PRLP Evaluation Criteria	**Weight**
Flexibility to handle uncertainties (C_1)	0.10
Usage of automated disassembly systems / IT capacity (C_2)	0.10
Location (C_3)	0.15
Cost (C_4)	0.10
Average disassembly time (C_5)	0.10
Capacity (C_6)	0.05
Customer Service (C_7)	0.10
Waste Management (C_8)	0.10
Experience (C_9)	0.15
Quality (C_{10})	0.05

Step 2: Characteristics of alternative 3PRLPs (see Table 2) and limit profiles (see Table 3) are determined.

Table 2. Characteristics of 3PRLPs

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
3PRLP$_1$	100	50	100	10	100	20	20	100	100	100
3PRLP$_2$	50	80	100	30	60	10	100	70	80	100
3PRLP$_3$	80	80	100	20	100	30	90	80	80	80
3PRLP$_4$	50	50	100	40	80	50	20	80	80	100
3PRLP$_5$	100	50	100	70	100	70	70	100	100	100
3PRLP$_6$	100	50	30	50	70	10	20	100	30	50
3PRLP$_7$	50	50	60	100	50	100	80	70	50	50
3PRLP$_8$	70	80	80	90	85	100	90	80	70	70
3PRLP$_9$	50	40	70	80	50	80	10	70	70	50
3PRLP$_{10}$	50	90	80	30	70	50	20	50	50	50
3PRLP$_{11}$	85	85	80	50	80	70	40	90	90	90
3PRLP$_{12}$	70	85	80	60	85	20	100	70	70	70
3PRLP$_{13}$	80	85	90	60	80	30	70	80	80	80
3PRLP$_{14}$	90	90	90	90	80	40	80	100	100	100
3PRLP$_{15}$	90	70	90	10	70	60	90	80	80	70
3PRLP$_{16}$	70	80	70	20	80	70	30	70	70	70
3PRLP$_{17}$	60	70	70	30	60	90	40	70	70	70
3PRLP$_{18}$	70	50	70	50	50	50	50	60	70	60
3PRLP$_{19}$	80	70	70	60	80	70	70	70	80	80
3PRLP$_{20}$	85	80	90	40	80	70	80	90	90	90
3PRLP$_{21}$	90	80	80	40	90	60	40	50	50	50

Table 3. Limit Profiles

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
LP$_1$	60	50	60	30	50	40	50	50	40	70
LP$_2$	80	70	80	70	70	70	70	70	60	80

***Step 3**:* Maximum (f*) and minimum (f-) values are determined for each criterion as presented in Table 4.

Table 4. Maximum and Minimum Values

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
f^*	100	90	100	100	100	100	100	100	100	100
f^-	50	40	30	10	50	10	10	40	30	50

Step 4: S, R and Q Values of 3PRLPs are determined as presented in Table 5. Then ranking of 3PRLPs with respect to S, R and Q values are obtained (see Table 6).

Table 5. *S*, *R* and *Q* Values of 3PRLPs

3PRLP's	**Sj**	**Rj**	**Qj**	**3PRLP's**	**Sj**	**Rj**	**Qj**
$3PRLP_1$	0.313	0.100	0.385	$3PRLP_{12}$	0.376	0.064	0.265
$3PRLP_2$	0.415	0.100	0.465	$3PRLP_{13}$	0.330	0.044	0.135
$3PRLP_3$	0.301	0.089	0.322	$3PRLP_{14}$	0.159	0.044	0.000
$3PRLP_4$	0.496	0.100	0.529	$3PRLP_{15}$	0.403	0.100	0.456
$3PRLP_5$	0.191	0.080	0.194	$3PRLP_{16}$	0.540	0.089	0.511
$3PRLP_6$	0.679	0.150	0.911	$3PRLP_{17}$	0.597	0.080	0.515
$3PRLP_7$	0.640	0.107	0.676	$3PRLP_{18}$	0.631	0.100	0.636
$3PRLP_8$	0.347	0.064	0.242	$3PRLP_{19}$	0.419	0.064	0.300
$3PRLP_9$	0.695	0.100	0.687	$3PRLP_{20}$	0.293	0.067	0.211
$3PRLP_{10}$	0.654	0.107	0.688	$3PRLP_{21}$	0.521	0.107	0.583
$3PRLP_{11}$	0.295	0.067	0.212	LP_1	0.792	0.129	0.898
				LP_2	0.450	0.086	0.425

Table 6. Ranking of 3PRLPs with respect to *S*, *R* and *Q* values

3PRLP's	**Sj**	**Rj**	**Qj**
$3PRLP_1$	6	13	10
$3PRLP_2$	11	13	13
$3PRLP_3$	5	11	9
$3PRLP_4$	14	13	16
$3PRLP_5$	2	8	3
$3PRLP_6$	21	23	23
$3PRLP_7$	19	19	19
$3PRLP_8$	8	3	6
$3PRLP_9$	22	13	20
$3PRLP_{10}$	20	19	21
$3PRLP_{11}$	4	6	5
$3PRLP_{12}$	9	3	7
$3PRLP_{13}$	7	1	2
$3PRLP_{14}$	1	1	1
$3PRLP_{15}$	10	13	12
$3PRLP_{16}$	16	11	14
$3PRLP_{17}$	17	8	15
$3PRLP_{18}$	18	13	18
$3PRLP_{19}$	12	3	8
$3PRLP_{20}$	3	6	4
$3PRLP_{21}$	15	19	17
LP_1	23	22	22
LP_2	13	10	11

Step 5: Initial assignment of 3PRLPs is carried out by checking the two conditions of VIKOR. The results of the initial assignment can be summarized as follows:

Best: 3PRLP1, 3PRLP3, 3PRLP5, 3PRLP8, 3PRLP11, 3PRLP12, 3PRLP13, 3PRLP14, 3PRLP19, 3PRLP20

Moderate: 3PRLP2, 3PRLP4, 3PRLP7, 3PRLP9, 3PRLP10, 3PRLP15, 3PRLP16, 3PRLP17, 3PRLP18, 3PRLP21

Worst: 3PRLP6

Step 6: All 3PRLPs were successfully assigned in the initial assignment step of the VIKORSORT. That is why there is no need for step 6 (final assignment).

The 3PRLPs in the best class have priority over the 3PRLPs in other two classes. Appropriate development programs can be designed for 3PRLPs in moderate and worst classes.

CONCLUSIONS

Increasing environmental problems and the rise on e-commerce increased the importance of RL operations. Outsourcing of RL operations to 3PRLPs is common practice among companies due to the high equipment and workforce costs associated with RL operations. That is why evaluation of 3PRLPs has an utmost importance on the successful and cost-effective implementation of a company's RL operations. Although the selection of the most suitable 3PRLP is a very active research area, there is no study on the sorting of 3PRLPs. That is why we sorted 3PRLPs into predefined ordered classes using a sorting methodology. In future studies, other sorting methodologies such as Promsort and Flowsort can be used for the sorting of 3PRLPs.

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MITIGATING CUSTOMER INITIATED WARRANTY FRAUD FOR REMANUFACTURED PRODUCTS IN REVERSE SUPPLY CHAIN

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Abstract *− Methods of tackling new product frauds have been proposed in recent literature. However, no significant literature exists relating to investigating issues connected to fraud detection and prevention in the remanufacturing sector. The issue of warranty fraud arising from a warranty service agent has been recently addressed; however the issue of remanufactured product warranty frauds arising from the customer has yet to be explored. This study aims to examine problems in the consumer electronics remanufacturing sector, and examines strategies available to the warranty provider to tackle fraud originating from the customer. Discreet event simulation is employed to contrast how well a sensor embedded product may improve upon the existing system by comparing relevant fraud statistics. The sensor embedded scenario was able to preemptively stop more frauds, but further research into sensor cost would be required to truly ascertain the value of sensor implementation.*

Keywords − End-of-life, Fraud, Remanufacturing, Warranty, Reverse logistics

INTRODUCTION

A remanufactured product may perform as well as a new product; however the consumer may not perceive that as being the case. This shows up as a level of uncertainty in the mind of the consumer regarding the apparent quality of the remanufactured product, and might lead to a decision to opt out of buying it. Remanufacturers therefore feel the need to provide additional assurance to the consumer through the use of tools such as product warranties. In systems such as warranty servicing, which involve multiple parties, each with their own goals, motivations, and competing interests working together, it is inevitable that fraud will appear. Warranty fraud frequently occurs when a component part, which is not within the manufacturer's warranty period, is placed in a product which is within the manufacturer's warranty period. The product is then returned to the manufacturer or the manufacturer's representative for replacement of the allegedly defective component part pursuant to the warranty. The absence of an effective means for controlling the fraudulent substitution of warranted parts imposes substantial costs on the manufacturers and consumers of such parts and the products in which they are used (Hayes, 2005).

This type of fraud can be seen both in larger products such as automobiles, to smaller products such as consumer electronics. This paper attempts to improve upon existing methods of fraud prevention/detection by considering the implementation of sensors. The success or failure of sensor implementation will depend on if there are any improvements in the proposed systems fraud statistics which include the number of frauds that go unchecked, the total cost of inspection, revenue lost from fraud and number of falsely charged claims.

Using discrete event simulation, the study was able to conclude that sensor implementation has generally positive benefits when it comes to the issue of fraud detection and prevention and this work acts as a necessary stepping stone in dealing with more complex fraud scenarios (That may involve two or more parties acting in collusion).

LITERATURE REVIEW

Over the past few decades there has been an interest in environmentally conscious manufacturing which arose partly due to the implementation of 3government legislation and the dwindling of natural resources. The field of Environmentally Conscious Manufacturing and Product Recovery (ECMPRO) has produced many research papers that are of interest in setting up this study. Gungor and Gupta (1999) presented a state of the art

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survey paper covering most papers published through 1998 in the field of ECMPRO. A later paper by Ilgin and Gupta (2010) presented another updated survey in the same area.

These reviews served to show the building interest in this area, and while at the present time certain issues may not be prevalent (due to a lack of product volume), steps should be taken preemptively to deal with problems that will acerbate with time, such as fraud.

One problem that needs to be confronted in remanufacturing operation is the high degree of variability in the operation processing times. According to Ilgin and Gupta (2010), the level of uncertainty in the quantity, quality and timing of returned products further complicates the analysis of remanufacturing systems. It is therefore also important for manufacturers to balance their sales strategies in response to the introduction of remanufacturing. Some large manufacturers have adopted remanufacturing marketing programs to promote recycling and selling of the remanufactured or refurbished products (Wu 2012).

Another study by Guide and Li (2010) carried out auctions to understand the willingness of a consumer to pay for both new and remanufactured consumer and commercial products. Additionally, Vadde, Kamarthi and Gupta (2006) focused on the pricing strategies with obsolescence. They considered two models to counter the prospect of product obsolescence gradually and suddenly with the consideration of the risk in demand decrease and inventory increase.

Warranty has in the past been used as a tool for competitive marketing. Many manufacturers and researchers have explored a host of ways to make a product more appealing by experimenting with warranty policies by doing things such as adding additional services, extending the periods, offering favorable terms etc. Podolyakina (2017) identified the relative level of cost incurred to the manufacturer in order to fully satisfy the consumers warranty expectation. There is evidence that more expensive complex products involve more extended decision making, thereby enhancing the probability that the warranty could play a significant role (Wilkes and Wilcox, 1981). The consumer relies more often upon the manufacturer than they do upon the retailer as to the nature and quality of the goods; and this fact has strongly influenced courts in warranty cases (Southwick, 1963). The majority of the extant literature was focused on warranties with respect to the new product industry. Many of the same issues have been tackled in the remanufacturing sector as well. Alqahtani and Gupta (2017) considered a 2 dimensional warranty policy with the objective to maximize consumer confidence and minimize cost to the remanufacturer for a remanufactured product (washing machine).

Warranty providers outsource their product maintenance claims to external service agents who charge between 1-5 % for their services (Murthy and Jack, 2016). Warranty fraud is a significant problem affecting motor vehicles and other consumer products having multiple components that are the subject of a warranty. These frauds are typically only between the manufacturer and the service agent. A study by Murthy and Jack (2016) used game theory to tackle service agent fraud in the cases where the service agent exaggerates the value of the claim to the manufacturer.

There are methods and systems for obtaining and analyzing data using embedded sensors in electronic products for warranty management. A data collection unit in an electronic product collects and reports data about environmental factors that is relevant about a warranty agreement and transmits the data over a communications link to a data interpretation unit. The use of such sensors to address issues in consumer electronics products has been suggested in the past to address issues both at EOL (Ilgin and Gupta, 2011, for washing machines) and even during a products life (Dulman and Gupta, 2018 for laptops) thus suggesting that sensor embedded products (SEP) could be an effective way of catching fraud.

Based on the literature review we can see that fraud is still a prevalent issue in the consumer product industry. However the majority of extant literature focuses on new products, little research is focused on frauds pertaining to remanufactured products. While a number of techniques (such as game theory) have been used in the past, many models consider frauds to be one of events and do not incorporate factors such as prior history and player motivation. Additionally the trend of sensor implementation has proven to be a boon in solving other problems and literature shows that it has potential in dealing with fraud. These points influenced the direction and methodology followed in this study.

FRAUD OVERVIEW

Apart from direct costs such as revenue loss, warranty fraud has many indirect consequences. Repair data received from service agents are often used as a tool for research and development. Manufacturers use information acquired from field data to address product quality issues and take corrective action. This idea works well in principle but if this data include fictitious or claims of dubious nature, separating real quality problems from fraudulent billing can be difficult. As a result, unreliable product quality feedback may delay corrective actions (Kurvinen, Töyrylä and Murthy, 2016). This is an escalating problem as it might also result in product recalls which are unnecessary and highly expensive and reduce the effectiveness of predictive maintenance. This also leads to incorrect decision making, as the manufacturer might terminate profitable products that are incorrectly assumed to be loss making. Warranty fraud can also affect the warranty provider's reputation and damage its brand. This is the case, for example, when customers are wrongly denied warranty service or receive poor service due to fraud (Kurvinen, Töyrylä and Murthy, 2016). While many studies assume the customer being on the receiving end of the fraud, in this instance we try to examine how the customer attempts to defraud the other parties.

The occurrence of customer driven fraud is not confined to just the warranty period as it very often takes place even after the warranty has expired. Fraudulent warranty claims may also be associated with products that have never been purchased by the customer. Customer fraud typically relates to cases where a customer tries to have a repair or replacement done although there is no warranty coverage. This can be the case when the warranty has expired, the customer has damaged the product, or the service action is not covered by a warranty. Usually, the fraud done by a customer is limited to one or few cases per purchased product, although large-scale fraud also exists (Kurvinen, Töyrylä and Murthy, 2016). A number of different instances of warranty fraud are compiled in tables 1 and 2 (summarized by Kurvinen, Töyrylä and Murthy, 2016)

Table 1. Table of frauds originating from customer

Fraud victim	Motivation	Method
Warranty provider	Refund or replacement	Unjustified return or replacement of item that is not faulty or is a fake
	Service cost avoidance	Getting out of warranty products repaired under warranty
	Extra products or earning	Claiming and reselling parts or replacement items
	Service level improvement	Claiming better service than being entitled for

Table 2. Table of frauds where Customer is victim

Fraud Source	Motivation	Method
Service agent	Extra revenue	Overselling extended warranties
	Extra revenue	Selling nonexistent extended warranties
	Extra revenue	Charging the customer for in-warranty service
	Extra revenue	Up selling a replacement product when the customer is entitled to warranty service
	Extra revenue	Purposeful lack of first-time resolution
Warranty provider	Extra income	Overselling extended warranties
	Extra income	Selling nonexistent warranties
	Extra income	Charging the customer for in warranty service
Sales channel	Extra revenue	Overselling extended warranties
	Extra revenue	Selling nonexistent warranties
	Inventory refreshment	Getting new item from OEM and using a used item in replacement

We attempt to narrow down the scope of the customer warranty fraud by examining a specific scenario of fraud, namely the case of component substitution. For instance, having bought multiple numbers of similar products at different times (e.g., LED light bulbs or tablets), the customer may try to utilize the warranty of the newest product to have the old one replaced. In a similar way, defective parts in an out-of-warranty product can be changed to an in-warranty product and claimed under warranty. If the equipment or the proof of purchase does not have a serial number or the parts used are not serial number tracked, it is hard to control whether the proof of purchase relates to the faulty product. The same applies to large installations that consist of multiple equipment installed at different times and that contain in-warranty and out-of warranty products. In this situation, gaps in the warranty provider's entitlement process or data can be used to obtain service also for out-of-warranty products. In this paper we attempt to model an instance of substitution type customer driven warranty fraud for a consumer electronic product.

DESCRIPTION OF THE SYSTEM

Based on relative importance the different parties can be sub divided into 3 categories which are described in table 3 (Assumes that the remanufacturer is the primary warranty provider). The Primary parties refer to those that are chiefly involved in the warranty service chain, the secondary parties assist the primary parties in warranty operations, whereas the tertiary parties have no direct role in the warranty operations, but they are invested in the performance of the warranty service.

Table 3. Parties involved in a warranty servicing scenario

Category	Parties
Primary	Remanufacturer, Service agents, Customers
Secondary	Parts manufacturer, sales channel , Warranty administrator
Tertiary	Leasers ,Inspectors, Logistics companies, Underwriters & Insurers, Government, Shareholders

Component substitution fraud mainly involves the primary parties, in that the consumer is the fraud's perpetrator and the service agents (and by extension the remanufacturer) are the victims.

In a typical warranty service system, when a product is rendered nonfunctional, it is inspected to determine the cause of failure. The information about any such failure is transmitted to the service personnel who conducts the required service operations; for example, replacing the failed component or components. After this process, failed products are transferred to the service facility. After the maintenance process takes place, the products are brought back to working condition. Once the maintenance service operations are complete, the products are returned to the customers. The generalized activity flow chart for all types of warranty maintenance is shown in figure 1 below.

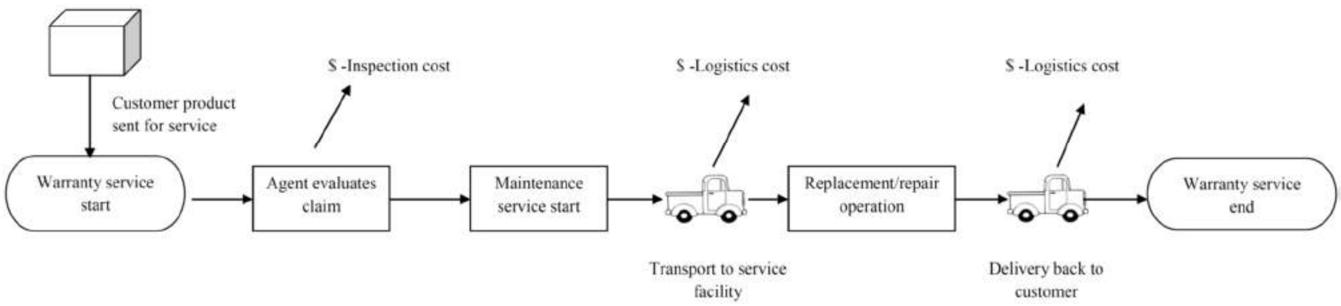

Figure 1. Warranty service operation for products

The above case presented assumes that the claim is true and that the customer is acting in good faith, However when introducing the concept of fraud into the scenario, it is assumed that for certain cases that at least one component in the product to be serviced originates from another product that is no longer under warranty. The service of such a product would violate the warranty agreement between the customer and remanufacturer. In addition to the extra service cost incurred, there would also be additional inspection and logistics costs to account for. The next section describes two simulation scenarios that were considered to model the problem further.

SIMULATION SCENARIOS

The study makes use of discrete event simulation to model customer driven fraud. The model was simulated using Rockwell arena software, the input to the simulation model are customer claims, which arrive at a rate governed by a Poisson distribution function. The logistics costs were assumed at a fixed rate per trip (to and from repair center), while the inspection cost was assumed on an hourly basis. We consider the following two cases for our research.

Case 1 –Regular Systems

In a regular system, when a warranty claim is made by the customer, it is the service agent's responsibility to first verify that the claim is true and conduct any services to fulfill the warranty contract. There exist built in systems to catch substitution frauds. For instance in electronic products, each part posses serial numbers that can be cross checked in order to determine if the component is from the same product or series. This process is fairly time intensive and cannot catch all types of substitution fraud (components that may be used across multiple product series such as batteries might be substituted between products of different generations without the service agent being any wiser). In cases of fraud we consider multiple forms of cost to the remanufacturer. Productivity loss occurs when service agents are trying to rectify claims that are fraudulent while putting true claims on hold. In the system, productivity loss time is calculated by determining the time between receiving the faulty claim and the service completion time. Maintenance costs include the costs that are incurred as a result of inspecting the product failure. Since a corrective maintenance strategy is chosen and the failed components are replaced, the material cost associated with the replacement of the components is added to the overall maintenance cost. Finally, logistics costs are also taken into consideration within maintenance costs.

Case 2 - With Sensors

In sensor embedded scenarios we assume that sensors can make up for some of the short falls that exist in regular systems. To highlight this effect we consider the existence of human error in the model and as such consider claims to be reviewed by multiple inspectors that may fall into one of 4 categories, each with slightly different process times and fraud detection capabilities. The model assumes that the customers past fraud history will have an effect on the decision to commit frauds in the future. For instance, the model assumes that if a customer has been previously successfully in committing fraud, the truthfulness of the next claim will be different from if they were previously caught. In addition sensors are assumed to retain data on which parts have been replaced in previous inspections which theoretically should prevent a repeat of fraud using the same product. In theory, sensors should be able to shorten the time required to verify that all the components from the same product as well as prevent additional substitution scenarios (the battery example). In addition to costs that are incurred in the regular scenario, we also assume the cost of sensor implementation. This will allow us to make the determination if the cost of sensor implementation is worth any potential fraud catching benefits.

RESULTS & CONCLUSIONS

Preliminary results show that the sensor embedded system performed better than the regular system in terms of its ability to catch and deter frauds. There was a 22% decrease in the number fraudulent claims that escaped, a 17 % decrease on the average time it takes to process claims and an 18.6% decrease in total logistics costs. Based on early results, it was judged that the cost savings from fraud and maintenance justified the price of sensor implementation. This paper described the literature surrounding the issues of fraud and warranties. This review served to show the importance in tacking the issue of fraud in the remanufacturing service industry. The different ways in which customer driven fraud affects the warranty service industry were elaborated on. Lastly the problem was modeled using simulation to better understand and combat warranty fraud. Only one potential application of the sensor at dealing with fraud was modeled, but there are many more that have yet to be tackled. The issue of warranty fraud has been an overlooked problem in the area of remanufacturing, and further exploration would prove beneficial in promoting remanufacturing as a whole.

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DESIGN PROBLEMS IN CLOSED-LOOP SUPPLY CHAIN NETWORKS WITH A FEEDBACK ROUTE FOR RECOVERED MATERIALS

Miho Ishii[1], Kengo Nakamura[2], Tetsuo Yamada[3]

Abstract **–** *Mass consumption and depletion of resources have become serious global environmental problems. To address this, manufacturers of assembly products need to design an economical closed-loop supply chain (CLSC) network that determines forward and reverse logistics, that is, transporting assembly products from factories to markets and end-of-life (EOL) products from markets to recycling/disposal centers. There are two types of CLSC: with and without feedback of recycled materials to assembly factories. This study proposes a model for a CLSC network with the feedback route. First, the model of a logistics network is formulated using integer programming. Here, the total cost is minimized, including the transportation, route and facility opening, disposal, and recycling costs, while the target recycling rate is constrained. An example of a product and network scenario is presented and numerical experiments are conducted to validate the proposed model. Finally, two types of models—with and without a feedback route—are compared and discussed.*

Keywords **–** *Facility Location, Integer Programing, Opened and Closed Loop, Recyclability Evaluation Method, Reverse Logistics*

INTRODUCTION

Resource depletion is a global environmental problem that has recently been worsening. Thus, there is a growing necessity for material circulation to prevent natural resource depletion (Kobayashi, 2003). From an industrial perspective that consumes natural resources, the waste-free supply chain is required for foundation of sustainable development (Guide & Wassenhove, 2001). And environmental consciousness suggests the production of new product for environmental standards and requirements, and at the same time, to administer reverse supply chain (Pochampally et al, 2008). Then, the integration of forward and reverse logistics is a Closed-Loop Supply Chain (CLSC), that is the transportation of assembly products from factories to markets and EOL products from markets to recycling or disposal centers for recycling. To promote material circulation, manufacturers need to design CLSC network that produces new products and reproduces recycled materials from end-of-life (EOL) products (Nagasawa et al, 2017; Kokubu et al, 2015). Recycled materials can be used to make new products to replace virgin materials. However, recycling EOL products tends to be expensive due to the cost of processes such as disassembly and recovery (Kobayashi, 2003). To reduce the costs of recycling, disassembly parts selection is conducted. Disassembly parts selection is often carried out at recycling centers according to the status of the EOL products (Yamada, 2008). The collected EOL products differ in their status, depending on the usage, and the extent of recycling, which is different for each EOL product. Therefore, after EOL products are collected at collection centers, they are classified by product status (Kimura et al, 2004).

One of the efficiency of material reproduction in the CLSC network is measured by return and recycling rates. Return rate is the weight proportion of EOL products collected from customers (Savaskan & Wassenhove, 2004). In Japan, 57% of large appliances with EOL status are in storage at users' homes (Ministry of the Environment, 2018). On the other hand, the recycling rate is the proportion for weight of recycled materials contained in a product (Akahori et al, 2008). That is the return rate denotes the amount of EOL products collected from customers, and the recycling rate indicates the amount of recycled materials from EOL products. When a CLSC network is constructed, these rates should be considered to promote material circulation.

The literatures on the supply chain including the life cycle option are shown in Table 1. Alshamsi and Diabat (2015) described the reverse supply chain network of large home appliances. Nagasawa et al (2017) modeled the facility relocation of a recycling supply chain based on the cost of opening and closing facilities. Özceylan

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et al (2014) designed a CLSC network and performed a sensitivity analysis of the return rate. Chen et al (2017) designed a CLSC network that integrated cost and environmental problems in the solar energy industry. Amin and Baki (2017) proposed a model of a global CLSC network considering exchange rates and tariffs. However, these studies did not consider the return and recycling rates. Moreover, the previous studies on reverse supply chain and CLSC did not have data on product material. Therefore, they forecasted on only cost and the number of collected and disassembled the products, even though the purpose of designing CLSC for material circulation is to recover material values from EOL products. None of the network designs included recycling disassembly, disposal, and disposal costs of EOL products and income from sale of materials was also not considered as part of the return rate. Ijuin et al (2017) proposed reverse network with scenarios for the status EOL products (Igarashi et al, 2014), with different degrees of disassembly and recycling cost using the recyclability evaluation method (Hitachi, Ltd., 2018; Akahori et al, 2008), However, they did not consider the forward supply chain and the return rate. Ishii et al (2017) designed a CLSC network with return and recycling rates using material data. However, they did not consider the usage of recovered materials. In order to promote material recycling, it needs to evaluate how much recycling is done in the constructed supply chain and whether recycled materials have been utilized. Therefore, it is necessary to consider the feedback route and recycling rate. Additionally, since the recycling rate may be affected by the quantity of returned EOL products, it is also necessary to consider recovery rate and recycling rate at the same time. However, the previous studies did not model closed-loop supply chain network with a feedback route and did not evaluate consider the recovery rate and recycle rate at the same time.

This study proposes a model for a CLSC network with the feedback route and evaluates the efficiency of the constructed network by using the material data contained in the product. Section 2 describes and formulates the CLSC network with and without a feedback route. The feedback route is a transportation route for recovered materials from recycling centers to factories. An objective function is to minimize the total cost including transportation, route and facility opening, disposal and recycling costs, the return and recycling rates are express as constraints. Section 3 explains product and network scenarios. Section 4 describes the numerical experiments to validate the proposed model, and compares two types of models—with and without the feedback route—. Section 5 concludes this study and suggests directions for future work.

DESIGN METHOD OF CLOSED-LOOP SUPPLY CHAIN NETWORK

Model Formulation

This section describes CLSC network models with and without a feedback route for recycled materials based on Ishii et al (2017), and formulates the models based on Ishii et al (2017) using integer programing (Hillier & Lieberman, 2005).. (A) in Figure 1 shows the CLSC model without feedback route as proposed by Ishii et al (2017), whereas (B) shows the one with a feedback route as proposed in this study. First, the assembly products are supplied from factories to markets. After a usage phase, Second, EOL products with different status are sent to a collection center from the markets to achieve a target return rate. Each collected EOL product can be classified based on their status. The EOL products with different status have different recycling rate and recycling cost. Third, collected EOL products are examined to transfer whether recycling or disposal centers based on recycling rate and cost. In the open-type model, feedback route is not considered. On the other hand, the close-type model has the feedback route of recycled materials from recycling center to factory. Thus, all recycled materials are sent to factories by the feedback route in order to manufacture parts for next generation.

Table 1. Literature on the Supply Chain Including the Life Cycle Option

Literature	Target	Life cycle option				Indicate				Purpose	
		Collection	Recycling	Disposal	Feedback route	Return rate	Recycling rate	Product status	Material data	Objectiv fanction	Method
Ijuin et al (2017)	RSC	○	○	○	-	-	○	○	○	Minimizing cost	Integer programming
Ahmed and Ali (2015)	RSC	○	○	○	-	-	-	-	-	Maximize Profit	Mixed integer liner programming
Nagasawa et al (2017)	CLSC	○	○	-	○	-	-	-	-	Minimizing cost	Mixed integer programming
Özceylan et al (2014)	CLSC	○	-	○	○	○	-	-	-	Minimizing cost	Mixed integer non-liner programming
Chen et al (2017)	CLSC	○	○	○	○	-	-	-	-	Minimizing cost Minimizing CO_2 emission	Mixed integer liner programing
Amin and Fazle (2017)	CLSC	○	-	○	○	-	-	-	-	Maximize time delivery Maximize Profit	Mixed integer liner programming
Ishii et al (2017)	CLSC	○	○	○	-	○	○	○	○	Minimizing cost	Integer programming
This study	CLSC	○	○	○	○	○	○	○	○	Minimizing cost	Integer programming

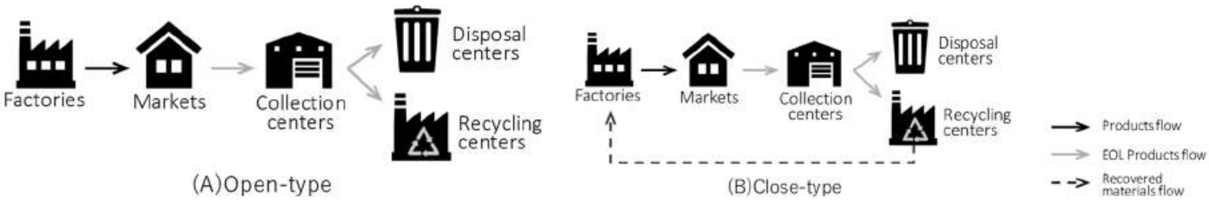

Figure 1. CLSC Model of (A) Open-Type and (B) Close-Type

F	:	Set of factories ($a \in F$)
MA	:	Set of markets ($b \in MA$)
G	:	Set of collection centers ($g \in G$)
P	:	Set of recycling centers ($p \in P$)
H	:	Set of disposal centers ($h \in H$)
K	:	Set of EOL product status ($k \in K$)
RR	:	Return rate [%]
RCR_0	:	Constraint of recycling rate [%]
$LC_{pro,ab}$	:	Products transportation cost from facility a to b [US$]
$LC_{mat,abk}$	:	Materials transportation cost with status k from facility a to b [US$]
WC	:	Unit transportation cost [US$/g km]
DC	:	Disposal cost [US$]
d_{ab}	:	Distance between facility a and b [km]
OC_{ab}	:	Route opening cost between facility a and b [US$]
FC_a	:	Fixed opening cost at facility a [US$]
RCC_k	:	Recycling cost for EOL products with product status k [US$]
RCW_k	:	Recycling weight for EOL products with product status k [g]
PW	:	Weight of product [g]
PA_{pk}	:	Binary variable; 1 if EOL product with status k is recyclable at recycling center p, otherwise 0
$N_{product,b}$	:	Demand of products on market b
$Q_{max,a}$	:	Capacity of facility a
M	:	Very large number (Big M)
f_{ab}	:	Number of products transported between facility a and b
f_{abk}	:	Number of EOL products transported with product status k between facility a and b
u_a	:	Binary variable; 1 if facility a is opened, otherwise 0
z_{ab}	:	Binary variable; 1 if route between facility a and b is opened, otherwise 0
$N_{product,gk}$	:	Number of products with product status k in a recycling center g

(A) Open-Type Model

$$\sum_{a\in F}\sum_{b\in MA} LC_{pro,ab}f_{ab} + \sum_{b\in MA}\sum_{g\in G} LC_{pro,bg}f_{bg} + \sum_{g\in G}\sum_{p\in P}\sum_{k\in K} LC_{pro,gp}f_{gpk} + \sum_{g\in G}\sum_{h\in H}\sum_{k\in K} LC_{pro,gh}f_{ghk} + \sum_{a\in F}\sum_{b\in MA} OC_{ab}z_{ab} + \sum_{b\in MA}\sum_{g\in G} OC_{bg}z_{bg} + \sum_{g\in G}\sum_{p\in P} OC_{gp}z_{gp} + \sum_{g\in G}\sum_{h\in H} OC_{gh}z_{gh} + \sum_{p\in P}\sum_{a\in F} OC_{pa}z_{pa} + \sum_{a\in F} FC_a u_a + \sum_{g\in G} FC_g u_g + \sum_{p\in P} FC_p u_p + \sum_{h\in H} FC_h u_h + \sum_{g\in G}\sum_{p\in P}\sum_{k\in K} RCC_k f_{gpk} + \sum_{g\in G}\sum_{h\in H}\sum_{k\in K} DC f_{ghk} \ . \tag{1}$$

$$\sum_{a\in F} f_{ab} = N_{product,b} \quad \forall b \in MA \ . \tag{2}$$

$$\sum_{g\in G} f_{bg} \le N_{product,b} \quad \forall b \in MA \ . \tag{3}$$

$$\sum_{p\in P} f_{gpk} + \sum_{h\in H} f_{ghk} = N_{product,gk} \quad \forall g \in G, \forall k \in K \ . \tag{4}$$

$$\frac{\sum_{g\in G} PW \times f_{bg}}{PW \times N_{product,b}} = RR \quad \forall b \in MA \ . \tag{5}$$

$$\frac{\sum_{g\in G}\sum_{p\in P}\sum_{k\in K} RCW_k \times f_{gpk}}{PW \times \sum_{b\in MA} N_{product,b}} \ge RCR_0 \ . \tag{6}$$

$$\sum_{g\in G} f_{gpk} \le M \times PA_{pk} \quad \forall p \in P, \forall k \in K \ . \tag{7}$$

$$\sum_{b\in MA} f_{ab} \leq Q_{max,a}u_a \quad \forall a \in F \ . \tag{8}$$
$$\sum_{b\in MA} f_{bg} \leq Q_{max,g}u_g \quad \forall g \in G \ . \tag{9}$$
$$\sum_{g\in G}\sum_{k\in K} f_{gpk} \leq Q_{max,p}u_p \quad \forall p \in P \ . \tag{10}$$
$$\sum_{g\in G}\sum_{k\in K} f_{ghk} \leq Q_{max,h}u_h \quad \forall h \in H \ . \tag{11}$$
$$f_{ab} \leq Mz_{ab} \quad \forall a \in F, \forall b \in MA \ . \tag{12}$$
$$f_{bg} \leq Mz_{bg} \quad \forall b \in MA, \forall g \in G \ . \tag{13}$$
$$f_{gp} \leq Mz_{gp} \quad \forall g \in G, \forall p \in P \ . \tag{14}$$
$$f_{gh} \leq Mz_{gh} \quad \forall g \in G, \forall h \in H \ . \tag{15}$$
$$f_{ab}, f_{bgk}, f_{gpk}, f_{ghk} \geq 0 \ . \tag{16}$$
$$u_a, u_g, u_p, u_h = \{0,1\} \ . \tag{17}$$
$$z_{ab}, z_{bg}, z_{gp}, z_{gh} = \{0,1\} \ . \tag{18}$$
$$LC_{pro,ab} = WC \times d_{ab} \times PW \ . \tag{19}$$

Equation (1) is the objective function to minimize the total cost. The total cost includes five types of costs, such as transportation, facility and route opening, recycling, and disposal costs. Equation (2) is a constraint that satisfies each demand in the market. Equation (3) shows that the number of EOL products that can be collected from each market b is equal or less than the demand $N_{product,b}$. Equation (4) ensures that the number of EOL products with status k at collection center g meets the sum of EOL products with status k transported to the recycling center p and the disposal center h. Equation (5) and (6) are constraints on the return and recycling rates respectively. In (5), the ratio between the total EOL products weight at all collection centers and the total product weight in the market b is given as a constraint of the return rate RR. In addition, the actual recycling rate RCR should be greater than one of recycling rate RCR_0 as in (6). Actual recycling rate is the proportion of product weight that is actually recycled in the total product weight. Equation (7) gives the recyclable EOL statuses with status k for each recycling center p. Equations (8) to (11) give the capacity of facilities that the products are processed at the only open facilities, and the transportation capacities are specified as $Q_{max,a}$, $Q_{max,g}$, $Q_{max,p}$, $Q_{max,h}$. Equations (12) to (15) show that both products and EOL products can be transported only in the open route. Equation (16) is a non-negative condition of the number of transporting. Equation (17) and (18) indicate 0-1 constraints. Equation (19) gives the product transportation cost between facility a and b.

(B) Close-Type Model

$$\sum_{a\in F}\sum_{b\in MA} LC_{pro,ab}f_{ab} + \sum_{b\in MA}\sum_{g\in G} LC_{pro,bg}f_{bg} + \sum_{g\in G}\sum_{p\in P}\sum_{k\in K} LC_{pro,gp}f_{gpk} + \sum_{g\in G}\sum_{h\in H}\sum_{k\in K} LC_{pro,gh}f_{ghk} + \sum_{p\in P}\sum_{a\in F}\sum_{k\in K} LC_{mat,pak}f_{pak} + \sum_{a\in F}\sum_{b\in MA} OC_{ab}z_{ab} + \sum_{b\in MA}\sum_{g\in G} OC_{bg}z_{bg} + \sum_{g\in G}\sum_{p\in P} OC_{gp}z_{gp} + \sum_{g\in G}\sum_{h\in H} OC_{gh}z_{gh} + \sum_{p\in P}\sum_{a\in F} OC_{pa}z_{pa} + \sum_{a\in F} FC_a u_a + \sum_{g\in G} FC_g u_g + \sum_{p\in P} FC_p u_p + \sum_{h\in H} FC_h u_h + \sum_{g\in G}\sum_{p\in P}\sum_{k\in K} RCC_k f_{gpk} + \sum_{g\in G}\sum_{h\in H}\sum_{k\in K} DC f_{ghk} \ . \tag{20}$$

$$f_{ab}, f_{bgk}, f_{gpk}, f_{ghk}, f_{pak} \geq 0 \ . \tag{16}$$
$$z_{ab}, z_{bg}, z_{gp}, z_{gh}, z_{pa} = \{0,1\} \ . \tag{18}$$
$$\sum_{a\in F} f_{pak} = \sum_{g\in G} f_{gpk} \quad \forall p \in P, \forall k \in K \ . \tag{21}$$
$$\sum_{p\in P}\sum_{k\in K} f_{pa} \leq Q_{max,a}u_a \quad \forall a \in F \ . \tag{22}$$
$$f_{pa} \leq Mz_{pa} \quad \forall p \in P, \forall a \in F \ . \tag{23}$$
$$LC_{mat,abk} = WC \times d_{ab} \times RCW_k \ . \tag{24}$$

This model uses the constraints from (2) to (19) in the (A) open-type model. Equation (16) and (18) are updated to (16)' and (18)'. Moreover, (21) to (24) are added. Equation (20) is the objective function to minimize the total cost. The transportation cost of recycled materials from a recycling center p to a factory a is added to in (1). Equation (16)' is a non-negative condition of the number of transporting. Equation (18)' indicate 0-1 constraints. Equation (21) is constraint that all recovered materials with status k recycled at recycling center p are transported to factories a. Equation (22) give the capacity of facilities that the products are processed at the only open facilities, and the transportation capacities are specified as $Q_{max,a}$. Equations (23) shows that recycled materials can be transported only in the open route. Equation (24) shows the recycled materials transportation cost from the recycling center *p* to factory *a*.

EXAMPLE OF CLOSED-LOOP SUPPLY CHAIN NETWORK DESIGN

Product Scenario: In this section, the same example from the previous study (Ishii et al, 2017) is used to validate the new model. The personal computer (PC) (Igarashi et al, 2014) is used as an example of an assembled and EOL product and is assumed to be a single product with stable long-term demand.

The collected EOL product has different product status. Thus, it is assumed that there are different product statuses based on the scenarios of Igarashi et al (2014). In the same way as, each product status has different recycling cost and rate as shown in table 2. The recycling cost and weight of each product status is calculated by using the recyclability evaluation method (Hitachi, Ltd., 2018; Akahori et al, 2008). The recycling cost is the sum of the disassembly, processing, disposal, landfill, costs and revenue from sales of materials. The recycling cost of product statuses 2 to 4 is negative, which means that a positive profit is earned through the sale of recycled materials. On the other hand, the recyclable product status depends on deferent capability of each recycling center. It is assumed that there are three different recycling centers which have different recycle capabilities as shown in table 2. Circles "○" in table 2 represents the recyclable EOL statuses for each recycling center. For example, the EOL products with status "2" can be transported recycling centers in Chofu or Chiba only to recover materials from EOL products. The disposal cost of each EOL product is assumed to be 10 [US$].

Network Scenario: Based on the product scenario, this section gives examples of a network scenario. Shinjuku, Yokohama, and Chiba are assumed to be the products' markets. There are three candidate locations for factories, collection centers and recycling centers respectively, while there is one candidate location for a disposal center. The candidate those facilities are set based on the price of land for industrial use (LIFE Emotion Inc., 2017), establishment sites and opening costs for facilities are set, the road distance between facilities by using Google Inc. (2017) is assumed. Other assumptions are as follows:

- EOL products have the same amount of the four product statuses at each collection center.
- The amount of products demand of each market is 10,000.
- The unit transportation cost is 0.000002 [US$/g·km].
- The route opening costs are 0 [US$], assuming that domestic and existing network can be used.
- Each facility has a capacity constraint of 25,000.
- The return rate RR = 90%, the recycling rate constraint RCR_0 = 60%.

RESULTS OF NETWORK CONFIGURATION

(A) Open-type: Figure 2 shows the results of network structure in open-type. The opened facilities and transportation quantity of products on each route are described. Table 3 shows results of actual recycling rate and total cost. All returned EOL products of product statuses 2, 3 and 4 were recycled. However, only 77.1% of the EOL products with status 1 were recycled and 22.9% were disposed, with a disposal cost. Therefore, all the EOL products should be recycled to reduce the total cost. However, 2,000 EOL products of status 1 are disposed due to the low capacity of a recycling center. In the recycling center in Chiba, 25,000 EOL products were transported, so that the number of transported EOL products from collection centers recycled the capacity at the recycling center in Chiba. Therefore, to recycle the disposed 2,000 EOL products, an additional recycling centers should be opened. To examine the effect of the availability of a disposal center, another experiment was conducted where the disposal center was not available and other assumptions remained. The result of the case that disposal center was not available are shown in Figure 3. In this case, all EOL products were recycled and so the recycling rate became 3.7% higher than one in when a disposal center is available. This situation is better from the view of recycling rate. However, the total cost was 2.26 times higher as the network configuration was designed with two recycling centers. That leads the facility-opening cost to be increased. To minimize the total cost, the open-type network was designed as in Figure 2. The maximum capacity of one recycling center, that is, 25,000 EOL products, were recycled and the remaining 2,000 were disposed. According to the above comparison, the total cost was reduced when a disposal center is available. On the other hand, the recycling rate was increased when a disposal center was not available.

(B) Close-type: Figure 4 shows the result of a close-type network structure. The opened facilities and the transportation quantity of each route are described. Table 3 shows the results of actual recycling rate and total cost. As shown in Figure 2 and 4, opened facilities were the same, except for factories. In the open-type, factories in Tochigi and Hitachi were selected to reduce the facility-opening cost. On the other hand, in the close-type, Ome and Tochigi were selected. One of the reason is to decrease the transportation cost of recycled materials from the recycling center to the factory. In the close-type case, factories were connected to both markets and recycling centers. Therefore, facilities were concentrated around markets and the transportation distance decreases.

Discussion: In this section, the results of open and close-types are compared. Table 4 shows the results of the total cost and breakdown of open and close-types. Table 5 shows the results of the total transportation cost and breakdown of open and close-types. The total transportation cost of the close-type was higher by 16 % than that of the open-type. This is because the close-type required longer amount of logistics because of the recycled materials were send to the factories, therefore the transportation cost become higher by the feedback route. Facility-opening costs for the close-type were also higher than for the open-type. This is because the factory in Ome that is close to markets was opened in the close-type. The factory in Ome of the close-type which are located in an urban area had higher opening cost than that of rural areas such as Tochigi and Hitachi. However, the factories in urban areas has one advantage to shorten the distances between markets and factories. Thus, as shown in Table 5, the transportation cost of the close-type is lower by 19% than that of the open-type, when excluding the feedback route.

Table 2. Recycling Weight and Cost for Each EOL Product Status, and Recyclable EOL Products Statuses

Product status k		1	2	3	4
Recycling weight RCW_k [g]		5170	5170	4792	4792
Recycling cost RCC_k [US$]		0.4061	-1.0373	-1.9544	-1.9544
	Ota	—	—	○	○
Recycling centers	Chofu	—	○	○	○
	Chiba	○	○	○	○

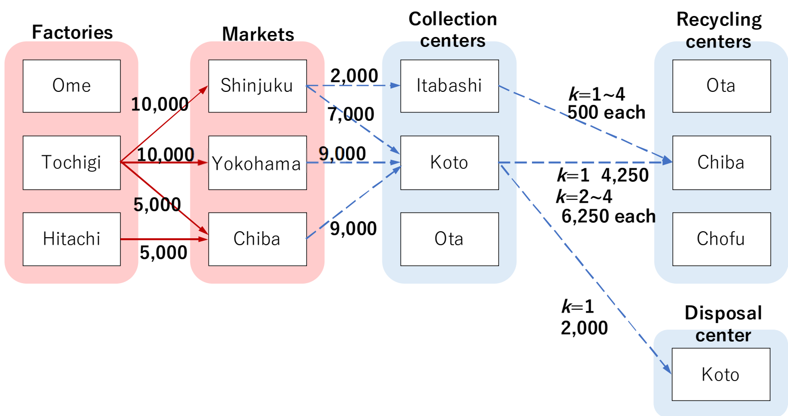

Figure 2. The Results of Network Structure in Open-Type

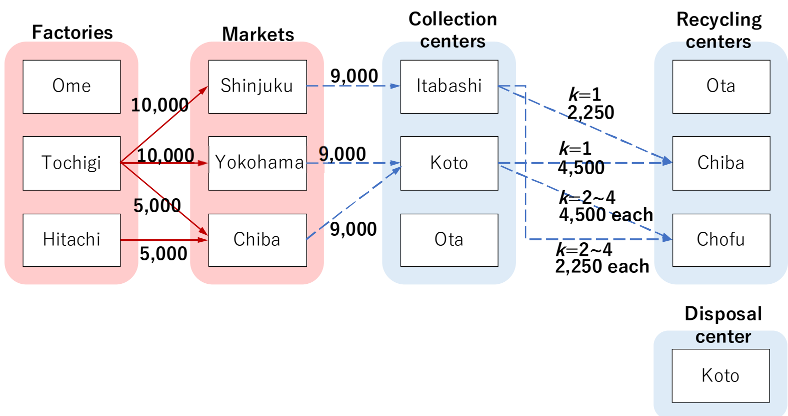

Figure 3. The Results of Network Structure in Open-Type, if Disposal Center is not Available

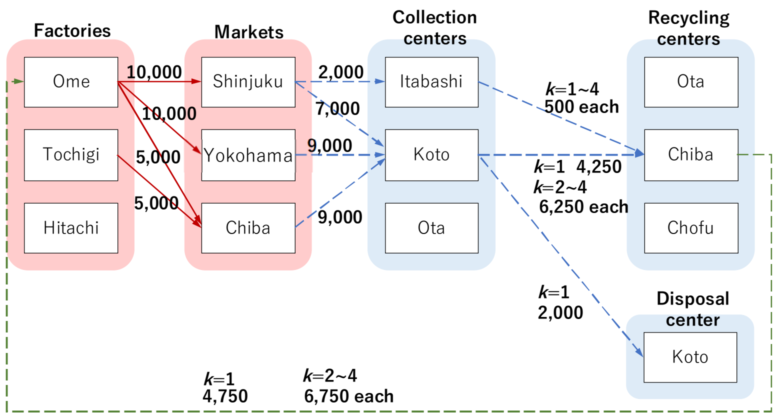

Figure 4. The Result of a Close-Type Network Structure

Table 3. Results of Actual Recycling Rate and Total Cost in Open and Close-Type

		Open-type		Close-type
	Disposal center	Available	Not available	Available
Constraints	Return rate [%]	90.0	90.0	90.0
	Recycling rate constraint [%]	60.0	60.0	60.0
Results	Recycling rate [%]	66.5	70.2	66.5
	Total cost [US$]	101,265	228,859	135,527

Table 4. Breakdown and the Total Cost

	Open-type	Close-type
Actuary recycling rate [%]	66.5	66.5
Total cost [US$]	101,265	135,527
Total transportation cost [US$]	75,422	89,684
Facility opening cost [US$]	37,300	57,300
Recycling cost [US$]	-31,457	-31,457
Disposal cost [US$]	20,000	20,000

Table 5. Breakdown of Transportation Cost

		Open-type	Close-type
Total transportation cost [US$]		75,422	89,684
Transportation Cost [US$]	Factories - markets	45,164	30,603
	Markets - collection centers	9,761	9,761
	Collection centers - recycling/disposal centers	20,497	20,497
	Recycling centers - factories (feedback route)	0	28,823

CONCLUSION

This study proposed the CLSC network model with the feedback route based on recycled materials. Numerical experiments were conducted to validate the effect of the proposed model. The differences between the opened and closed model types were compared. The influence of these models on network configuration and cost was analyzed. As illustrated in the numerical experiments, the following trends were observed: in open-type, factories with low facility-opening costs were selected to reduce costs. The network was then spread out from the market area. In close-type, a factory close to the markets was selected to reduce the transportation cost. The network was then concentrated around the markets area. Future work should include the recovery rate, which is the sum of the recycling rate and the reuse rate, and design a network with multiple periods.

ACKNOWLEDGMENT

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EVALUATION OF ASIAN SUPPLIER AND DISASSEMBLY PARTS SELECTIONS FOR CARBON EMISSIONS AND COSTS

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Abstract − *In recent years, global warming due to CO_2 emissions and the depletion of natural resources have become increasingly serious environmental issues facing the world. The recycling of assembled products can reduce the consumption of exhaustible materials and the CO_2 emission by avoiding the procurement of new materials. The CO_2 emissions produced from material manufacturing differ significantly between countries, as each country has a different energy mix (i.e., the combination of energy sources such as coal, natural gas, solar, wind, and nuclear power, among others). In general, emerging countries have higher CO_2 emissions and lower procurement costs, while developed countries have lower CO_2 emissions and higher procurement costs. Therefore, to reduce CO_2 emissions, the development of a supplier selection that is both low-carbon and economic should be achieved by procuring materials from suppliers in both developed and emerging countries. One of the methods to save natural resources is recycling parts from end-of-life (EOL) assembly products. Thus, selection for parts that are economic and low-carbon is conducted to select disassembled parts for recycling that can reduce CO_2 emissions in an economic manner. However, the low-carbon supplier selection and the disassembled parts selection were evaluated separately, although the CO_2 emissions of each step are different among the countries. This study evaluates two methods for supplier selection of procurement and disassembly parts selection during the recycling stage. First, a bill of materials (BOM) is prepared using Asian supplier selection with the 3D-CAD model and LCI database. Second, disassembled parts of the EOL assembly products from the BOM data are selected for either recycling or disposal using 0-1 integer programming with an ε constraint method. Finally, the results of the disassembly parts selection, in terms of CO_2 emission reduction and costs, are analyzed.*

Keywords − *Assembled products, CO_2 reduction, Life cycle inventory database, Material circulation, Recycling*

INTRODUCTION

The global supply chain consists of suppliers, manufacturers, distributors, retailers, and customers spread across developed and emerging countries (Urata et al, 2017). In order to procure parts and manufacture products with lower cost, assembly products are manufactured on the global supply chain.

Global warming has become one of the most environmental problems facing the world in recent years. To address global warming, 188 countries joined the 21st Conference of Parties in 2015 (COP21) to determine target CO_2 reduction and work towards developing a more sustainable society. The Japanese government committed to 26% target CO_2 reduction from their 2013 levels by 2030 (UNFCCC, 2018). When new materials are procured for assembly products on the global supply chain, CO_2 emissions in material manufacturing stage are unavoidable. Therefore, material-based CO_2 emissions must be reduced to realize a more sustainable society.

When parts for assembled products are procured by manufactures which means the beginning of product life cycle, the CO_2 emissions from producing the materials are different between countries because each country has a different energy mix (Yoshizaki et al, 2016). Energy mix is the combination of energy sources, such as coal, gas, wind, and nuclear power used to meet the demands and needs in each country. In general, emerging countries have higher CO_2 emissions and lower procurement costs, while developed countries have lower CO_2 emissions and higher procurement costs in parts procurement (Kondo et al, 2017). When procurement parts for assembled products, manufacturers need to select supplier in order to reduce procurement cost and CO_2

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emissions (Yoshizaki et al, 2014). Therefore, a supplier selection with both low-carbon and economic should be achieved by procuring materials from suppliers in both developed and emerging countries.

On the other hand, at the end of product lifecycle, recycling end-of-lifecycle (EOL) products can effectively recover CO_2 emissions because it helps avoiding the production of new materials. The cost for recycling assembled products depends on the material types used in each part, as materials require different recycling techniques at varying costs. To recover CO_2 emissions and reduce costs, disassembly parts selection (Igarashi et al, 2014) is required to determine which parts to dispose of and which to recycle. Thus, selecting disassembled parts should be conducted for recycling that can reduce CO_2 emissions in an economic manner.

Supplier selection in the procurement stage and disassembly parts selection in the EOL stage for assembled products have been studied separately. For example, Yoshizaki et al (2014) proposed a supplier selection of assembly products to reduce greenhouse gas emissions and procurement costs. On the other hand, Igarashi et al (2014) proposed a disassembly parts selection of assembled products to recover CO_2 emissions and reduce recycling costs. However, the supplier and disassembly parts selections for assembled products are carried out on the same lifecycle. Therefore, the two types of suppliers and disassemblly parts selections for assembled products must be considered at the same time in terms of the whole lifecycle.

This study evaluates an integrated low-carbon selection method for selecting suppliers in the procurement stage and disassembly parts in the recycling stage of assembled products. First, a bill of materials (BOM) is prepared using a 3D-CAD model (Inoue et al, 2011) and an LCI database with the Asian international input-output (I/O) tables (Yoshizaki et al, 2016). Second, the disassembled parts of EOL assembly products from the BOM data are selected (Igarashi et al, 2014) for either recycling or disposal using 0-1 integer programming with an ε constraint method. Finally, the results of the supplier and disassembly parts selection for reducing CO_2 emissions and costs are analyzed in terms of the whole lifecycle.

PROCEDURE

Overview

This section explains the procedures for selecting suppliers and disassembly parts for recycling with environmental and economic factors. Figure 1 shows the procedures of integrated selection stages for Asian supplier and disassembly parts with carbon emissions and costs in this study. The procedures are conducted in two stages: Asian supplier selection for procurement parts, and disassembly parts selection from EOL products.

At stage 1, the Asian supplier selection has 2 steps. First, material based CO2 emission and procurement cost for each part at the material procurement stage are estimated with the 3D-CAD model and the LCI database

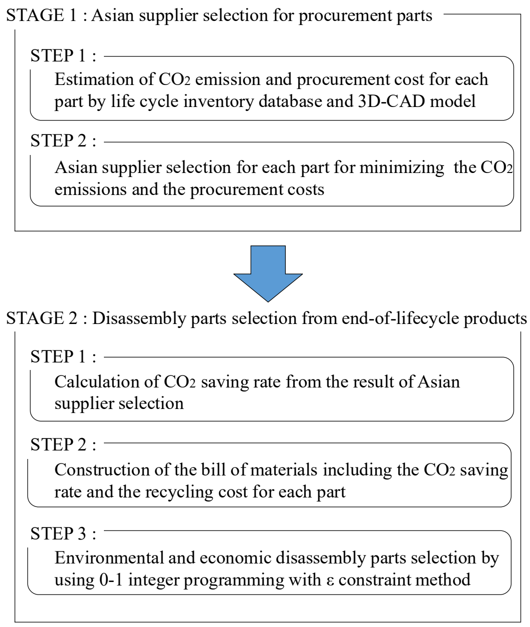

Figure 1. The Procedures of Integrated Selection Stages for Asian Supplier and Disassembly Parts with Carbon Emissions and Costs

with Asian international I/O tables. Second, similar to Yoshizaki et al (2014), the supplier selection for each part is determined for minimizing both CO2 emissions at procurement stage and procurement costs. This supplier selection has already been carried out by Yoshizaki et al (2014) so that it is used as the input data for this study.

At stage 2, the disassembly parts selection is conducted in 3 steps. In step 1, the CO2 saving rate is calculated by dividing total CO2 emissions by CO2 emissions for each part according to the results of the Asian supplier selections. In step 2, the BOM is constructed to include the CO2 saving rate and recycling cost for each part. The recycling costs are estimated with the Recyclability Evaluation Method (REM) (Hiroshige et al, 2002) using data on the weights, material types, and disassembly task types for each part. Finally, in step 3, the disassembly parts selection is determined using 0-1 integer programming with ε constraint method to minimize recycling costs and achieve the target recycle CO2 saving rates.

Stage 1: Asian Supplier Selection for Procurement Parts

In order to solve the bi-objective problem in stage 1, this section formulates Asian supplier selection with ε constraint method. At stage 1, Asian supplier selection is formulated similarly to the method of Yoshizaki et al (2014). 0-1 integer programming (Hiller & Lieberman, 2005) with ε constraint method (Eskandarpour et al, 2015) are used in order to solve the bi-objective problem for minimizing total procurement costs and the CO2 emission at procurement stage. The notation used for Asian supplier selection is shown in detail below:

j: Index of parts (j=1,2,…, N)
l: Index of supplier (l=1,2,… , M)
N: Number of parts
M: Number of suppliers
PC_{jl}: Procurement cost of part j at supplier l
e_{jl} : CO_2 emission at procurement stage of part j at supplier l
TPC: Total procurement cost
D: CO_2 emission at procurement stage by product
R_{max}: Maximum CO_2 emission of the configuration
x_{jl}: Binary value; 1 if part j at supplier l is selected or else 0
$\varepsilon_{CO_2, s}$: Constraint of CO_2 emission in supplier selection

The bi-objective functions for Asian supplier selection are set as (1) and (2). Equation (1) indicates minimizing the total procurement cost and (2) means the calculation for minimizing the CO2 emissions. In order to solve the multiple objective optimization, the objective function (2) is changed to the constraint (3) as well as Yoshizaki et al (2014). In this study, a supplier for each part of the procurement stage is selected to achieve a 26% reduction in CO2 emissions from a case that is selected all Chinese suppliers for each part. Equation (4) means the constraint without selecting the same parts from more than one supplier.

$$TPC = \sum_{j=1}^{N}\sum_{l=1}^{M} PC_{jl} x_{jl} \rightarrow Min. \tag{1}$$

$$D = \sum_{j=1}^{N}\sum_{l=1}^{M} e_{jl} x_{jl} \rightarrow Min. \tag{2}$$

Subject to:

$$D \le \varepsilon_{CO_2,s} \times R_{\max}. \tag{3}$$

$$\sum_{l=1}^{M} x_{jl} = 1 \quad j \in J \ . \tag{4}$$

Stage 2: Disassembly Parts Selection for EOL Products

This section formulates disassembly parts selection with an ε constraint method. At stage 2, the method of disassembly parts selection is formulated similarly to the method of Igarashi et al (2014). The bi-objective problem for minimizing total recycling costs and maximizing the CO2 saving rate at disassembly stage is solved by using 0-1 integer programming (Hiller & Lieberman, 2005) with ε constraint method (Eskandarpour et al, 2015). The CO2 saving rate is defined as a rate of the CO2 emission for each part to all parts in assembled products (Igarashi et al, 2014). The notation used for disassembly parts selection is shown in detail below:

i: Index for predecessors of part j
j: Index of parts (j=1,2,…, N)
N: Number of parts
c_j: Recycling cost at part j
g_j: CO_2 saving rate at part j
E: CO_2 saving rate at disassembly stage
TRC: Total recycling cost
y_j: Binary value; 1 if part j is recycling, or else 0
P_j: Set of tasks that immediately precede task j at part j
$\varepsilon_{CO_2,d}$: Constraint of CO_2 saving rate in disassembly parts selection

The bi-objective functions for disassembly parts selection are set as (5) and (6). Equation (5) means the calculation for minimizing the sum of recycling cost and (6) shows the calculation for maximizing the sum of CO2 saving rate. Equation (8) ensures the disassembly precedence relationships among tasks. Also, 0-1 integer programming with ε constraint method is used to solve this bi-objective problem. Therefore, the environmental objective function (6) is replaced by the constraint (7) as well as Igarashi et al (2014). Optimization is performed by changing the target CO2 saving rates to 20, 40, …, 80%. This allows us to minimize recycling cost while still achieving the target CO2 saving rate.

$$TRC = \sum_{j=1}^{N} c_j y_j \rightarrow Min. \tag{5}$$

$$E = \sum_{j=1}^{N} g_j y_j \rightarrow Max. \tag{6}$$

Subject to:

$$E \geq \varepsilon_{CO_2,d}. \tag{7}$$

$$y_i - y_j \geq 0 \quad i \in P_j. \tag{8}$$

CASE STUDY

Product Example

This section explains a vacuum cleaner as a case study for applying the methods in this study. Table 1 shows the BOM of the vacuum cleaner with part names, material types, weights, CO2 emission, and recycling cost for each part using the 3D-CAD model, LCI database with Asian international I/O tables (Sugiyama et al, 2012) and REM (Hitachi, Ltd, 2015). It is assumed that two suppliers are set for each part; the developed country supplier is set as Japan, while the emerging country supplier is set as China because it is the largest importer of Japanese products and the second largest exporter of products to Japan (JETRO, 2018).

From table 1, it is found that the recycling cost of part #9 (Left body) is the highest, and part #21 (Outer flame of the fan) is the lowest among all of the parts in the vacuum cleaner. Additionally, the CO2 emission of part #19 (Motor) accounts for more than 90% of the total product CO2 emissions in each country. Therefore, this study assumed that part #19 (Motor) is always purchased from Japan and disassembled for recovering its CO2 volumes, the supplier and disassembled parts selections are conducted without part #19 (Motor).

Figure 2 shows the disassembly precedence relationships of the vacuum cleaner (Igarashi et al, 2014). The solid arrows indicate constrained relationships, while the dotted arrows indicate unconstrained relationships. This disassembly precedence relationship shown in Figure 2 are subject to (7).

Three Scenarios of Supplier Selection for Each Part

This section explains three scenarios of supplier selection for each part. The disassembled parts selection is carried out using 0-1 integer programming (Hiller & Lieberman, 2005) with an ε constraint method (Eskandarpour et al, 2015). In this study, the three scenarios is considered a different supplier selection for each part. Firstly, scenario 1 - a Chinese supplier is always selected for all parts - has the highest CO2 emission (9,120 [g·CO2-eq]) and the lowest procurement cost (1.62 [US$]) of the three scenarios. Secondary, Scenario 2 - a Japanese supplier is always selected for all parts - has the lowest CO2 emission (2,030 [g·CO2-eq]) and the highest procurement cost (3.14 [US$]) of the three scenarios. Finally, scenario 3 means that a supplier for each part is selected to achieve 26% CO2 emission reduction and lower procurement cost, similar to Yoshizaki et al (2014). On scenario 3, parts #2 (Wheel stopper), #12(Mesh filter), #20 (Rubber of outer flame of fan) and #21(Outer flame of fan) are selected from Japanese supplier. Scenario 3 represents 26% CO2 emission reduction from scenario 1 (6,746.1 [g·CO2-eq]) and has the second highest procurement cost (2.01 [US$]) of the three scenarios.

Table 1. Bill of Materials (BOM) of the Vacuum Cleaner

No.	Part name	Material type	Weight [g]	CO_2 emission [g.CO_2-eq]		Recycling cost [US$]
				Japan	China	
1	Wheel	PP	7.07	13.52	42.39	0.22
2	Wheel stopper	PP	1.71	3.27	10.25	0.20
3	Upper nozzle	PP	50.35	48.14	150.95	0.17
4	Lower nozzle	PP	41.25	39.44	123.67	0.17
5	Nozzle	PP	34.50	32.98	103.43	0.17
6	Right handle	PP	48.93	46.78	146.69	0.13
7	Switch	PVC	4.65	4.02	12.59	0.13
8	Left handle	PP	51.70	49.43	154.99	0.17
9	Left body	PP	187.27	179.04	561.43	0.37
10	Right body	PP	179.88	171.98	539.27	0.17
11	Dust case cover	PMMA	36.57	66.52	208.60	0.17
12	Mesh filter	cloth/Fider	18.45	390.38	2249.44	0.18
13	Connection pipe	Al/Al alloy	47.17	39.85	316.01	0.17
14	Dust case	PMMA	175.69	319.59	1002.14	0.17
15	Exhaust tube	PVC	32.04	27.67	86.76	0.17
16	Upper filter	cloth/Fider	17.74	375.36	2162.88	0.18
17	Lower filter	PP	29.33	28.04	87.93	0.17
18	Protection cap	ABS	22.29	30.15	94.54	0.17
19	Motor	Motor	279.27	29465.72	207446.13	0.11
20	Rubber of outer flame of fan	Rubber	22.85	50.44	235.83	0.19
21	Outer flame of fan	Al/Al alloy	55.11	46.55	369.20	0.09
22	Lower fan	PP	15.08	14.42	45.21	0.17
23	Fan	Al/Al alloy	62.10	52.46	416.03	0.13

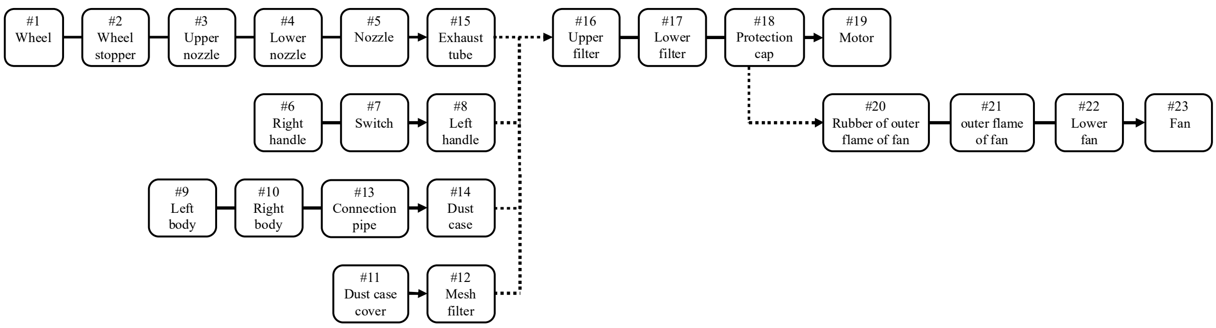

Figure 2. Disassembly Precedence Relationships of the Vacuum Cleaner (Igarashi et al, 2014)

RESULTS

Total Recycling Cost and the Total CO_2 Saving Rate of the Disassembly Parts Selection

In order to analyze influence on disassembly parts selection by supplier selection, this section discusses about the results of the supplier and disassembly parts selection. Table 2 shows the results of the supplier and disassembly parts selections of the three scenarios. In table 2, when the part is procured from Chinese supplier, boxes' color is white, and when the part is procured from Japanese supplier, boxes' color is gray. From table 2, it is found that part #16 (Upper filter) is always recycled when the target CO_2 saving rate was over 20% in all scenarios. This is because the CO_2 saving rate of part #16 (Upper filter) is either the 1st or 2nd highest for all parts across the scenarios, but the recycling cost is higher by only 3.4% than the average recycling cost. When the target CO_2 saving rate is increased to 60%, part #11 (Dust case cover) and part #12 (Mesh filter) are also recycled in scenarios 1 and 2. However, part #13 (Connection pipe) and part #14 (Dust case) are recycled in scenario 3 instead of part #11 (Dust case cover) and #12 (Mesh filter). One of the reasons for this is that the CO_2 saving rate of part #13 (Connection pipe) and #14 (Dust case) is increased by procuring four parts for parts #2 (Wheel stopper), #12 (Mesh filter), #20 (Rubber of outer flame of fan) and #21 (Outer flame of fan) from Japan. When the parts are procured from Japan, the CO_2 saving rate of these parts is decreased. Thus, the CO_2 saving rate of the other parts procured from China is increased. Therefore, the recycling costs can be reduced when the suppliers for each part are selected from both Japan and China.

Additionally, if the target CO_2 saving rate is set at 60% or 80%, recycling costs in scenario 3 are the lowest for each scenario. For example, when the target CO_2 saving rate is 60%, the total recycling cost and CO_2 saving rate in scenario 1 are 1.08 [US$] and 62.3%, respectively. However, in scenario 3, the recycling cost is reduced by 1% and the CO_2 saving rate is increased by 10% from scenario 1. Thus, by procuring four parts for parts #2 (Wheel stopper), #12 (Mesh filter), #20 (Rubber of outer flame of fan) and #21 (Outer flame of fan) from Japan to be combined with the Chinese parts, there is the case that scenario 3 is able to achieve a supplier and disassembly parts selection that increases the CO_2 saving ratio and reduces the recycling costs compared to scenarios 1 and 2. Additionally, achieving a low-carbon and economic disassembly parts selection is required to increase the CO_2 saving rate of recycled parts. Thus, the parts required for recycling are procured from China, while other parts are procured from Japan to reduce the recycling costs. Therefore, the results demonstrates that there is a case where supplier and disassembly selection methods can effectively reduce recycling costs while increasing the CO_2 saving rate for recycling parts.

Table 2. The Results of the Supplier and Disassembly Parts Selections of the Three Scenarios

No.	Part name	Scenario 1 : All Chinese supplier					Scenario 2 : All Japanese supplier					Scenario 3 : Supplier selection for achieving 26% CO_2 reduction				
		Target CO_2 saving rate					Target CO_2 saving rate					Target CO_2 saving rate				
		0%	20%	40%	60%	80%	0%	20%	40%	60%	80%	0%	20%	40%	60%	80%
1	Wheel															
2	Wheel stopper															
3	Upper nozzle															
4	Lower nozzle															
5	Nozzle															
6	Right handle					Recycle		Recycle		Recycle	Recycle					Recycle
7	Switch					Recycle					Recycle					
8	Left handle					Recycle					Recycle					
9	Left body				Recycle	Recycle				Recycle	Recycle				Recycle	Recycle
10	Right body				Recycle	Recycle				Recycle	Recycle				Recycle	Recycle
11	Dust case cover			Recycle	Recycle	Recycle			Recycle	Recycle	Recycle			Recycle		Recycle
12	Mesh filter			Recycle	Recycle	Recycle			Recycle	Recycle	Recycle			Recycle		Recycle
13	Connection pipe					Recycle					Recycle				Recycle	Recycle
14	Dust case					Recycle					Recycle				Recycle	Recycle
15	Exhaust tube															
16	Upper filter		Recycle	Recycle	Recycle	Recycle		Recycle	Recycle	Recycle	Recycle		Recycle	Recycle	Recycle	Recycle
17	Lower filter															Recycle
18	Protection cap															
20	Rubber of outer flame of fan															
21	Outer flame of fan															
22	Lower fan															
23	Fan															
Total recycling cost [US$]		0.00	0.18	0.54	1.08	1.87	0.00	0.32	0.54	1.22	1.87	0.00	0.18	0.54	1.07	1.74
Recycling CO_2 saving rate [%]		0.00	23.70	50.69	62.76	80.67	0.00	20.80	40.98	60.57	80.86	0.00	32.10	40.98	68.49	80.84

…Japanese supplier

…Chinese supplier

Total CO_2 Emissions and Costs of the Two Stages

This section explains the relationships both supplier and disassembly parts selection in this study. Table 3 shows the total CO_2 emissions and costs of the two stages, as the procurement and disassembly stages, for each scenario. The CO_2 emissions in the procurement stage are recovered as the CO_2 recovery volume in the disassembly stage. Therefore, the total CO_2 emissions of the two stages indicate the value of the CO_2 recovery volume subtracted from the CO_2 volume in the procurement stage. The total cost of the two stages is the sum of the procurement and recycling costs. Moreover, it is observed that the target CO_2 saving rate of 0% in scenario 2 (without the two selections) and the target CO_2 saving rate 60% in scenario 3 (with the two selections) have CO_2 emissions and costs within 2%. This case means that the CO_2 emissions with and without the two types of selections exhibit little variation. Therefore, there is a case that the same CO_2 emissions and costs are obtained without either supplier or disassembly parts selection.

On the other hand, the total CO_2 emissions and costs in the three scenarios are shown to identify the relationships between the supplier and disassemblly parts selections. Figure 3 shows the relationship between the total CO_2 emissions and costs of the two stages across the three scenarios. The dotted line in Figure 3 represents an exponential approximation conducted in Microsoft Excel 2013, and all plots of the three scenarios followed by the exponential approximation. It is found that the total CO_2 emissions and costs of the two stages have almost the same relationship across all three scenarios. The relationship demonstrates that CO_2 emissions can be reduced with only a slight increase in cost when the assembled product has high CO_2 emissions. For example, when the target CO_2 saving rate is 20% in scenario 1, the total CO_2 emissions of the two stages are reduced by 24% and the total costs increased by 11% compared to the scenario 1 target CO_2 saving rate is 0%. When the target CO_2 saving rate is 80% in scenario 1, the total CO_2 emissions of the two stages was reduced by 17%, but the total costs increased by 49% above those of the CO_2 saving rate of 60%. One of the reason is that the CO_2 recovery value in disassembled stage is similar to CO_2 emission value in procurement stage on same materials.

Table 3. Total CO_2 Emissions and Costs of the Two Stages

Stages	Objectives	Scenario 1 : All Chinese supplier					Scenario 2 : All Japanese supplier					Scenario 3 : Supplier selection for achieving 26% CO_2 reduction				
		Target CO_2 saving rate					Target CO_2 saving rate					Target CO_2 saving rate				
		0%	20%	40%	60%	80%	0%	20%	40%	60%	80%	0%	20%	40%	60%	80%
Procurement parts	CO_2 emission [g.CO_2-eq]	9,120					2,030					6,746				
	Procurement cost [US$]	1.62					3.14					2.01				
Disassembled parts	CO_2 recovery value [g.CO_2-eq]	0	2,162	4,624	5,728	7,360	0	422	832	1,230	1,642	0	2,166	2,766	4,621	5,451
	Recycling cost [US$]	0.00	0.18	0.54	1.08	1.87	0.00	0.32	0.54	1.22	1.87	0.00	0.18	0.54	1.07	1.74
Total CO_2 emissions in two stages [g.CO2-eq]		9,120	6,959	4,496	3,393	1,760	2,030	1,608	1,198	800	388	6,746	4,581	3,980	2,125	1,295
Total costs in two stages [US$]		1.62	1.80	2.16	2.70	3.49	3.14	3.46	3.68	4.36	5.01	2.01	2.19	2.55	3.08	3.75

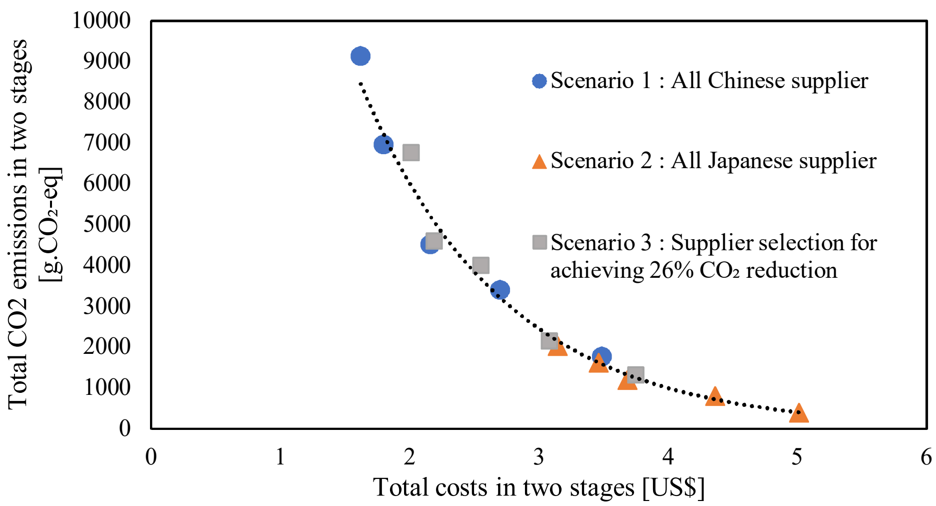

Figure 3. Total CO_2 Emissions and Costs of Two Stages in a Scatterplot

CONCLUSION

This study proposed two methods for selecting suppliers at procurement and disassembly parts during the recycling stage for assembly products. First, BOM was prepared using the Asian supplier selection results from a 3D-CAD model and the LCI database. Second, disassembled parts of EOL assembly products from the BOM data were selected for either recycling or disposal by using 0-1 integer programming with ε constraint method. Finally, the results of the disassembly parts selection were analyzed in terms of CO2 emission and costs.

- Recycling costs can be reduced more efficiently when suppliers for each part are selected from both Japan and China. This is because the CO_2 saving rate of part #13 (Connection pipe) and part #14 (Dust case) in scenario 3 was increased by procuring four parts from Japan.
- There is a case that the results found a case that supplier and disassembly selection methods can effectively reduce recycling costs while increasing the CO_2 saving rate for recycling parts. For example, when the target CO_2 saving rate is 60%, the total recycling cost and CO_2 saving rate in scenario 1 are 1.08 [US$] and 62.3%, respectively. However, the recycling cost is reduced 1.07 [US$] and the CO_2 saving rate is increased 68.5% in scenario 3.

Further studies should select suppliers and disassembly parts simultaneously to reduce CO2 emissions and costs effectively, and consider disassembly parts selection not only for recycling but also for reuse.

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EFFECTS OF CARBON TRADING SYSTEM WITH MULTI CRITERIA DECISIONS OF OPTIMAL ORDER QUANTITY AND BEST SUPPLIER SELECTION

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Abstract *– Since manufacturers require to pursue lower costs, materials and parts for assembly products are often produced and transported in global supply chain including both developed and emerging countries. However, the company discharges greenhouse gas (GHG) emissions when the materials are produced from natural resources on the supply chains. With regard to resolve global warming caused by GHG emissions, material-based GHG emissions needs to be measured and reduced in the global supply chain. Moreover, material-based GHG emissions are different among the countries due to energy mix for electric power. To reduce the GHG emissions, the government have introduced carbon tax and emissions trading system in many countries and regions such as Asia. Under the emissions trading system, the companies are quantitatively allocated the free emission credits by a government, and the companies with beyond or under the target GHG emissions can trade in an emissions trading market. These systems promote the low-carbon society to manufacturers by reducing GHG emissions. This study proposes a multi criteria decisions of optimal order quantity and best supplier selection by introducing the emissions trading system in Asia, and investigates the effect of the emissions trading system in procurement. First, a low-carbon and economic supplier selection method with an optimal order quantity considering the emissions trading system is formulated by using integer programming to minimize the total procurement cost and GHG emission. Next, numerical experiments are conducted to obtain the best supplier and the optimal order quantity for each part under the emissions trading system. Finally, the effect with and without the emissions trading system is discussed.*

Keywords – Asian life cycle inventory database, Bill of materials, Cap-and-trade, Global supply chain, Global warming

INTRODUCTION

Manufacturers are required to pursue lower procurement costs, thus materials and parts for assembly products are often produced and transported in global supply chain including both developed and emerging countries. A global supply chain means connecting efficiently across multiple countries in the supply chain which is consisting of suppliers, manufacturers, distributors, retailers, and customers (Ravindran & Warsing, 2013). When the materials for assembly products are produced from natural resources on the supply chains, the company discharges greenhouse gas (GHG) emissions which is one of the main causes for global warming (Inaba et al, 2014; Itsubo et al, 2007).

In order to resolve global warming, it is needed to reduce the GHG emissions in the global supply chain. In China, the total current global CO_2 emissions are highest such as 28.7% of the global CO_2 emissions, and are accounted for more than 40% in Asia in 2013 (The World Bank, 2018). For advancing to a sustainable low-carbon society, the Paris Agreement was held among 188 countries at the 21st Conference of Parties (COP 21) in 2015 (United Nations Framework Conversation on Climate Change, 2018). In Japan, the government submitted a target plan to decrease GHG emissions by 26% from their 2013 levels by 2030 (Arima, 2017), therefore, it is required to reduce the GHG emissions (Ministry of the Environment, 2015) by constructing a low-carbon supply chain in the global supply chains economically.

With regard to reduce the GHG emissions by each country, each government in many countries and regions such as Europe and Asia have introduced a carbon tax and emissions trading system (Urata et al, 2017). Under the emissions trading system, a government gives the free emission credits to each company, and these credits

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can be traded among the companies whose GHG emissions are beyond and under the target in an emissions trading market (Adachi, 2014; Yang et al, 2018). The companies whose GHG emissions are beyond the target can purchase the credit to keep the target. On the other hand, the one which have under the target GHG emissions can sell the credit so that they can get a profit (Adachi, 2014; Zakeri et al, 2015). Therefore, emissions trading system promote reduction of the GHG emissions efforts to manufacturers since the companies can receive economic benefits when they reduce the GHG emissions (Adachi, 2014). Until now, this system is introduced in many countries and regions. For example, European Union Emissions Trading System (EU-ETS) reduced the GHG emissions by 24% from 2005 to 2015 (Ministry of the Environment, 2018a), and the Chinese government is planning to introduce the emissions trading system (Ministry of the Environment, 2018a).

However, Tan et al (2014) pointed out that an intended impact was caused when the environmental regulation was set. As an example for carbon tax, when the carbon prices are different among the countries, the World Bank Group (2018) noted out that there was a risk of a carbon leakage. This means the companies escape to the country with lower carbon price from one with higher carbon price to minimize its cost by carbon tax (Ministry of the Environment, 2018b) like "carbon tax haven". However, there are little carbon leakage under the emissions trading system in EU-ETS (Ministry of the Environment, 2018a).

Regarding the GHG emissions in the supply chain, according to SHARP Corporation (2017), the material production stage for electric products and home appliances, such as copiers, cell phones, refrigerators, air conditioners, and TVs, have the more than 90% CO_2 emissions in the forward supply chains which consists of parts/materials manufacturing, assembly manufacturing, and logistics stages. Hence, reducing the GHG emissions at the material procurement stage plays an important role in the supply chain.

To reduce the GHG emissions in the supply chains, life cycle assessment (LCA) (Inaba et al, 2014) and life cycle inventory (LCI) databases (Sugiyama et al, 2012) can estimate and visualize the GHG emissions for each material. The LCA can estimate the amount of resources collected from the environment and the materials discharged to environment in the product life cycle quantitatively (Inaba et al, 2014). The LCI database is also known as a representative unit's process data collected at the national or regional level, covering a wide range of industries (Sugiyama et al, 2012). By using the LCI database with the Asian international input-output (I/O) tables (Yamaguchi et al, 2012), it is possible to compare the environmental impact of the design in global supply chains among Asia (Urata et al, 2017).

According to the LCI database with the Asian international input-output (I/O) tables, the countries have different GHG emissions for each material/part since the GHG emission levels for each material are different in each country (Kokubu et al, 2015). One of the reasons is that the material-based GHG emissions are different among the countries due to energy mix for electric power from coal, natural gas, and nuclear resources. Generally, in developed countries, materials manufactured with lower GHG emissions and higher procurement costs, while in emerging countries, materials manufactured with higher GHG emissions and lower procurement costs (Kokubu et al, 2015). The low-carbon and economic supplier selection means that selecting the suppliers considering appropriate for their specific purposes, especially low procurement cost for parts (Yoshizaki et al, 2016). Therefore, when each material/part is procured on the global supply chain, the suppliers from both developed and emerging countries are needed to be selected for reducing the procurement costs and the GHG emissions simultaneously.

Moreover, in order to procure parts, it is required to determine the order quantity for each supplier to achieve the low procurement costs and GHG emissions. The order quantity means the number of products or parts when these are determined as replenishment in one order (Cyber Concurrent Management Research Group, 2004), and it is important decision-making for reducing the procurement costs to determine the optimal order quantity (Japan Industrial Management Association, 2002).

From the literatures with the emissions trading system, Almutairi and Elhedhli (2014) and Bing et al (2015) treated the cost minimizing problem under the emissions trading system. However, the environmental factor was not considered. Additionally, Chaabane et al (2012) and Yang et al (2018) solved the problem of minimizing the total cost and GHG emissions and presented the effective decision for designing sustainable supply chains or companies under the emissions trading system. However, they did not do the sensitivity analysis of carbon price though different carbon price may affect the total cost and GHG emissions. Zakeri et al (2015) and Gonela (2018) considered the problem of cost and environment under the emissions trading system and conducted the sensitivity analysis of carbon price, however, they the optimal order quantity and select the best supplier were not determined. Moreover, Urata et al (2017) proposed a model of an Asian global supply chain network and minimized not only the procurement/transportation cost but also the material-based CO_2 emissions. They also conducted an emissions cost sensitivity analysis under the carbon trading, which costs are estimated by adding to the total cost when the amount of CO_2 emissions beyond the target reduction ratio for the CO_2 emissions (Urata et al, 2017). However, the emissions trading system considered in Urata et al (2017) was not optimized. Finally, Kondo et al (2017b) proposed a low-carbon and economic supplier selection method by introducing the carbon tax and analyzed the carbon and economic impact of the carbon tax on the supply chain. However, the emissions trading system was not introduced. Consequently, these studies did not consider the emissions trading system with optimal order quantity and best supplier selection. However, it is important for the manufacturer to procure parts by determining them for minimizing the cost and GHG emissions.

This study proposes a multi criteria decisions of optimal order quantity and best supplier selection by introducing the emissions trading system, and investigates the effects of the Asian emissions trading system in procurement stage. First, a low-carbon and economic supplier selection method with optimal order quantity by introducing the emissions trading system was formulated. By using ε constraint method as integer programming, the procurement costs and the GHG emissions for each part are aimed to minimize. Next, numerical experiments are conducted to obtain the best supplier and the optimal order quantity for each part under the emissions trading system. Finally, based on the results of optimal order quantity and best supplier selection, the effects with and without the emissions trading system is discussed.

The outline of this paper is as follows: Section 2 explains the procedures of the multi criteria decisions of optimal order quantity and best supplier selection by introducing the emissions trading system. Additionally, the optimal order quantity and best supplier selection with emissions trading system are formulated by using integer programming. Section 3 explains a case study and scenarios of supplier selection in Asia. Sections 4 and 5 show and discusses the results with and without emissions trading system. Finally, Section 6 concludes this study and proposes future works.

METHODOLOGY

Overview

This section shows the overview of a multi criteria decisions of optimal order quantity and best supplier selection with the emissions trading system in Asia based on Kondo et al (2017b). Figure 1 shows the procedures of a low-carbon and economic supplier selection method with optimal order quantity by considering the emissions trading system by using the LCI database with the Asian international I/O tables similar to Kondo et al (2017b) in steps 1 to 3. In this study, raw material production and logistics are set as the system boundary which is defined as the boundary from nature including the entire processes at LCA (Inaba et al, 2014; Itsubo et al, 2007).

First, from Fig. 1, in order to construct a bill of materials (BOM), the types of materials are identified by department names in the LCI database with Asian international I/O tables (Kondo et al, 2017a) in step 1.

Next, the census of manufacture in Japan (Ministry of Economy, Trade and Industry, 2017) is used in order to estimate the Japanese procurement costs for each part in step 2 since the 3D-CAD model, which has part name, material name, part numbers needed a product and weight for parts, does not have the procurement cost information. Additionally, in order to estimate the procurement costs for each part manufactured in other Asian countries, a price level in each country is used because of the different economic conditions in each country. For example, this study assumed that the Chinese procurement costs for each part are 0.517 times lower than the Japanese one (Kondo et al, 2017b).Then, in step 3, the procurement costs in each country which are estimated in step 2, and the LCI database with the Asian international I/O tables are used in order to estimate the GHG emissions for each part in each country.

After that, by using integer programming with ε constraint method (Eskandarpour et al, 2015), a low-carbon and economic supplier selection method with optimal order quantity by considering the emissions trading system is formulated in step 4.

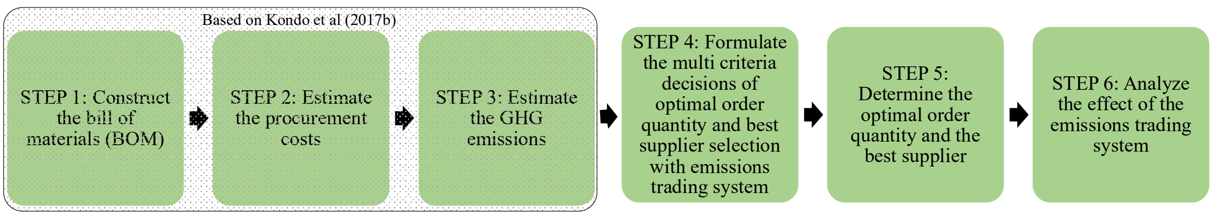

Figure 1. Procedures of a Low-Carbon and Economic Supplier Selection Method with Optimal Order Quantity by Considering the Emissions Trading System.

In step 5, in order to determine the optimal order quantity and best supplier, a mathematical programming package developed by Numerical Optimizer (NTT DATA, 2017) is used. Finally, the results of optimal order quantity and best supplier selection with emissions trading system in Asia are shown and the effect with and without the emissions trading system are discussed in step 6.

Formulate the Optimal Order Quantity and Best Supplier Selection with the Emissions Trading System

In order to minimize the procurement/emissions trading costs and the total GHG emissions, this section explains the formulation of a proposed method. A low-carbon and economic supplier selection method with optimal order quantity by considering the emissions trading system in Asia is formulated as integer programming with ε constraint method in step 4. Two objective functions are set as shown (1) and (2) in this study. In step 5, by using mathematical programming package with Numerical Optimizer (NTT DATA, 2017), this bi-objective problem is solved to determine the optimal order quantity and best supplier. The notation and formulation used in this study are shown as follows.

J : Set of parts, $J=\{1,2,\ldots,j,\ldots,|J|\}$
L : Set of suppliers, $L=\{1,2,\ldots,l,\ldots,|L|\}$
PC_{lj} : Procurement cost of part j from supplier l
e_{lj} : GHG emissions for part j at supplier l
E_{max} : Total GHG emissions of the initial configuration
$\varepsilon_{GHG,c}$: Constraint of total GHG emissions
f_{lj} : Quantity of part j transported from supplier l
n_j : Quantity of part j needed for a product
$N_{product}$: Quantity of product demands
$Q_{min,lj}$: Minimum order quantity from supplier l for part j
$CPRICE$: Unit cost of emissions trading price per ton
C_{max} : The emission allowance
TPC: Total cost
E: Total GHG emissions at material production stage

In order to minimize the total cost for each part considering the emissions trading system in Asia, and to minimize the total GHG emissions for each part, the economic and environmental objective functions are set as (1) and (2), respectively (Yoshizaki et al, 2016). The total cost TPC is estimated the sum of the procurement cost and the emissions trading cost in (1). The emissions trading costs in (1) are estimated by multiplying the carbon price and the amount which calculated deducting the total GHG emissions from the emission allowance similar to Zakeri et al (2015). Equation (2) means the total GHG emissions calculated at the material production stage. By transporting the objective function (2) aimed to minimize the GHG emissions to the constraint (3) with ε constraint method (Eskandarpour et al, 2015) as well as Yoshizaki et al (2014), the bi-objective optimization is solved. By changing ε, such as to 94, 90, 80 … i.e., 50 (%) for each target reduction ratio for GHG emissions (Yoshizaki et al, 2014), the optimal solutions are obtained in order to carry out the optimization to each of those combinations by changing the εGHG,c in (3).

The constraint set in (4) ensures that the quantity of parts required by the product demand for each part j must be satisfied the quantity of parts procured from suppliers. Additionally, (5) means that the number of procured parts flj is determined at equal to or greater than the minimum order quantity Qmin, lj from supplier l.

$$TPC = \sum_{j\in J}\sum_{l\in L} PC_{lj}f_{lj} + CPRICE(E - C_{max}) \rightarrow Min\,. \quad (1)$$
$$E = \sum_{j\in J}\sum_{l\in L} e_{lj}f_{lj} \rightarrow Min\,. \quad (2)$$
$s.t.$
$$E \le \varepsilon_{GHG,C}E_{max}\,. \quad (3)$$
$$\sum_{l\in L} f_{lj} = n_j N_{product} \qquad \forall j \in J. \quad (4)$$
$$f_{lj} \ge Q_{min,lj} \qquad \forall l \in L, \forall j \in J. \quad (5)$$

CASE STUDIES

Assumptions

In this study, the decision method of optimal order quantity and best supplier selection is adopted to a cell phone case study similar to Kondo et al (2017a, 2017b). The BOM of the cell phone (Kondo et al, 2017b) is conducted and has the part/material name, the necessary number of parts for a product, weight, unit price of each material, the procurement cost and the GHG emission for each part. The part/material name, the necessary number of parts for a product and weight for each part are obtained from 3D-CAD model (Yoshizaki et al, 2014). Additionally, the material unit prices are calculated by using the census of manufacture (Ministry of Economy, Trade and Industry, 2017), and the procurement cost and the GHG emission for each part are estimated as shown in the steps 2 and 3, respectively.

Here are the assumptions of case study for the supplier selection in this study as below:

- There are two suppliers which all where each part can be procured. These suppliers are located in Japan and China as developed and emerging countries. The reason why these two countries are chosen is that China is the largest importer and the second largest exporter of products to Japan (JETRO, 2016).
- The product demand quantity is not a decision variable but a fixed parameter and is assumed to be 1,000 products in this study.
- In this study, minimum order quantity of each part procurement is 1 for each supplier.
- The part #11 LCD made of glass is selected from Japan suppliers because of the too small percentages of weights for the glass such as 0.49%.

Scenarios of the Supplier Selection with Emissions Trading System

In this section, in order to solve the bi-objective problem formulated in Section 2.3, the scenarios of the supplier selection with emissions trading system are explained.

In Japan, the emissions trading system has been introduced at region level such as Tokyo and Saitama prefectures, but not introduced at country level (Ministry of the Environment, 2018a). Therefore, there is a possibility that Japanese government introduces the emissions trading system at country level.

In order to investigate the effect of emissions trading system and the intended impact in emissions trading system in this study, there are two scenarios of cost minimization: with and without emissions trading system. One scenario with the cost minimization under the emissions trading system in this study, the emission allowance Cmax is set as 26% reduction for the total GHG emissions of the initial configuration. The reason is that it is the target reduction ratio for GHG emissions at Paris agreement in Japan, and this study aimed to minimize the total cost, including the sum of the procurement costs and the emissions trading system costs.

On the other hand, the scenario without the emissions trading system (Yoshizaki et al, 2016) is aimed to minimize the procurement costs only by using a mathematical programming package developed by Numerical Optimizer (NTT DATA, 2017) in order to determine the optimal order quantity and best supplier, while the reduction ratios for the GHG emissions are 0% and 50%. It is assumed that the emissions trading is done among the companies in Japan, and the selling emission allowance is always sold.

RESULTS

With vs. Without the Emissions Trading System

In order to examine the effect of the emissions trading system, this section compares with and without the emissions trading system and the different emissions trading price with the emissions trading system.

Figure 2 shows the behaviors of the total cost, the total GHG emissions and the breakdown of the total cost. It is observed from Figure 2, the total cost and the emissions trading costs are increased as increasing the emissions trading price until 118.49 [$/t]. However, the emissions trading costs are decreased and can be profitable over 118.49 [$/t], so that the total costs are became lower as increasing the emissions trading price. The reason why the emissions trading costs are decreased is that the results of the supplier selection are changed.

Table 1 shows the results of the supplier selection with and without the emissions trading system at 0% target reduction ratio for GHG emissions. From Table 1, the suppliers for #9 junction are changed from Chinese to Japanese ones when the emissions trading price is 130.05 [$/t] since #9 junction has the highest GHG emissions in the cell phone.

On the other hand, the GHG emissions are decreased only 1% until the emissions trading price is 118.49 [$/t], and then decreased. When the emissions trading price is 289.00 [$/t], the total GHG emissions are lower by 44% than when the emissions trading price is 144.50 [$/t]. However, the total cost is increased monotonically until 118.49 [$/t] and then decreased as increasing the emissions trading price.

Therefore, it is found that there are cases the total cost and GHG emissions are lower than the case without the emissions trading system. It is considered that the total costs and total GHG emissions can be decreased simultaneously if the companies can sell extra saved GHG emissions from the setting the emissions allowance through the emissions trading system.

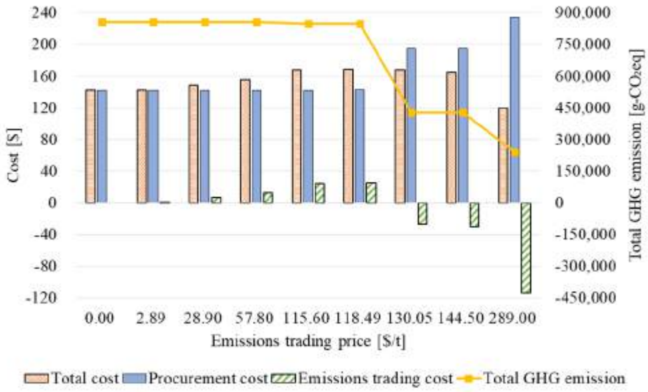

Figure 2. Behaviors of the Total Cost, the Total GHG Emissions and the Breakdown of the Total Cost.

Table 1. Results of the Supplier Selection: With and Without the Emissions Trading System (ε=0%)

Part Number	Part Name	0 [$/t] (without the emissions trading system)		Emissions trading price											
				2.89 [$/t]		57.80 [$/t]		118.49 [$/t]		130.05 [$/t]		144.50 [$/t]		289.00 [$/t]	
		Japan	China	Japan	China	Japan	China	Japan	China	Japan	China	Japan	China	Japan	China
1	Battery cover	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
2	Battery	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
3	Back case	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
4	Board	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000
5	Microphone	0	1000	0	1000	0	1000	1000	0	1000	0	1000	0	1000	0
6	Camera	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
7	Main button	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
8	Number button	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
9	Junction	0	1000	0	1000	0	1000	0	1000	1000	0	1000	0	1000	0
10	Front case	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
11	LCD	1000	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	0
12	Speaker	0	1000	0	1000	0	1000	1000	0	1000	0	1000	0	1000	0
Total procurement cost [$]		142.84		142.84		155.07		168.53		167.73		164.73		119.91	
Total GHG emission [g-CO₂eq]		856470.00		856470.00		856470.00		846720.00		425670.00		425670.00		240410.00	
Emissions trading price [$]		0.64		0.64		12.87		25.23		-27.07		-30.07		-113.69	

The Policy Mix: Direct Regulation and the Emissions Trading System

In order to examine the effect of the policy mix, direct regulation, which means the target reduction ratio for GHG emission is set by using the ε constraint method (Eskandarpour et al, 2015), and the emissions trading system, this section compares with and without the target reduction ratio for GHG emissions in the emissions trading system.

Table 2 shows the results of the supplier selection in the case of the policy mix which is 50% target reduction ratio for GHG emissions in the emissions trading system. From Table 2, it is found that when the emissions trading price is under 57.80 [$/t], the part #5 microphone, #9 junction and #12 speaker are procured from both Japanese and Chinese suppliers. This is because that these parts are made of SUS which has the highest Chinese GHG emissions level in the cell phone. The GHG emissions are minimized by setting the target reduction ratio for GHG emissions and emissions trading costs are lower than without the target reduction ratio.

On the other hand, when the emissions trading price are over 130.05 [$/t], all parts are procured from only Japanese or Chinese suppliers. It is considered that the total cost is minimized by procuring from Japanese suppliers for most parts.

Table 2. Results of the Supplier Selection: The Policy Mix (ε=50%)

Part Number	Part Name	0 [$/t] (without the emissions trading system)		Emissions trading price											
				2.89 [$/t]		57.80 [$/t]		118.49 [$/t]		130.05 [$/t]		144.50 [$/t]		289.00 [$/t]	
		Japan	China	Japan	China	Japan	China	Japan	China	Japan	China	Japan	China	Japan	China
1	Battery cover	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
2	Battery	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
3	Back case	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
4	Board	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000
5	Microphone	0	1000	995	5	995	5	1000	0	1000	0	1000	0	1000	0
6	Camera	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
7	Main button	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
8	Number button	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
9	Junction	0	1000	994	6	994	6	994	6	1000	0	1000	0	1000	0
10	Front case	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	1000	0
11	LCD	1000	0	1000	0	1000	0	1000	0	1000	0	1000	0	1000	0
12	Speaker	0	1000	997	3	997	3	1000	0	1000	0	1000	0	1000	0
Total procurement cost [$]		142.84		193.89		182.61		170.13		167.73		164.73		119.91	
Total GHG emission [g-CO_2eq]		856470.00		428234.41		428234.41		428196.30		425670.00		425670.00		240410.00	
Emissions trading price [$]		0.64		-0.59		-11.88		-24.36		-27.07		-30.07		-113.69	

Therefore, it is found that when the emissions trading price is lower than 57.80 [$/t], the optimal order quantity for the part #5 microphone, #9 junction and #12 speaker are depend on the emissions trading price, and the other parts are procured from the Chinese suppliers for minimizing the total costs. Additionally, when the emissions trading price is higher than 130.05 [$/t], the optimal order quantity for all parts is 1,000 because the total costs and GHG emissions are minimized.

CONCLUSIONS

This study proposed a multi criteria decisions of optimal order quantity and best supplier selection by introducing the emissions trading system, and investigated the effects of the Asian emissions trading system in procurement stage. First, a low-carbon and economic supplier selection method with optimal order quantity by introducing the emissions trading system was formulated. By using ε constraint method as integer programming, the procurement costs and the GHG emissions for each part were aimed to minimize. Next, numerical experiments were conducted to obtain the best supplier and the optimal order quantity for each part under the emissions trading system. Finally, based on the results of optimal order quantity and best supplier selection, the effects with and without the emissions trading system were discussed. The main conclusions in the experiments are as follows:

- It is found that there are cases the total costs and GHG emissions are lower than the case without the emissions trading system. Therefore, the total cost and the total GHG emissions can be decreased simultaneously if the companies can sell extra saved GHG emissions from the setting the emissions allowance through the emissions allowance.
- It is found that when the emissions trading price is lower than 57.80 [$/t], the optimal order quantity for the part #5 microphone, #9 junction and #12 speaker are depend on the emissions trading price, and the other parts are procured from the Chinese suppliers for minimizing the total costs. Therefore, the total cost and the total GHG emissions can be reduced simultaneously by changing some parts.

One of the further studies should adapt this proposed method to other products through the 3D-CAD models, and consider among the other countries in the LCI databases with Asian I/O tables. Another study should consider the amount of selling emissions credits under the emissions trading system since the companies do not have to sell the all emissions allowance.

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FORECASTING ANNUAL PASSENGER NUMBER FOR AIR TRAVEL

Pinar Mızrak Ozfirat[1], Rahime Sancar Edis[2]

Abstract *– The number of air travel passengers is increasing rapidly by time. This is due to the fact that time is getting more valuable and costly in business life and supply in air travel is increasing. When there is an increasing trend in a process, it needs more effort to control and plan the future of that process. In addition more costs may be incurred due to inaccurate forecasting and false data. Similarly, for the increasing trend in air travel passengers, effective and accurate forecasting is necessary. In order to make effective planning for airline companies and airport terminals and to supply sufficient quality in air travel, forecasting future passenger numbers is important. Future passenger number will give the demand for air travel. This demand should be satisfied by the supply of airline companies. Therefore, for planning the number of flights, the type of aircraft which are part of capacity and logistics decisions of airline companies, it is important to determine future demand in air travel. In this study, domestic passenger numbers from 2003 to 2016 in Turkey are analyzed. Linear, exponential, logarithmic, polynomial regression methods and Holt's method are applied. These methods are compared according to mean absolute percentage error and the methods which fit the data in the best way are selected. Forecasts for passenger numbers in 2017, 2018, 2020 and 2025 are computed using the selected methods.*

Keywords – Forecasting passenger number, Regression, Holt's Method, Mean Absolute Percentage Error

INTRODUCTION

The use of air travel has increased considerably in recent years. So that planning and managing air travel becomes an important problem both for the airline companies and for the airport terminals. One of the significant factor that effects this problems is the demand of the air travel. If the number of air travel passengers can be predicted with an acceptable error, this will enable right demand data to plan and manage the systems.

Similar to the world trend, the use of air travel rapidly increased in Turkey in last 15 years. This rapid increase brings the need for effective management of aircraft, personnel and airport terminals both for airline companies and terminal management companies. Also, it is important to estimate the future demand in order to plan and organize services in a cost effective way and good quality manner.

Due to its effect on efficient planning of airport terminals, airline companies, air travel demand is also of concern both for practitioners and researchers. Some of the recent studies carried out in this area employ effective techniques which try to decrease error in forecasts. For example Kim and Shin (2016) tests different regression methods, Dantas et. al. (2017) employs Holt Winters methods, Fildes et. al. (2011) uses econometric models for air passenger demand forecasting.

In this study, several different forecasting methods including regression methods and Holt's method are used to estimate future air travel passenger number in Turkey. The methods employed are compared in terms of mean absolute percentage error (MAPE) and future forecasts are provided.

Similar to this study, there exists also papers handling case studies in different countries. For example, Sismanidou and Tarradellas (2017) consider demand forecasting for the case of Madrid Barajas International Airport, Scarpel (2013) handle air passenger forecasting problem at Sao Paulo International Airport, Gelhausen et. al. (2018) develops a new model to estimate passenger and flight numbers for German Airports. It can be seen from the literature research that efforts to make better forecasting on air travel demand is increasing in the recent years. One of the reasons for this situation is that air travel passenger numbers, flight numbers, volumes are increasing rapidly all over the world. Therefore, studies in this area including this study would be beneficial not only for researchers but also for practitioners from the field such as executives, managers of airport terminal/airline companies.

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The rest of the paper is organized as follows. In Section 2, the forecasting methods employed are explained in detail. Computational results are provided in Section 3. Finally, conclusion is given in Section 4.

FORECASTING METHODS

In this study, domestic passenger numbers from 2003 to 2016 in Turkey are analyzed. The realized values can be seen in Table 1 (www.tuik.gov.tr, 2018). It can be seen from the data that annual passenger number is increasing rapidly. Therefore, in order to decide on expansions of airport terminals, to plan future capacities of airline companies and to schedule number and aircraft of flights, it is very important to get accurate forecasts on future air travel demand. The main reasoning behind this study lies in the need for future forecasts on air passenger numbers.

Table 1. Number of domestic passengers between years 2003 and 2016. (www.tuik.gov.tr, 2018).

Year	No. of Passengers	Year	No. of Passengers
2003	9 128 124	**2010**	50 575 426
2004	14 438 292	**2011**	58 258 324
2005	20 502 516	**2012**	64 721 316
2006	28 799 878	**2013**	76 148 526
2007	31 970 874	**2014**	85 416 166
2008	35 832 776	**2015**	97 041 210
2009	41 226 959	**2016**	102 499 358

The visualized version of the values are given in Figure 1. As can be seen from the figure, the related data shows an increasing trend pattern. So that, only the computational methods related to trend patterns are concerned. One of the method used for the trend based series is the regression analysis. Using these values regression analysis is carried out using linear, exponential, logarithmic and polynomial models. The detailed computations of all regression models are given in sections 2.1. Another method used for the trend based time series is the Holt's method (Nahmias, 2009). Holt's method (Nahmias, 2009) is also applied to the related data and the details are given in section 2.2.

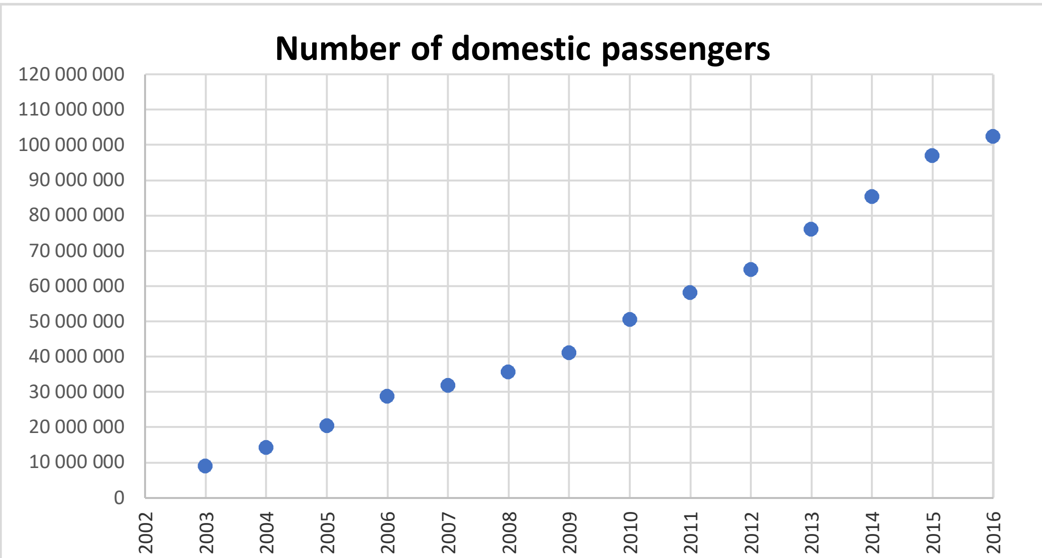

Figure 1. Plot Graphic of Number of Domestic Passengers

Regression

In the first step of the study, regression analysis is carried out on the data given in Table 1 (www.tuik.gov.tr, 2018). Different regression models are analyzed. These are namely, linear regression, exponential regression, logarithmic regression and 2nd degree polynomial regression. The graphs of the fitted regression models can be seen in Fig 2.

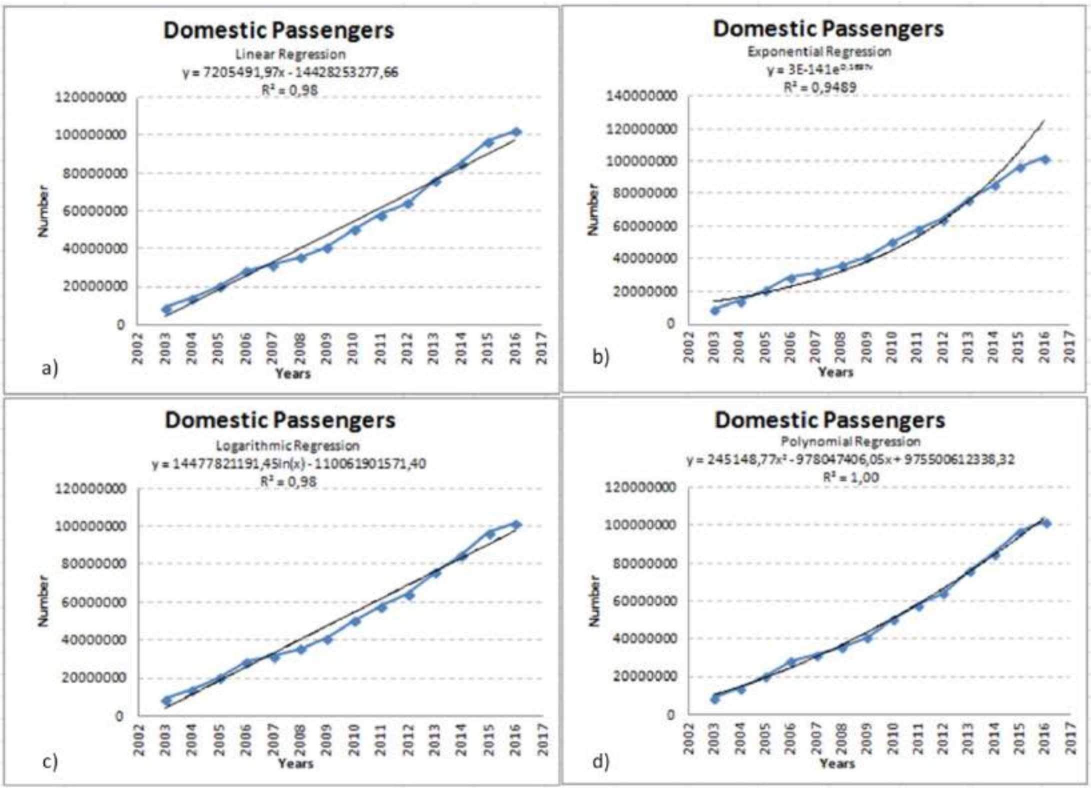

Figure 2. (a) Linear Regression Model (b) Exponential Regression Model (c) Logarithmic Regression Model (d) Polynomial Regression Model

In addition, equations of the fitted models, corresponding coefficient of determination (R2) values and mean absolute percentage errors (MAPE) are provided in Table 2 below. MAPE values given in Table 2 are computed using "(1)".

$$MAPE = \frac{\sum_{t=1}^{n} \frac{|F_t - D_t|}{D_t}}{n} \cdot 100 \qquad (1)$$

where
t: parameter for period t, t=1..n
F_t: forecast for period t,
D_t: Realized passenger number in period t.

Table 2. The Results of the Regression Models

Regression Model	Regression Equation	R^2	MAPE (%)
Linear	y = 7205491,97x-14428253277,66	0,98	11,25
Exponential	$y = 3*10^{-141} * e^{0,1697x}$	0,95	15,17
Logarithmic	y = 14477821191,45 ln(x)-110061901571,40	0,98	11,32
Polynomial	$y = 245148,77x^2$-978047406,05x+975500612338,32	1	4,44

As seen in Figure 1 and Table 2, the highest R2 value belongs to 2nd degree polynomial regression model. Linear and logarithmic models also turned out to be close to polynomial regression. Similarly, when MAPE values are considered, lowest error is provided by 2nd degree polynomial regression model. Therefore, among the four models, 2nd degree polynomial regression model is selected to explain the variation in data most suitably.

Holt's Method

Another well-known forecasting model for the trend based time series is the Holt's method which is also known as a double-exponential smoothing method (Nahmias, 2009). To apply this method, two smoothing constants, α and β, have to be specified within a limit of $0 \leq \alpha, \beta \leq 1$. Smoothing constants α and β are required for the calculation of the intercept equation and slope equation respectively. These equations are given below.

$$S_t = \alpha D_t + (1-\alpha)(S_{t-1} + G_{t-1}) \tag{2}$$
$$G_t = \beta(S_t - S_{t-1}) + (1-\beta)G_{t-1} \tag{3}$$

where
S_t : value of intercept at time *t*
D_t: value of demand at time *t*
G_t: value of slope at time *t*

As can be seen from the formulations, to start the method initial value of intercept, S_0 , and initial value of slope, G_0 have to be determined.

When we are at time t and want to obtain the forecast value of the next period, this is called as one-step ahead forecast and can be calculated by the formula, $F_{t+1} = S_t + G_t$. Similarly, when we are at time t and want to obtain the forecast value of a τ period later, this is a τ-step ahead forecast and can be calculated by $F_{t+\tau} = S_t + \tau G_t$

As can be seen from the smoothing formulations, there are four important components, α, β, S_0 and G_0 , needed to be determined appropriately, to get "good" forecast values. We tried out a number of different values of these four components and determined the most appropriate values α=1, β=0.6, S_0 = 1920000 and G_0 = 7208100. The forecast values of the method for the periods 2003 to 2016 can be seen in the Figure 3.

As can be seen from the figure, Holt's method with the specified α, β, S_0 and G_0 values fits the real data quiet well. This also can be verified by the MAPE value of 4.583%. The MAPE values of the 2nd degree polynomial regression model and the Holt's method are fairly close. So that these two models can be used to forecast the demand of the future periods.

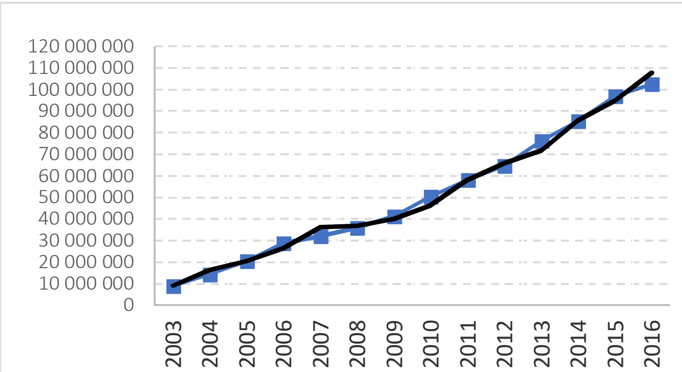

Figure 3. Forecast Values of Holt's Method.

COMPUTATIONAL RESULTS

After analyzing five different methods for forecasting passenger number, 2nd degree polynomial regression and Holt's method are selected to fit the data in the best way. These two models are used to forecast the passenger number in 2017, 2018, 2020 and 2025. In Table 3 and Figure 4 below, the forecasts projected by the two methods can be seen.

Table 3. Future Forecasts for Passenger Number Using the Selected Forecasting Methods.

Forecast Method	2017	2018	2020	2025
2^{nd} degree polynomial regression	115038690	126166571	149893225	217790068
Holt's Method	110070302	117641246	132783135	170637856

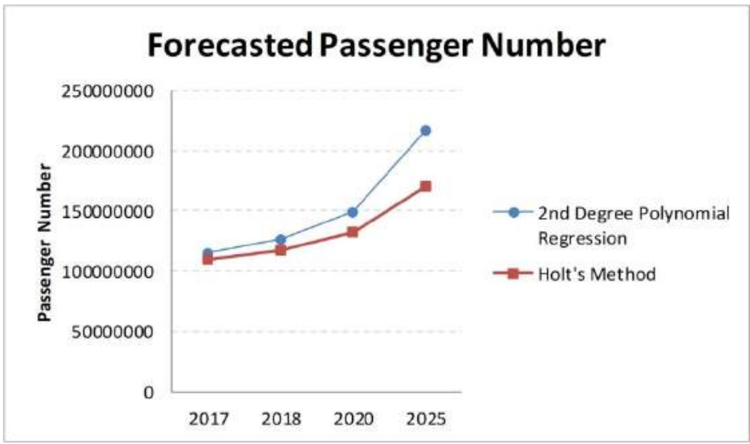

Figure 4. Forecasted passenger number using the selected methods.

CONCLUSION

In this study, passenger number for air travel is considered. Domestic passenger numbers between 2003 and 2016 in Turkey are analyzed and different forecasting models are fit to the data. Among the forecasting methods tested, Holt's method and 2nd degree polynomial regression model are found to represent the data most efficiently. Using the two models, domestic passenger number for 2017, 2018, 2020 and 2025 are forecasted. Using these computations, future planning for flights and airport terminals can be made more effectively. Airport terminal administrations and airline companies may make benefit of forecasting future passenger number to keep and increase the quality and timeliness of services. As a future direction of research, the data on hand can be turned into monthly basis and more sophisticated forecasting methods such as recurrent neural networks can be employed to analyze the data. By this way, effect of seasonality can also be seen and analyzed.

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MULTI-CRITERIA DECISION-MAKING MODEL FOR ANALYSIS OF PRODUCT DESIGNS

Aditi D. Joshi[1], *Surendra M. Gupta*[2]

Abstract *– High potential for disassembly, reuse, recycling, and remanufacturing is beneficial in management of End-Of-Life (EOL) products. Product designs favoring these recovery techniques can help to reduce the recovery costs. Hence, considering environmental aspect and product recovery during the product design phase can help Original Equipment Manufacturers (OEMs) design products for recovery. This indicates the importance of analysis of product designs for product recovery.*

This paper proposes a methodology based on Analytic Hierarchy Process (AHP) and Goal Programming (GP) to evaluate various End-of-Life product design alternatives. The End-of-Life (EOL) products received by an Advanced-Remanufacturing-To-Order-Disassembly-To-Order (ARTODTO) system are embedded with sensors and RFID tags to reduce or eliminate the uncertainties related to qualities and quantities of the received EOL products. The received EOL products are used to satisfy various products, components and materials demands. The system evaluates the design alternatives based on variety of qualitative and quantitative criteria. First, the qualitative criteria are evaluated and prioritized using AHP and then qualitative criteria along with the quantitative criteria are evaluated using goal programming. The model determines the most feasible design alternative to satisfy the demands. A numerical example is considered to illustrate the proposed methodology.

Keywords – Analytic Hierarchy Process, Goal Programming, Product Design, Product Recovery

INTRODUCTION

Organizations are becoming aware of the environmental impact of the disposal of product wastes. Governments have started to impose rules and regulations on Original Equipment Manufacturers (OEMs) to make them responsible for processing their products at the end of their lives. Reuse, remanufacturing, recycling and disposal are some of the widely used End-Of-Life (EOL) product recovery options. Disassembly is also an important process that is almost always performed before any of the EOL product recovery processes. If a product cannot be reused, then remanufacturing is perhaps the next most environmentally friendly recovery process (Gungor and Gupta, 1999).

There are several uncertainties related to the quality, quantity, and conditions of the components in the returned EOL products. Embedding sensors and Radio Frequency Identification (RFID) tags in the products at the time of their production help in reducing these uncertainties by constantly monitoring their conditions during their use phase. The information captured by these devices help in estimating the remaining lives of the components (Vadde et al., 2008). Optimal product recovery decisions can be made once the remaining lives of components are known.

Product design, apart from remaining lives can also affect the optimal product recovery decision. A product needs to be designed in such a way that it can ease the process of disassembly and remanufacturing at the end of its life. Therefore, product designers are considering environmental aspects in the product design phase. Various methodologies such as 'Design for X (DfX)', 'material selection' are proposed to ease the product designing process for the designers (Ilgin and Gupta, 2010).

This paper identifies and discusses various qualitative and quantitative criteria for evaluating product designs. An example of Air Conditioners (ACs) is considered here with two design alternatives viz., Windows Air Conditioner (Windows AC) and Split Air Conditioner (Split AC). The Advanced-Remanufacturing-To-Order-Disassembly-To-Order (ARTODTO) system receives the EOL ACs to satisfy products, components and materials demands. The two design alternatives are evaluated based on two qualitative viz., dimensions and

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location of use and three quantitative viz., total profit, quality level and number of disposed items criteria. The proposed model uses Analytic Hierarchy Process (AHP) and Goal Programming (GP) to identify the most favorable product design for product recovery.

LITERATURE REVIEW

Product design considers various design attributes such as cost, functionality and manufacturability. Another aspect added to this list is environmental consciousness. Li et al. (2015) presented a state- of- the- art review paper on environmentally conscious product design. The authors classified 120 references published through 2005 to 2015 into five sections: product eco-design, design for disassembly, design for recycling, material selection and eco-design software tools. Many studies have been performed in order to help designers choose environment friendly design preferences. For example, Cheung et al. (2015) proposed and developed a roadmap based on the example of defense electronic system to ascertain the disposal costs by the OEMs and to determine a new approach to predict the EOL costs. Kim and Moon (2016) proposed a design methodology to determine a products degree of modularity. de Aguiar et al. (2017) proposed a diagnostic tool to help designers in decision making by evaluating the recyclability of products during the design phase using the products structure and indexes. The proposed tool can also compare different recyclability scenarios and choose the best one from the environments' point of view. Li et al. (2018) proposed a time-series forecasting procedure for evaluating a product's recyclability at the product design phase. The authors considered several economic and environmental factors of different phases of the product's life cycle and predicted the cost of recycled material at the product's EOL. The authors also illustrated a case study of a cylinder engine design which concluded that the methodology was fully capable of providing decision support to designers by accessing the recyclability of the product at the design phase. Ilgin et al. (2015) and Gupta and Ilgin (2018) studied various multi-criteria decision-making techniques and applications in environmentally conscious manufacturing and product recovery.

PROBLEM STATEMENT

The ARTODTO system considered here receives EOL products embedded with sensors and RFID tags and recovers them to meet products, components and materials demands. The sensors and RFID tags capture all the information during the product's life cycle. Once the products are returned at their EOL, the captured information is stored in a database and then it is used to determine additional information such as remaining lives of products and components. Based on this data, the products and components are categorized into different bins, known as life bins. For example, if the products and components are divided into 3 life bins, life bin 1 can contain components of remaining lives of at least one year, life bin 2 may contain components of remaining lives between one and two years and life bin 3 may contain components of remaining lives of at least two years. Any item with remaining life of less than one year is considered as life-time deficit and is disposed of. The products and components demand are based on these life bins. The ARTODTO system then remanufactures the products to meet the products demands, disassembles the components to meet the components demands and recycles the materials to meet the materials demands. Any additional requirement is met by outside procurement and any excess products, components and materials are stored for future use.

A product can be made available into different design alternatives depending on customer requirement. For example, in this paper, an example of ACs is considered which are available into two design alternatives windows AC and split AC. The main function and components used in both the alternatives are the same. But their dimensions and locations of use can be different. All these factors indirectly affect the disassembly process for product recovery, which in turn affects the recovery cost. Thus, to determine the ease of disassembly, a disassembly index is introduced which is defined as follows:

$$\text{Disassembly factor} = \frac{\text{No.of subassesmblies to separate}}{\text{Total number of subassemblies}} \quad (1)$$

An EOL product is disassembled when it contains one or more target components, or any broken or missing component which needs to replaced or any lower levels which consists of target, broken or missing components (Cheung et al. 2015).

METHODOLOGY

Figure 1 represents the proposed methodology. First, all the design alternatives that are received by the ARTODTO system are determined. Then the qualitative and quantitative criteria to evaluate these design alternatives are identified. If only the quantitative criteria were to be considered, only GP can be sufficient. But for qualitative criteria, AHP is necessary to calculate the target values and priorities of the design alternatives. Once the values are determined, a GP model is formulated and solved using a partitioning algorithm. In the partitioning algorithm, first the goals are prioritized by the decision maker. Then the first goal with highest priority is optimized to reach its target value. Next, the first goal with the achieved target value is added as a constraint while optimizing the second goal to reach its target value. This process is continued, until the last goal is optimized. The achieved values of all the goals at this stage become the solution to the problem.

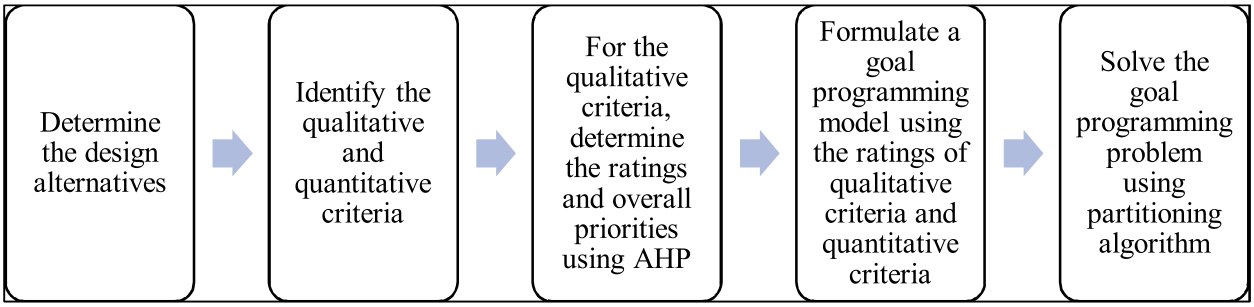

Figure 1: Proposed Methodology

NOMENCLATURE

Variable/ Parameter	Description
Q	Quality level;
$QDIS$	Total number of components disposed of;
SV	Stored value ($);
TP	Total profit ($);
TDC	Total disassembly cost ($);
$TDISPC$	Total disposal cost ($);
$THOLC$	Total holding cost ($);
$TOPC$	Total outside procurement cost ($);
$TRECC$	Total recycling cost ($);
$TREMC$	Total remanufacturing cost ($);
x_{ij}	1 if component j in EOL product i is functional;
y_{ij}	1 if component j in EOL product i is non-functional;
B	Set of remaining-life-bins (for components);
b, i, j, k, m, t	Running numbers;
a_i	1 if product i is disassembled;
b_i	1 if product i is remanufactured;
c_i	1 if product i is recycled;
d_i	1 if product i is disposed of;
s_i	1 if product i is stored;
$Scom_j$	1 if component j is stored;
$Smat_j$	1 if material of component j is stored;
ca_j	Assembly cost of component j ($);
cdc_j	Disposal cost of a component j ($);
chc_j	Holding cost of a component j ($);
chp_i	Holding cost of a product i ($);
chm_j	Holding cost of material of component j ($);
crc_j	Recycling cost of component j ($);
$Drem_{im}$	Demand for product i in remaining-life-bin m;
$Dcom_{jb}$	Demand for component j in remaining-life-bin b;
$Dmat_j$	Demand for recycling of material from component j;
$Vrem_{im}$	Resale value of product i from remaining-life-bin m;
$Vcom_{jb}$	Resale value of component j from remaining-life-bin b;
$Vmat_j$	Resale value of material from component j;

def_{ijb}	1 if components j in EOL product i is disassembled because of remaining life deficiency and placed in remaining-life-bin b during remanufacturing, zero otherwise;
dfc_{imj}	1 if component j of EOL product i is remaining-life-deficient for life bin m;
df_{tj}	Disassembly factor of component j in design alternative t;
cdd_j	Disassembly cost of complete destructive disassembly;
$cndd_j$	Disassembly cost of complete non-destructive disassembly;
fd_j	Number of non-functional components js that are disposed of;
fr_j	Number of non-functional components js that are recycled;
I	Set of EOL products on hand;
J	Set of components dealt with;
M	Alias for B (for products);
mis_{ij}	1 if component j is missing in EOL product i, zero otherwise;
b_{itm}	1 if EOL product i is remanufactured to a product of design t of bin m;
opc_{jb}	Number of components j from remaining-life-bin b procured from outside;
l_{jb}	Outside procurement cost of a component j for life-bin b ($);
phc_i	Holding cost of product i ($);
rep_{imtjb}	1 if a component j from life-bin b needs to be used to remanufacture EOL product i in order to make a product of design alternative t for life-bin m, zero otherwise;
wi	Number of components js in remaining-life-bin b that are recycled;
rp_{ij}	1 if component j in EOL product i is disassembled during remanufacturing, zero otherwise;
rv_j	Resale value of component j ($);
sc_{jb}	Number of components js in remaining-life-bin b that are stored;
spv_i	Stored value of product i ($);
x_{ijb}	1 if component j in EOL product i is disassembled and placed in remaining-life-bin b, zero otherwise;
β_{ij}	The highest life-bin that component j of EOL product i can be placed in;

ANALYTIC HIERARCHY PROCESS

The graphical representation of AHP is shown in figure 3. The overall goal of the process is to find the best design alternative between the two considered here. The criteria for the evaluation are dimensions and location of use. Each design alternative is evaluated for each criterion as shown in the figure. Two choose the best design alternative, pairwise comparisons are made and the pairwise comparison matrices are provided by the decision makers.

Pairwise Comparison Matrices:

Criterion

$$\begin{array}{c} \\ Dimensions \\ Location\ of\ Use \end{array} \begin{array}{c} \begin{array}{cc} Dimensions & Location\ of\ Use \end{array} \\ \begin{bmatrix} 1 & 3 \\ 1/3 & 1 \end{bmatrix} \end{array}$$

Dimensions

$$\begin{array}{c} \\ Windows\ AC \\ Split\ AC \end{array} \begin{array}{c} \begin{array}{cc} Windows\ AC & Split\ AC \end{array} \\ \begin{bmatrix} 1 & 4 \\ 1/4 & 1 \end{bmatrix} \end{array}$$

Location of use

$$\begin{array}{c} \\ Windows\ AC \\ Split\ AC \end{array} \begin{array}{c} \begin{array}{cc} Windows\ AC & Split\ AC \end{array} \\ \begin{bmatrix} 1 & 2 \\ 1/2 & 1 \end{bmatrix} \end{array}$$

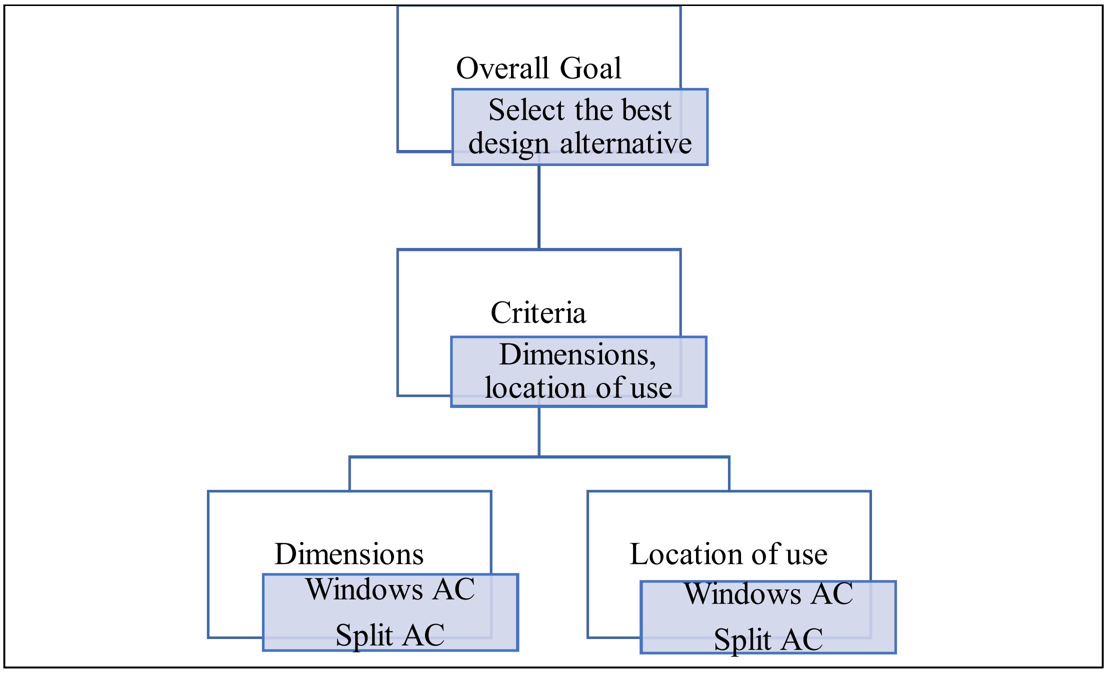

Figure 2: Graphical Representation of AHP

Using the provided pairwise comparison matrices, the target values for the criteria and overall priorities of the design alternatives are determined.

Table 1: Priorities of Criteria

Criterion		**Dimensions**		**Location of use**	
Dimensions	0.75	Windows AC	0.8	Windows AC	0.666
Location of use	0.25	Split AC	0.2	Split AC	0.333

Table 2: Overall Priorities of Design Alternatives

	Criterion	
	Dimensions	Location of use
Windows AC	0.8	0.666
Split AC	0.2	0.333

Overall priority for Windows AC = 0.75(0.8) + 0.25(0.666) = 0.7665
Overall priority for Split AC = 0.75(0.2) + 0.25(0.333) = 0.2333

The overall priorities of the design alternatives indicate that Windows AC is preferred over Split AC when they are evaluated using the two qualitative categories only. The priorities provided in table 1 are used as target values for the dimensions and location of use criteria in GP.

MATHEMATICAL MODEL FOR GOAL PROGRAMMING

The design alternatives are evaluated based on two qualitative (dimensions and location of use) and three quantitative criteria (total profit, quality level and number of disposed items). The qualitative criteria are first evaluated using AHP to get the target priorities. Then the qualitative criteria along with the quantitative criteria are evaluated using GP. In GP, criteria are referred to as goals.

The first goal of the system is to maximize the total profit. The aspiration level is set at TP*. It is expressed as follows:

$$\min \eta_1 \tag{2}$$

$$TP + \eta_1 - \rho_1 = TP^* \tag{3}$$

The second goal of the system is to maximize the quality level. The aspiration level is set at Q*. The mathematical expression is written as follows:

$$\text{Min } \eta_2 \tag{4}$$

$Q + \eta_2 - \rho_2 = Q^*$ (5)

The third goal of the system is to minimize the number of disposed items. The aspiration level is set at QDIS*. It is expressed as follows:

$\text{Min } \rho_3$ (6)

$QDIS + \eta_3 - \rho_3 = QDIS^*$ (7)

The fourth goal is to maximize the priority of dimensions. Since dimension criteria is more important than the location of use, it its priority is maximized. The aspiration level is set as DIM*.

$\min \eta_4$ (8)

$DIM + \eta_4 - \rho_4 = DIM^*$ (9)

The fifth goal is to minimize the priority of location of use. Since the location of use is less important than the dimensions, its priority is minimized. The aspiration level is set as LU*.

$\text{Min } \rho_5$ (10)

$LU + \eta_5 - \rho_5 = LU^*$ (11)

$TP = RSR + SV - TDC - TREMC - TRECC - TOPC - THOLC - TDISPC$ (12)

$RSR = \sum_{i\in I} Drem_{im} * Vrem_{im} + \sum_{j\in J} Dcom_{jb} * Vcom_{jb} + \sum_{j\in J} Dmat_j * Vmat_j$ (13)

$SV = \sum_i s_i * Vrem_i + \sum_j Scom_j * Vcom_j + \sum_j Smat_j * Vmat_j$ (14)

$TDC = \sum_{i\in I, j\in J} a_i \left[\left(y_{ij} * df_{tj} * cdd_j \right) + \left(x_{ij} * df_{tj} * cndd_j \right) \right]$ (15)

$TREMC = \sum_{i\in I, j\in J} rp_{ij} \left(x_{ij} \left(cndd_j + ca_j \right) \right) + \left(y_{ij} \left(cdd_j + ca_j \right) \right)$ (16)

$TRECC = \sum_{i\in I} c_i * \left(\left(df_{tj} * cdd_j \right) + crc_j \right) + \sum_{j\in J} fr_j * crc_j$ (17)

$TOPC = \sum_{j\in J, b\in B} opc_{jb} * l_{jb}$ (18)

$THOLC = \sum_{i\in I} s_i * chp_i + \sum_{j\in J} Scom_j * chc_j + \sum_{m\in M} Smat_j * chm_j$ (19)

$TDISPC = \sum_{i\in I} d_i * (cdd_j + cdc_j) + \sum_{j\in J} fd_j * cdc_j$ (20)

$Q = \sum_{i\in I, j\in J, b\in B} (x_{ijb}(\beta_{ij} - b) + rep_{imjb}(b - m)) + \sum_{i\in I, m\in M, j\in J} (x_{ij} b_{itm} - \sum_{b\in B} rep_{imjb})(\beta_{ij} - m)$ (21)

$QDIS = \sum_{i\in I, j\in J} d_i \left(x_{ij} + y_{ij} \right) + fd_j$ (22)

Constraints

$a_i + b_i + c_i + d + s_i = 1 \quad \forall I$ (23)

$\sum_{b\in B} x_{ijb} = a_i * x_{ij} \quad \forall i, j$ (24)

$\sum_{m\in M} b_{itm} \geq Drem_i \quad \forall i, t$ (25)

$\sum_{i\in I, j\in J} (a_i + b_i) * x_{ij} + opc_{jb} - Scom_j - fr_j - fd_j$ (26)

$\sum_{b\in B, m\in M | b\geq m} rep_{imjb} = b_{itm} \left(y_{ij} + mis_{ij} + dfc_{imj} \right) \quad \forall i, j, m$ (27)

$\sum_{b\in B, m\in M} rep_{imjb} \leq 1 \quad \forall i, j$ (28)

$\sum_{b\in B, m\in M | b<m} rep_{imjb} = 0 \quad \forall i, j$ (29)

$fr_j + fd_j = \sum_{i\in I} (c_i + d_i) * y_{ij} \quad \forall j$ (30)

DATA

This paper considers an ARTODTO system which receives EOL ACs with two design alternatives: split AC and windows AC. Both the design alternatives have the same function of providing cool air and they both share the following eight components: evaporator, control box, blower, air guide, motor, condenser, fan, and compressor. Table 3 through Table 7 provide the input data to solve the problem.

Table 3. Component reuse demand and component recycling demand

Component	Component Demand
Evaporator	30
Control Box	20
Blower	0
Air Guide	0
Motor	15
Condenser	13
Fan	15
Compressor	5

Table 4. Disassembly factors for Windows and Split ACs

	Windows AC	Split AC
Evaporator	0.17	0.20
Control Box	0.17	0.20
Blower	0.50	0.60
Air Guide	0.50	0.80
Motor	0.50	0.50
Condenser	0.17	0.50
Fan	0.50	1.00
Compressor	0.17	0.50

Table 5. Product demands, purchase cost and disposal cost

Product	Demand	Purchase Cost ($)	Disposal Cost ($)
Windows AC	10	100	2
Split AC	12	300	2

Table 6. Resale component price, material price, stored component value and holding cost.

Component	Resale Component Price ($)	Material Price ($)	Stored Component Value ($)	Holding Cost ($)
Evaporator	93.67	13.00	60.00	12.00
Control Box	15.00	2.20	20.00	6.00
Blower	8.37	5.00	6.00	3.00
Air Guide	11.25	5.00	8.00	3.00
Motor	54.25	2.20	50.00	10.00
Condenser	52.00	13.00	30.00	15.00
Fan	6.84	2.20	7.00	2.00
Compressor	104.81	13.00	45.00	10.00

Table 7. Component disposal cost, outside procurement cost and material disposal cost.

Component	Component Disposal Cost ($)	Outside Procurement Cost ($)	Material Disposal Cost ($)
Evaporator	0.60	187.34	0.40
Control Box	0.40	35.00	0.20
Blower	0.70	16.74	0.50
Air Guide	0.40	22.50	0.30
Motor	0.60	108.49	0.40
Condenser	0.70	103.99	0.40
Fan	0.60	13.68	0.40
Compressor	0.70	209.61	0.50

RESULTS

The model was solved using LINGO 16.0. The results are displayed in Table 8 and Table 9.

Table 8. Aspiration levels and values of goals

Goals	Aspiration Level	Step 1	Step 2	Step 3	Step 4	Step 5
Total profit	50,000	55,000	50,000	50,000	50,000	50,000
Quality Level	500	490	505	500	500	500
Number of disposed items	220	350	280	250	250	250
Dimensions	0.75	0.65	0.70	0.75	0.75	0.75
Location of use	0.25	0.35	0.31	0.28	0.25	0.25

Table 8 shows that the model achieved the aspiration levels for total profit, quality level, dimensions and priority of location of use but underachieved the goal of number of disposed items.

Table 9. Component details

Component	Disassembled	Remanufactured	Recycled	Stored	Disposed of
Windows AC	15	10	10	5	10
Split AC	25	15	0	5	5

Table 9 displays the details of components disassembled, remanufactured, recycled, stored and disposed of. The details illustrate that a greater number of split ACs were disassembled and remanufactured than the Windows ACs while more Windows ACs were recycled and disposed of than the Split ACs. Therefore, the results indicate the Split ACs is the more favorable design than the Windows AC. It can be noticed that when only the qualitative criteria were evaluated using AHP, Windows AC was a preferred design but when all the criteria and demands are considered, Split AC is found to be a better design.

CONCLUSION

Environmentally conscious manufacturing and product recovery have become popular due to increasing public awareness and the strict rules and regulations by government towards conserving the environment. Original Equipment Manufacturers (OEMs) are implementing product recovery techniques to comply with government rules, and also to earn profits. One of the key factors OEMs are considering in the End-Of-Life (EOL) product management is product design. This paper discussed the importance of product design on the EOL recovery processes, and indicated how the product design affects recovery costs.

In this paper, an Advanced-Remanufacturing-To-Order-Disassembly-To-Order system was proposed for the evaluation of design alternatives of EOL products. The products were remanufactured, disassembled, and recycled to meet the products, components, and materials demands. Various qualitative and quantitative criteria of design alternatives are evaluated using Analytic Hierarchy Process and Goal Programming to identify the most feasible product design. For the example of Air Conditioners considered in this paper, Split AC was a more favoured design than Windows AC.

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USE OF A ROBUST OPTIMIZATION IN DESIGNING A CLOSED-LOOP SUPPLY CHAIN NETWORK

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Abstract *– This paper addresses the design of a Closed Loop Supply Chain (CLSC) network where the impact of government regulations on carbon emission is considered. We consider multiple manufacturers, remanufacturers, warehouses and collection centers. For shipping products between the facilities in the CLSC, multiple transportation alternatives are evaluated where each one has a different carbon emission rate and load capacity. Due to the uncertainty in the demand of new products, remanufactured products and number of returned products, a scenario-based robust optimization model is proposed. In the proposed model, the design variables includes the number of facility centers to activate (viz., manufacturers, remanufacturers, collectors) while the control variables include the number of new and remanufactured products. Due to variability in demand, one-way substitution is considered where a new product may be substituted for the shortage in demand of a remanufactured product (downward substitution). For the carbon emission regulations, we consider the carbon tax policy, in which a financial penalty is incurred due to carbon emission during production and transportation activities.*

Keywords – Carbon Tax Policy, Closed Loop Supply Chain, Downward Substitution, Robust Optimization.

INTRODUCTION

The increased number of EOL products can pose a huge risk to the environment. According to Environmental Protection Agency (EPA), the United States generates 12 billion tons of industrial waste annually, over one third of which is hazardous. With this increasing rate, the number of landfill areas where non-hazardous waste can be buried is decreasing at an alarming rate. According to a report on climate changes done by the Intergovernmental Panel in 2014, global emissions of GHGs have increased by 10 billion metric tons within the period between 2000 and 2010, even with the increase in the policies that aim to prevent climate changes (Du et al., 2016).

For the purpose of reducing the burden on the environment, many industries were encouraged by government regulations to take back their EOL products, apply recovery processes and dispose them in an environmentally responsible manner (Ilgin & Gupta, 2010).

In an attempt to decrease industrial waste, a closed loop supply chain (CLSC) was formed. It is achieved by integrating forward and reverse supply chains. The forward supply chain (FSC) includes all activities, processes and operations that are involved in converting raw materials to a finished product and delivering it to the customer through a distributor, while the reverse supply chain (RSC) includes the activities and operations of collection and recovery of returned products. This begins with collection of returned products, which either go through disassembly and recovery, or disposal (depending on the condition of the returned product). Recovered products are finally delivered to the customer. The topic of CLSC strategically, tactically and operationally, has been widely studied (Ilgin, Gupta, & Battaïa 2010; Ilgin & Gupta, 2018).

The idea of CLSC has successfully shown its capability of achieving financial and environmental benefits. Today, many industries are employing the concept of CLSC in their practices, e.g. Xerox Corporation saved around $200 millions by remanufacturing copiers returned at the expiration of their lease contracts (Ferguson, 2009). However, designing CLSC network, which refers to planning a CLSC strategically, faces challenges when it comes to considering uncertainties of product demand, number of returned products and possibility of not satisfying customer demands. In this paper, we propose a model for designing a CLSC network that takes

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into account the uncertainties of new and remanufactured product demands, and number of products returned for various reasons. It also allows new products to substitute remanufactured products in case of not meeting customer demands (downward substitution) while the network is restricted by a carbon emission policy, which is carbon tax policy.

ROBUST OPTIMIZATION

Mulvey, Vanderbei and Zenios (1995) proposed a robust optimization (RO) approach that takes into account uncertain parameters. It is appropriate for problems with a high level of uncertainty, and where a decision cannot be changed once it is made. This approach includes two kinds of robustness, which are: solution robustness and model robustness. Solution robustness is when a solution is almost ideal for any realization of the scenario, while model robustness is when the solution is feasible for any realization of the scenario. Yu and Li (2000) proposed RO alternative formulation to overcome computational effort based on Li (1996) and the final formulation is represented below.

$$\text{MIN Z} = \sum_{sc} \rho_{sc}\ \xi_{sc} + \lambda \sum_{sc} \rho_{sc}[(\xi_{sc} - \sum_{sc'} \rho_{sc'}\ \xi_{sc'}) + 2\theta_{sc}] + \omega \sum_{sc} \rho_{sc}\ \delta_{sc} \quad (1)$$

s.t

$$Ax = b \quad (2)$$

$$B_{sc}x + C_{sc}y_{sc} + \delta_{sc} = e_{sc} \quad (3)$$

$$\xi_{sc} - \textstyle\sum_{sc} \rho_{sc}\ \xi_{sc} + \theta_{sc} \geq 0 \quad (4)$$

$$x, y_{sc}, \delta_{sc} \geq 0 \quad (5)$$

Where x represents the vector of design variables and y shows that of control variables. SC represents a variety of scenarios ($SC \in \Omega$), and there is a probability for every scenario ρ_{ε} ($\sum \rho_{\varepsilon} = 1$). When $\xi_{sc} - \sum_{sc} \rho_{sc}\ \xi_{sc} \geq 0$, then $\theta_{sc} = 0$ and $Z = \sum_{sc} \rho_{sc}\ \xi_{sc} + \lambda \sum_{sc} \rho_{sc}[(\xi_{sc} - \sum_{sc'} \rho_{sc'}\ \xi_{sc'})]$, otherwise if $\xi_{sc} - \sum_{sc} \rho_{sc}\ \xi_{sc} \leq 0$, then $\theta_{sc} = \sum_{sc} \rho_{sc}\ \xi_{sc} - \xi_{sc}$ and $Z = \sum_{sc} \rho_{sc}\ \xi_{sc} + \lambda \sum_{sc} \rho_{sc}[(\ \sum_{sc'} \rho_{sc'}\ \xi_{sc'} - \xi_{sc})]$. The first two parts of the (1) represents the mean and variance of solution (solution robustness) and the last part represents infeasibility penalty (model robustness).

PROBLEM DESCRIPTION AND ASSUMPTIONS

CLSC involves raw material suppliers, manufacturing, remanufacturing, distribution, collection and disposal centers in addition to multiple market locations. In the forward flow, the manufacturing centers produce new products using raw materials delivered from suppliers and remanufacture the slightly damaged returned products. Finished products are shipped to different market locations through the distribution centers. In the reverse flow, the EOL products, which are returned to market locations, are shipped to the collection centers. Due to the different conditions of the returned products, different quality levels are considered. At the collection centers, products are inspected. Slightly damaged returned products are shipped to manufacturers to be remanufactured while highly damaged returned products are shipped to specialized remanufacturing centers. The rest of returned products are disposed of. At the remanufacturing centers, the products are disassembled, cleaned, repaired/upgraded and shipped to market through distribution centers.

Environmental impact represented by carbon tax policy is taken into consideration; production activities in each manufacturing and remanufacturing facility are associated with carbon emission factors and penalized financially. Transportation contributes to a larger portion of carbon emitted and therefore, several modes of transportation with different carbon emission factors and limited capacity are considered in this paper. This will also provide a close form to an actual supply chain.

Due to price differences between new and remanufactured products and the federal government regulations that require differentiating these two products by labeling remanufactured products (Ashika et al., 2017) in addition to the customer's viewpoint, two different demand segments are assumed, in which a customer either demands a new product, a remanufactured product or both products. The demand of each type of product is assumed as uncertainty parameter since demand fluctuates seasonally, customer preferences changes and market competition is very high. Because of the high level of uncertainties associated with RSC activities due to unknown time to return products, quantity and quality of products returned (Gupta, 2013), we consider the number of returned products as an uncertainty parameter. We allow one-way downward substitution in the proposed model with a strict substitution policy, in which the new product fulfills the demand of the remanufactured product whenever it is not possible to satisfy the customer demand of remanufactured product. There are different reasons why product substitution is useful, that is, to maximize the service level and to reduce inventory level, setup cost and time (Lang 2010).

In order to formulate the above problem, we use robust optimization approach in which the uncertainty parameters are the new and the remanufactured product demand in addition to the number of returned products. The goal is to minimize the total system cost, where carbon tax policy is considered, by determining the number and location of each facility type, determining the production quantities, transportation quantities, purchasing raw material quantities and their supplier, quantity of new products to substitute remanufactured products and type of transportation mode to be used between the facilities.

The following assumptions are considered:

1. Raw material suppliers, manufacturing, remanufacturing, distribution, collection centers have capacity restriction and known number and locations.
2. Predefined market number and locations.
3. Production process of both new and remanufactured products could produce defective products.
4. The cost of opening facilities depends on the capacity and location of the facility.
5. Cost of purchasing raw material includes the cost to deliver raw materials from suppliers to manufacturing facility.
6. Cost of remanufacturing product includes disassembly, and upgrade/repair cost.
7. Returned products are classified into different quality levels.
8. Cost of remanufacturing products depends on the quality level of the returned products; products returned with major defects cost more to remanufacture.
9. At any market location, we assume it is acceptable to substitute remanufactured products and take new products instead.
10. When the demand of remanufactured product is not satisfied by a remanufactured product or substituted by a new product, shortage occurs with high cost.
11. Carbon emissions are due to production processes at manufacturing and remanufacturing facilities and for shipping products between facilities in the CLSC network based on type of transportation mode used in logistic activities (Benjaafar et al., 2013; Fahimnia et al., 2013).

MODEL NOTATIONS AND FORMULATION

Notations

Sets:

S	Set of raw material/component suppliers {1,2,3 … s}.
M	Set of candidate locations for manufacturing centers {1, 2, 3,….m}.
R	Set of candidate locations for remanufacturing centers {1, 2, 3,….r}.
W	Set of candidate locations for warehouse centers {1, 2, 3,….w}.
C	Set of customer/market locations {1, 2, 3, ….c}.
H	Set of candidate locations for collection centers {1, 2, 3,….h}.
MOD	Set of candidate locations for transportation modes {1, 2, 3, ….mod}.
K	Quality level of return product {1, 2, 3, ….k}.
SC	Set of scenarios {1,2,3, …..sc}.

General Parameters:

$DMNP_c^{sc}$	Demand for new products by the market location c under scenario sc.
$DMRP_c^{sc}$	Demand for remanufactured products by the market location c under scenario sc
R_c^{sc}	EOL products to the market location c under scenario sc.
B_k	Fraction of quality level k of return product.
CO	Number of component required to produce a unit of product.
TAX	Amount of tax paid per unit emitted.
λ	Weighing factor for solution robustness.
ρ_{sc}	Probability of scenario sc.
ω	Weighting factor to measure model robustness.

Fixed Costs:

FM_m	Fixed cost of constructing the manufacturing center in location m.
FR_r	Fixed cost of constructing the remanufacturing center in location r.
FW_w	Fixed cost of constructing the warehouse center in location w.
FH_h	Fixed cost of constructing the collection center in location h.

Unit Costs:

PC_m	Unit production cost of new product at the manufacturing center in location m.
$RCC_{k,m}$	Unit remanufacturing cost of EOL product of quality level k at the manufacturing center in location m.
INS_h	Unit inspection and sorting cost of EOL product at the collection center in location h.
$P_{s,m}$	Component purchasing cost from supplier s by the manufacturing center in location m.
$CRMSUB$	Cost of substituting new product by remanufactured product.

Shipping Costs:

$TRMW_{m,w,mod}$	Cost of shipping a unit of product from the manufacturing center in location m to the warehouse center in location w using mod transportation mode.
$TRRW_{r,w,mod}$	Cost of shipping a unit of product from the remanufacturing center in location r to the warehouse center in location w using mod transportation mode.
$TRWC_{w,c,mod}$	Cost of shipping a unit of product from the warehouse center in location w to the mark location c using mod transportation mode.
$TRCH_{c,h,mod}$	Cost of shipping a unit of EOL product from the market location c to the collection cent location h using mod transportation mode.
$TRHM_{h,m,mod}$	Cost of shipping a unit of EOL product from the collection center in location h to the manufacturing center in location m using mod transportation mode.
$TRHR_{h,r,mod}$	Cost of shipping a unit of EOL product from the collection center in location h to the remanufacturing center in location r using mod transportation mode.

Capacity Parameters:

$CAPM_m$	Production capacity at the manufacturing center in location m, in units.
$CAPR_r$	Remanufacturing capacity at the remanufacturing center in location r, in units.
$CAPW_w$	Capacity of the warehouse center in location w, in units.
$CAPH_h$	Capacity of the collection center in location h, in units.
$CAPS_s$	Capacity of the supplier s, in units.

Load Capacities of Transportation Mode:

$TMMIN_{mod}$	Min. load capacity of transportation mode m, in units.
$TMMAX_{mod}$	Max. load capacity of transportation mode m, in units.

Carbon Emission Parameters:

EP_m	Carbon emission in kg due to production a unit of product at manufacturing center in location m.
ER_r	Carbon emission in kg due to remanufacturing a unit of product at remanufacturing center in location r.
$ETMW_{m,w,mod}$	Carbon emission in kg due to shipping a unit of product from the manufacturing center in location m to the warehouse center in location w using mod transportation mode.
$ETRW_{r,w,mod}$	Carbon emission in kg due to shipping a unit of product from the remanufacturing center in location r to the warehouse in location w using mod transportation mode.
$ETWC_{w,c,mod}$	Carbon emission in kg due to shipping a unit of product from the warehouse in location w to the market location c using mod transportation mode.

$ETCH_{c,h,mod}$	Carbon emission in kg due to shipping a unit of EOL product from the market location c to the collection center in location h using mod transportation mode.
$ETHR_{h,r,mod}$	Carbon emission in kg due to shipping a unit of EOL product from the collection center in location h to the remanufacturing center in location r using mod transportation mode.
$ETHM_{h,m,mod}$	Carbon emission in kg due to shipping a unit of EOL product from the collection center in location h to the manufacturing center in location m using mod transportation mode.

Design Variables:

YM_m	1 if the manufacturing center is constructed in location m, 0 otherwise.
YR_r	1 if the remanufacturing center is constructed in location r, 0 otherwise
YW_w	1 if the warehouse is constructed in location w, 0 otherwise.
YC_h	1 if the collection center is constructed in location h, 0 otherwise.
$YTMW_{m,w,mod}$	1 if mod transportation mode is used between the manufacturing center in location m and the warehouse in location w, 0 otherwise.
$YTRW_{r,w,mod}$	1 if mod transportation mode is used between the remanufacturing center in location r and the warehouse center in location w, 0 otherwise.
$YTWC_{w,c,mod}$	1 if mod transportation mode is used between the warehouse center in location w and the market location c, 0 otherwise.
$YTCH_{c,h,mod}$	1 if mod transportation mode is used between the market location c and the collection center in location h, 0 otherwise.
$YTHM_{h,m,mod}$	1 if mod transportation mode is used between the collection center in location h and the manufacturing center in location m, 0 otherwise.
$YTHM_{h,m,mod}$	1 if mod transportation mode is used between the collection center in location h and the remanufacturing center in location r, 0 otherwise.

Control Variables:

XNP_m^{sc}	Quantity of new products produced in the manufacturing center in location m under scenario sc.
$XRPM_m^{sc}$	Quantity of remanufactured products produced in the manufacturing center in location m under scenario sc
$XRPR_m^{sc}$	Quantity of remanufactured products produced in the remanufacturing center in location r under scenario sc
$XQSM_{s,m}^{sc}$	Quantity of components shipped from the supplier s to the manufacturing center in location m using mod transportation under scenario sc.
$XQMW_{m,w,mod}^{sc}$	Quantity of new products shipped from the manufacturing center in location m to the distribution center in location w under scenario sc
$XRQRW_{r,w,mod}^{sc}$	Quantity of remanufactured products shipped from the remanufacturing center in location r to the distribution center in location w under scenario sc.
$XQWC_{w,c,mod}^{sc}$	Quantity of new products shipped from the distribution center in location w to the market location c using mod transportation mode under scenario sc.
$XRQWC_{w,c,mod}^{sc}$	Quantity of remanufactured products shipped from the distribution center in location w to the market location c using mod transportation mode under scenario sc.
$XRQCH_{k,c,h,mod}^{sc}$	Quantity of EOL products with quality level k shipped from the market location c to the collection center in location h using mod transportation mode under scenario sc.
$XRQHR_{k,h,r,mod}^{sc}$	Quantity of EOL products with quality level k shipped from the collection center in location h to the remanufacturing center in location r using mod transportation mode under scenario sc.

$XRQHM_{k,h,m,mod}^{sc}$	Quantity of EOL products with quality level k shipped from the collection center in location h to the manufacturing center in location m using mod transportation mode under scenario sc.
$XMSUB_{w,c,mod}^{sc}$	Quantity of new product used to substitute remanufactured products shipped from the distribution center in location w to the market location c using mod transportation mode under scenario sc.
$DISP_{k,h}^{sc}$	Quantity of EOL products with quality level k disposed of from the collection center in location h under scenario sc.
δNP_{c}^{sc}	Amount of not meeting the market locations c demanding new products under scenario sc.
δRP_{c}^{sc}	Amount of not meeting the market locations c demanding remanufactured products under scenario sc.
θ_{sc}	Deviation for violation of the mean under scenario sc.

Problem Formulation

Objective function

MIN $Z = \sum_{sc}\rho_{sc}\ \xi_{sc} + \lambda\sum_{sc}\rho_{sc}[(\xi_{sc} - \sum_{sc'}\rho_{sc'}\ \xi_{sc'}) + 2\theta_{sc}] + \omega\sum_{sc}\rho_{sc}\sum_{c}(\delta NP_{c}^{sc} + \delta RP_{c}^{sc})$ (6)

Where,

$$\xi_{sc} = TC_{sc} + TAX * ENVC_{sc} \quad \forall sc \quad (7)$$

$$TC_{sc} = TFC + TRM_{sc} + TPC_{sc} + TTC_{sc} + TCC_{sc} + TCS_{sc} \quad \forall sc \quad (8)$$

$$TFC = \sum_{\mathrm{m}}(\mathrm{FM_m} * \mathrm{YM_m}) + \sum_{\mathrm{r}}(\mathrm{FR_r} * \mathrm{YR_r}) + \sum_{\mathrm{w}}(\mathrm{FW_w} * \mathrm{YW_w}) + \sum_{\mathrm{H}}(\mathrm{Fh_H} * \mathrm{Yh_{hw}}) \quad (9)$$

$$TRM_{sc} = \sum_{s}\sum_{m} P_{s,m} * XQSM_{s,m}^{sc} \quad \forall sc \quad (10)$$

$$TPC_{sc} = \sum_{m} PC_{m} * XNP_{m}^{sc} + \sum_{k}\sum_{h}\sum_{m}\sum_{mod} RCC_{k,m} * XRQHM_{k,h,m,mod}^{sc} + \sum_{k}\sum_{h}\sum_{r}\sum_{mod} RCK_{k,r} * XRQHR_{k,h,r,mod}^{sc} \quad \forall sc \quad (11)$$

$$TCC_{sc} = \sum_{k}\sum_{c}\sum_{h}\sum_{mod} INS_{h} * XRQCH_{k,c,h,mod}^{sc} \quad \forall sc \quad (12)$$

$$TTC_{sc} = \sum_{m}\sum_{w}\sum_{mod} TRMW_{m,w,mod} * (XQMW_{m,w,mod}^{sc} + XRQRW_{m,w,mod}^{sc}) + \sum_{r}\sum_{w}\sum_{mod} TRRW_{r,w,mod} * XRQRW_{r,w,mod}^{sc} + \sum_{w}\sum_{c}\sum_{mod} TRWC_{w,c,mod} * (XQWC_{w,c,mod}^{sc} + XRQWC_{w,c,mod}^{sc} + XMSUB_{w,c,mod}^{s}) + \sum_{k}\sum_{c}\sum_{h}\sum_{mod} TRCH_{c,h,mod} * XRQCH_{k,c,h,mod}^{sc} + \sum_{k}\sum_{h}\sum_{m}\sum_{mod} TRHM_{h,m,mod} * XRQHM_{k,h,m,mod}^{sc} + \sum_{k}\sum_{h}\sum_{r}\sum_{mod} TRHR_{h,r,mod} * XRQHR_{k,h,r,mod}^{sc} \quad \forall sc \quad (13)$$

$$TCS_{sc} = \sum_{w}\sum_{c}\sum_{mod} CRMSUB * XMSUB_{w,c,mod}^{sc} \quad \forall sc \quad (14)$$

$$ENVC_{sc} = \sum_{m} EP_{m} * YM_{m} + \sum_{r} ER_{r} * YR_{r} + \sum_{m}\sum_{w}\sum_{mod} ETMW_{m,w,mod} * (XQMW_{m,w,mod}^{sc} + XRQRW_{m,w,mod}^{sc}) + \sum_{r}\sum_{w}\sum_{mod} ETRW_{r,w,mod} * XRQRW_{r,w,mod}^{sc} + \sum_{w}\sum_{c}\sum_{mod} ETWC_{w,c,mod} * (XQWC_{w,c,mod}^{sc} + XRQWC_{w,c,mod}^{sc} + XMSUB_{w,c,mod}^{s}) + \sum_{k}\sum_{c}\sum_{h}\sum_{mod} ETCH_{c,h,mod} * XRQCH_{k,c,h,mod}^{sc} + \sum_{k}\sum_{h}\sum_{m}\sum_{mod} ETHM_{h,m,mod} * XRQHM_{k,h,m,mod}^{sc} + \quad (15)$$

$\sum_k \sum_h \sum_r \sum_{mod} ETHR_{h,r,mod} * XRQHR^{sc}_{k,h,r,mod}$
$\forall sc$

Supplying raw material constraint

$\sum_s XQSM^{sc}_{s,m} = CO * XNP^{sc}_m \quad \forall m, sc \quad (16)$

Production constraints

$XNP^{sc}_m \geq \sum_w \sum_{mod} XQMW^{sc}_{m,w,mod} \quad \forall m, sc \quad (17)$

$XRPM^{sc}_m \geq \sum_w \sum_{mod} XRQMW^{sc}_{m,w,mod} \quad \forall m, sc \quad (18)$

$XRPR^{sc}_r \geq \sum_w \sum_{mod} XRQRW^{sc}_{r,w,mod} \quad \forall r, sc \quad (19)$

Balance constraints

$XRPM^{sc}_m = \sum_k \sum_h \sum_{mod} XRQHM^{sc}_{k,h,m,mod} \quad \forall m, sc \quad (20)$

$XRPR^{sc}_r = \sum_k \sum_h \sum_{mod} XRQHR^{sc}_{k,h,r,mod} \quad \forall r, sc \quad (21)$

$\sum_m \sum_{mod} XQMW^{sc}_{m,w,mod} = \sum_c \sum_{mod} XQWC^{sc}_{w,c,mod} + XMSUB^{sc}_{w,c,mod} \quad \forall w, sc \quad (22)$

$\sum_m \sum_{mod} XRQMW^{sc}_{m,w,mod} + \sum_r \sum_{mod} XRQRW^{sc}_{r,w,mod} = \sum_c \sum_{mod} XRQWC^{sc}_{w,c,mod} \quad \forall w, sc \quad (23)$

$\sum_m \sum_{mod} XRQMW^{sc}_{m,w,mod} + \sum_r \sum_{mod} XRQRW^{sc}_{r,w,mod} = \sum_c \sum_{mod} XRQWC^{sc}_{w,c,mod} \quad \forall w, sc \quad (23)$

$\sum_h \sum_{mod} XRQCH^{sc}_{c,h,mod} = kB_k * RE^{sc}_c \quad \forall c, sc \quad (24)$

$\sum_m \sum_{mod} XRQHM^{sc}_{k,h,m,mod} + \sum_r \sum_{mod} XRQHR^{sc}_{k,h,r,mod} +$
$DISP^{sc}_{k,h} = \sum_c \sum_{mod} XRQCH^{sc}_{c,h,mod} \quad \forall k, h, sc \quad (25)$

Control constraints

$\sum_w \sum_{mod} XQWC^{sc}_{w,c,mod} + \delta NP^{sc}_c = DMNP^{sc}_c \quad \forall c, sc \quad (26)$

$\sum_w \sum_{mod} XRQWC^{sc}_{w,c,mod} + \sum_w \sum_{mod} XMSUB^{sc}_{w,c,mod} + \delta RP^{sc}_c = DMRP^{sc}_c \quad \forall c, sc \quad (27)$

Transportation constraints

$YTHM_{h,m,mod} \leq YM_m \quad \forall h, m, mod \quad (28)$

$YTRW_{r,w,mod} \leq YR_r \quad \forall r, w, mod \quad (29)$

$YTHR_{.h,r,mod} \leq YR_r \quad \forall h, r, mod \quad (30)$

$YTWC_{w,c,mod} \leq YW_w \quad \forall w, c, mod \quad (31)$

$YTMW_{m,w,mod} \leq YW_w \quad \forall m, w, mod \quad (32)$

$YTRW_{r,w,mod} \leq YW_w \quad \forall m, w, mod \quad (33)$

$YTCH_{c,h,mod} \leq YC_h \quad \forall h, mod \quad (34)$

$YTHM_{h,m,mod} \leq YC_h \quad \forall h, m, mod \quad (35)$

$YTHR_{h,r,mod} \leq YC_h \quad \forall h, r, mod \quad (36)$

$XQMW^{sc}_{m,w,mod} + XRQMW^{sc}_{m,w,mod} \geq TMMIN_{mod} * YTMW_{m,w,mod} \quad \forall m, w, mod, sc \quad (37)$

$XQMW^{sc}_{m,w,mod} + XRQMW^{sc}_{m,w,mod} \leq TMMAX_{mod} * YTMW_{m,w,mod} \quad \forall m, w, mod, sc \quad (38)$

$XRQRW^{sc}_{r,w,mod} \geq TMMIN_{mod} * YTRW_{r,w,mod} \quad \forall r, w, mod, sc \quad (39)$

$XRQRW^{sc}_{r,w,mod} \leq TMMAX_{mod} * YTRW_{r,w,mod} \quad \forall r, w, mod, sc \quad (39)$

$XQWC^{sc}_{w,c,mod} + XRQWC^{sc}_{w,c,mod} + XMSUB^{sc}_{w,c,mod} \geq TMMIN_{mod} * YTWC_{w,c,mod} \quad \forall w, c, mod, sc \quad (40)$

$XQWC^{sc}_{w,c,mod} + XRQWC^{sc}_{w,c,mod} + XMSUB^{sc}_{w,c,mod} \leq TMMAX_{mod} * YTWC_{w,c,mod} \quad \forall w, c, mod, sc \quad (41)$

$\sum_k XRQCH^{sc}_{k,c,h,mod} \geq TMMIN_{mod} * YTCH_{c,h,mod} \quad \forall c, h, mod \quad (42)$

$\sum_k XRQCH^{sc}_{k,c,h,mod} \leq TMMAX_{mod} * YTCH_{c,h,mod} \quad \forall c, h, mod, sc \quad (43)$

$\sum_k XRQCH^{sc}_{k,c,h,mod} \geq TMMIN_{mod} * YTCH_{c,h,mod} \quad \forall c, h, mod, sc \quad (44)$

$\sum_k XRQCH^{sc}_{k,c,h,mod} \leq TMMAX_{mod} * YTCH_{c,h,mod} \quad \forall c, h, mod, sc \quad (45)$

$\sum_k XRQHM^{sc}_{k,h,m,mod} \geq TMMIN_{mod} * YTHM_{h,m,mod} \quad \forall h, m, mod, sc \quad (46)$

$\sum_k XRQHM_{k,h,m,mod}^{sc} \leq TMMAX_{mod} * YTHM_{h,m,mod}$ $\forall h, m, mod, sc$ (47)

$\sum_k XRQHR_{k,h,r,mod}^{sc} \geq TMMIN_{mod} * YTHR_{h,r,mod}$ $\forall h, r, mod, sc$ (48)

$\sum_k XRQHM_{k,h,r,mod}^{sc} \leq TMMAX_{mod} * YTHR_{h,r,mod}$ $\forall h, r, mod, sc$ (49)

Capacity constraints

$\sum_m XQSM_{s,m}^{sc} \leq CAPS_s$ $\forall s, sc$ (50)

$XNP_m^{sc} + XRPM_m^{sc} \leq CAPM_m * YM_m$ $\forall m, sc$ (51)

$XRPR_r^{sc} \leq CAPR_r * YR_r$ $\forall r, sc$ (52)

$\sum_k \sum_c \sum_{mod} XRQCH_{k,c,h,mod}^{sc} < CAPH_h * YC_h$ $\forall h, sc$ (53)

Auxiliary linearization constraint

$\xi_{sc} - \sum_{sc} \rho_{sc}\ \xi_{sc} + \theta_{sc} \geq 0$ $\forall sc$ (54)

Binary and non-negativity constraints

$YM_m, YR_r, YW_w, YC_h, YTMW_{m,w,mod}, YTHM_{h,m,mod}, YTRW_{r,w,mod}, YTHR_{h,r,mod}, YTWC_{w,c,mod}, YTCH_{c,h,mod} = \{0,1\}$ (55)

$XNP_m^{sc}, XRPM_m^{sc}, XRPR_m^{sc}, XQSM_{s,m}^{sc}, XQMW_{m,w,mod}^{sc}, XRQRW_{r,w,mod}^{sc}, XQWC_{w,c,mod}^{sc}, XRQWC_{w,c,mod}^{sc}, XRQCH_{k,c,h,mod}^{sc}, XRQHR_{k,h,r,mod}^{sc}, XRQHR_{k,h,r,mod}^{sc}, XRQHM_{k,h,m,mod}^{sc}, XMSUB_{w,c,mod}^{sc}, DISP_{k,h}^{sc}, \geq 0$ (56)

The first and second parts of Eq. (6) are intended to measure the mean value and variance of the objective function, respectively. The third part of Eq. (6) measures the model robustness with respect to infeasibility associated with control constraint in Eq. (26) and Eq. (27) under scenario s. The objective function given by Eq. (7) comprises the sum of economic costs and tax penalty times the total environmental costs. Eq. (8) to Eq. (14) give the components of the economic cost which are: the cost of opening a facility in the CLSC, the cost of purchasing raw materials, the cost of producing new and remanufactured products, the cost of processing products in the collection centers, the cost of transportation and the cost of substituting products. Eq. (15) measures the environmental costs that are incurred upon carbon emission, transportation and disposal. The problem constraints are represented in Eq. (16) – Eq. (56). Eq. (16) represents balance constraints for the raw material suppliers. Production constraints of new products and remanufacturing returned products, according to their quality level, are given in Eq. (17) – Eq. (19). Eq. (20) and Eq. (23) are flow balance constraints at manufacturing, remanufacturing and warehouse centers. Eq. (24) ensures that returned products are collected and consists of different quality levels. Eq. (25) is the flow balance constraint for the returned products where they are either sent, based on their quality level, to manufacturing centers or remanufacturing centers. The rest of the returned products are disposed of. The control constraints are represented in Eq. (26) and Eq. (27) where violation of these constraints is penalized in Eq. (6). In Eq. (26), the new products flow from warehouses must be equal to the market demand of new products. On the other hand, Eq. (27) is to ensure the market demand of remanufactured products is either satisfied by remanufactured products or new products in case of shortage. Eq. (28) – Eq. (36) are transportation constraints, which allows shipping products between open facilities only, using any transportation mode. Eq. (37) – Eq. (49) ensure shipping products using any transportation mode must be within certain capacity limitation. Eq. (50) – Eq. (53) are capacity constraints. Eq. (54) is an auxiliary constraint for linearization the variance part defined in Eq. (6). Finally, binary and non-negativity restrictions on variables are shown in Eq. (55) and Eq. (56), respectively.

NUMERICAL EXAMPLE

We consider a hypothetical CLSC network that consist of manufacturing centers = 3, remanufacturing centers = 3, warehouse locations = 3, collection centers = 3 and market locations = 10 which include markets that demand only new product, only remanufactured product and demand new and remanufactured product. Carbon emission per one unit produced in each manufacturing and remanufacturing center is considered due to production activities. Table 1,2,3 and 4 summarized some of the data considered in the model. 3 road transportation modes are available to ship products between facilities in the CLSC where each mode has a specified size, carbon emission and transportation cost (Mohammed et al., 2017). A flat substitution cost = \$10 is penalized for each product substituted. The tax of carbon emission is \$40/ton according to US Environmental Protection Agency (2015). The numbers of EOL products returned, demand of new and remanufactured products are considered uncertain. They are represented according to low returns/demand scenario, medium returns/demand scenario and high returns/demand scenario with probability of .2, .5 and .3 respectively.

According to the limited space of the paper, the results will be shown only for the case when λ = 1 and ω = 4000. It is assumed that two components are required to produce one unit of product CO = 2. 50% of returned products have minor defects, 30% have medium defects, 10% have high defects and 10% have serious defects.

Table1: General data

Parameters	Values
FM_m	Uniform (500000, 1500000)
FR_r	Uniform (500000, 800000)
FW_w	Uniform (400000, 500000)
FH_h	Uniform (400000, 450000)
$CAPM_m$	Uniform (1500, 2500)
$CAPR_r$	Uniform (1100, 1500)
$CAPW_w$	Uniform (3000, 3500)
$CAPH_h$	Uniform (1000, 1500)
$CAPS_s$	Uniform (6000,7000)
EP_m	Uniform (2.1,2.3)
ER_r	Uniform (1.6, 2)

Table2: Uncertainty parameters data

Scenario	probability	DMNP
Low	.2	Uniform (350, 450)
Medium	.5	Uniform (450, 550)
High	.3	Uniform (550, 600)

Table3: Transportation mode capacities

Transportation mode	Minimum capacity	Maximum capacity
Heavy duty truck	100	14000
Mid-size truck	100	10000
Light truck	100	5000

Table4: Transportation mode cost and carbon emission

Transportation mode	Trans. Cost ($/ton-km)	Carbon emission (kg/ton-km)
Heavy duty truck	0.125	0.297
Mid-size truck	0.118	0.0252
Light truck	0.11	0.048

RESULTS AND CONCLUSION

After running the model using the above data, the results of scenario 1 is 3,938,513, scenario 2 is 3,974,500 and scenario 3 is 4,039,372. The robust solution for this problem is 3,986,764. The results show that the first and second suppliers are selected to supply the components, the first and third manufacturing facilities must be opened, the third remanufacturing center must be opened, the second and the third warehouses must be opened and the first and third collection centers must be opened. In order to ship the products between the facilities in the CLSC network, the mid-size transportation mode truck is selected. It is noticed that in scenario 1, a number of 240 products are substituted while in scenario 2, a number of 137 products are substituted. No substitution is observed in scenario 3, which is due to a high number of products returned compared to the demand of remanufactured products. It is worth to mention that, in this model, product substitution is associated with the number of products returned. This paper presented the design of CLSC network when downward product substitution is allowed under the control of carbon tax policy. The proposed model shows a relationship between the number of returned products and product substitution. For future study, different optimization techniques under uncertainty can be implemented to solve the problem stated in this paper. This paper considered carbon tax policy. However, using other carbon emission policies would be interesting. Another possibility is to implement the proposed model on a real case study. In case of solving this problem on a large size scale, using meta-heuristic algorithms would be very useful.

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SOCIETAL MARKETING APPROACH IN LOGISTIC FIRMS: ANALYZING CORPORATE SOCIAL RESPONSIBILITY INITIATIVES OF LOGISTIC FIRMS IN TURKEY

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Abstract – *Managers are increasingly adopting societal marketing approach and so corporate social responsibility today. The main reason underlying this tendency is to contribute to society as a whole, as well as gaining profits. When the potential damages that will be given to environment and society by logistics operations are considered, logistics managers are also regarded as the ones who have to take social responsibility approach into account. However, to what extent Turkish logistics companies engage in corporate social responsibility activities have not been examined in detail yet. Thus, to provide insight about the current conditions of logistics companies in Turkey in terms of adopting corporate social responsibility initiatives, this study aims to depict the extent and nature of corporate social responsibility activities of Turkish logistics companies. The findings of the study present that there is a positive relationship between the extent of the corporate social responsibility activities of the logistics companies and their brand awareness.*

Keywords – *Corporate Social Responsibility, Logistic Firms, Societal Marketing Approach*

INTRODUCTION

Under holistic marketing approach, understanding not only financial returns but also nonfinancial returns of marketing activities to business and society is a must (Kotler and Keller, 2012). Thus, companies have to design their marketing activities more carefully than ever because their effects may extend beyond the company and the customers to society as whole. If marketing activities are designed and managed effectively, they can turn into a way to differentiate companies from their competitors, build strong brand equity, and attain notable sales. Moreover, well-conducted marketing activities can contribute to the corporate image and reputation, brand value and marketing performance, positively.

In that case, while companies are competing with each other to satisfy the needs and wants of their target consumers superiorly, they have to consider the long-term well-being of them and society, as well. So, they have to be aware of and forecast the ethical, legal, environmental and social extent of their activities. This understanding makes more companies adopt societal marketing approach today (Lambin, 1997).

Logistics firms are also included among these firms who care societal marketing approach. Since the beginning of 1970s, there has been an increasing interest regarding societal considerations in transportation and logistics decision making in all over the world (Poist, 1989). In logistics literature, there are also several researches which examined the corporate social responsibility activities of logistics companies (e.g., Carter and Jennings, 2002; 2004). However, to what extent logistics firms consider societal issues in their activities in Turkey has not been discussed well, up to now. To fill this gap, this study mainly aims to examine the corporate societal marketing initiatives of primary Turkish logistics firms.

Since, this study is going to be the first study in this context, and so the problem has not been examined more clearly, it is designed as an exploratory research. The findings of the study contribute to both logistics literature and marketing practice by showing a relationship between corporate social responsibility initiatives and brand awareness. In addition, it is expected that this study help guide to further academic research in the area of corporate social marketing approach in logistics

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LITERATURE REVIEW

Societal Marketing Approach

Marketing management is based on designing marketing strategies to build long-term profitable relationship with target customers. To create effective marketing strategies, determining on the philosophy which guides these strategies is critical. The philosophy also determines to what extent the importance should be given to the interests of customers, the organization, and the society at all (Kotler and Armstrong, 2012). There are alternative philosophies which are used to design and conduct marketing strategies. However, among these strategies, especially the societal marketing concept is the one which combines the interests of all parties: the customers, the company, and the society (Freeman, 1984).

Societal marketing concept seeks to create a balance between short-run and long-term welfare of customers through effective marketing strategies. The main understanding behind the societal marketing is both to deliver superior customer value, consider the requirements of the business, and maintain and improve customers' and society's future well-being. In this context, it is sometimes called "sustainable marketing" which emphasizes socially and environmentally responsible marketing (Kotler and Armstrong, 2012).

Contemporary companies have to work more today than they did in the past to preserve and enhance their ability to continue to serve future generations. In order to meet the needs of future generations while satisfying the present needs and wants of both customers and the company, societal marketing approach acts as a guiding philosophy. In addition, societal marketing helps companies to achieve their goals and fulfill their responsibilities. For that reason, the link between marketing, social and natural environment has gone hand in hand with societal marketing of the 1970s increasingly for a few decades (Piacentini et al., 2000).

In today business life, every manager must adopt a socially responsible and ethical behavior. Emphasizing ethics and social responsibility also leads to building and maintaining strong customer relationships through honesty and trust (Kotler and Keller, 2012). For that reason, contemporary managers have to concentrate on societal marketing approach in real sense. For several decades, increasing number of companies and managers have preferred to act in a way which contributes to society overall (Lambin, 1997) because the role of CSR in the strategic management process of companies is extremely critical for their profitability (Key and Popkin, 1998). In addition, prevailing literature demonstrates that there is a positive relationship between CSR activities and financial performance of companies (Pava and Krausz, 1996; Waddock and Graves, 1997).

Since corporate social responsibility activities are regarded as highly critical for companies, managers have to aware of how they engage in CSR activities. Social responsibility marketing brings different types of corporate social initiatives. These are collected under "corporate social marketing", "cause marketing", "cause related marketing", "corporate philanthropy", "corporate community involvement", "socially responsible business practices" (Kotler and Lee, 2004).

Corporate social marketing is primarily based on supporting campaigns which results in behavior change. Cause marketing is regarded as efforts to promote social issues through sponsorship, licensing agreements, and advertising. On the other hand, cause-related marketing is an action based on donating a percentage of revenues to a specific cause which occurring during the announced period of support. Corporate philanthropy includes giving money, goods or time to non-profit organizations, groups, or individuals. Corporate community involvement is based on providing in-kind or volunteer services in the community. Lastly, socially responsible business practice is all about adapting and conducting business practices which protect the environment and rights of human and animal (Kotler and Keller, 2012).

All in all, corporate social responsibility activities can be categorized into three orientations depending upon the strategic goals of corporation. These orientations are philanthropic CSR which includes charitable donors; promotional CSR which increases the mutually beneficial relationship exchange; and lastly value-creating CSR which is integrated into mission of firms (Austin, 2000; Chen et al., 2018; Pirsch et al., 2007). Today, one company can simultaneously adopt different types of CSR activities and see that they are highly beneficial to create favorable consumer response, as well as profits.

Social Responsibility Approach in Logistics

Since 1980s, the dominant approach in logistics was the "total enterprise approach". Under this approach, logistics was considered as a critical subsystem or one of the components of the overall firm system (Poist, 1989). In essence, total enterprise approach suggests that logistics systems should be designed optimal for and compatible with total enterprise goals. Simply put, under this approach, logistical systems should be created and managed for maximum profits of overall firm. For that reason, total enterprise approach principally concentrated on the management of inter-functional tradeoffs between logistics, marketing, production, finance, and so forth in making critical decision.

However, throughout the last decade, the strict emphasis on economic and profit considerations has given place to societal concerns in logistics more increasingly (Garver and Mentzer, 1999). So, social awareness and sensitivity to political, economic and natural environment have started to dominate the logistic practice and lead to need for a high sense of responsibility in every action in logistics (Carter and Jennings, 2002). This approach is called total responsibility approach in which societal relations transcends inter-functional relations.

Theoretically, total responsibility approach extends the total enterprise approach beyond enterprise and channel levels by taking societal level into considerations, as well. Principally, a total responsibility approach suggests that logistics managers have a responsibility to not only firm but also society, and so they should consider both societal and firm interests at the same time in logistical system design and administration decisions (Mentzer and Flint, 1997). The outgrowth of the social responsibility concept at the overall firm level in logistics highly parallels with societal marketing concept at the functional level. So, to preserve or enhance the consumers' and society's well-being, logistics managers have started to emphasize the importance of social responsibility in their decision making (Bowersox, 1998).

These societal relations are predicted on the fact that there is a dynamic interactive system between society and enterprise in which each affects and influences the other. Societal relations cover interactions and interfaces with publics which represent the either special or general interest of the society at large. The interaction with government and its departments, regulatory agencies, foreign governments, local communities, social activists and special interest groups, trade and professional associations, and educational institutions are all considered as relations with publics (Poist, 1989). In many times, these social relations are regarded as more unique than traditional logistical interfaces because they are indirectly related to production and distribution process of the firm and are primarily concerned with social goals rather than economic ones.

Since the early 1970s, there has been a great emphasis on the need for societal considerations in transportation and logistics decision making (Lambert and Stock, 1978). In actual practice, more and more logistics enterprises have given explicit and prominent treatment to societal considerations proposed under a total responsibility approach. Under this approach, logistics firms give special emphasis on identifying favorable societal tradeoffs. Simply put, they sacrifice short-term profits for potentially long term gains.

Till now, logistics with total responsibility approach deals with several societal problems and issues such as "employee education and training, corporate philanthropy, environmental and ecological control, urban renewal and development, civil rights and equal opportunity, occupational health and safety, and hunger and homelessness" (Poist, 1989:38). Furthermore, it is expected that logistics with social responsibility approach will reduce environmental and ecological concerns in areas such as "pollution control, protective packaging materials, plant and warehouse siting, hazardous material storage and transport, energy and resource conservation, and reverse logistics of materials to be recycled" (Poist, 1989:38). All in all, logistics operations done with socially responsible way can make the world we live better.

METHODOLOGY

Focusing on logistics industry in Turkey, the study aims to examine the extent and nature of CSR activities. In this respect, the study is designed as an exploratory and qualitative research which allows researchers "to understand particular cases in depth and detail; get at meanings in context and capture changes in dynamic environment" (Patton, 2002: 556). Since it is a qualitative research which aims to provide insight about the corporate social responsibility initiatives adopted by Turkish logistics companies, the aim of the study is not to generalize the findings of the research but to understand the extent and nature of CSR activities in Turkish logistics industry. In that case, rather than generalizability, gaining access to categories regarding in what aspects the CSR activities of the logistics companies can be adopted, is more important in the study (McCracken, 1988).

With regard to this, to construct a sample, purposive sampling is employed in the study because the aim of the study is not extending the results to the broader population but understanding the phenomena (Given, 2008). Purposive sampling or criterion-based sampling, is a strategy for selecting "particular settings, persons, or events deliberately to provide important information" that is unlikely gotten from other choices (Maxwell, 1996: 70). In addition, purposive sampling method is used in the study because selecting individuals, times and settings that provide information which you need to answer your research question is the concern in qualitative and non-probability sampling decisions (Maxwell, 1996). In this sense, the sample of the study is determined on the basis of the Turkish logistics companies that commonly came into mind of 125 logistics department students in Afyon

Kocatepe University, Bolvadin School of Applied Scienes. Particularly, this question is asked only logistics departments students because they are the ones who have more information about logistics companies as the potential human resources of logistics companies.

In the direction of the answers given by the students, Borusan Lojistik, Ekol Lojistik, CEVA, Horoz Lojistik, and Arkas are listed as the most repetitive responses. For that reason, all of these five logistics companies are included in the sample of the study. Among these companies, Borusan is the first company which is mostly come into the minds of students, while Arkas is the last. Ekol Lojistik, CEVA, and Horoz Lojistik are the second, third, and fourth the most repetitive logistics company names, respectively.

Decision regarding data collection method for the study is assessed under different criteria like the nature of the research, the type of data required for data analysis, the nature of the research topic, and time and budget constraints of researcher. So, to reveal the extent of their emphasis on societal marketing context, the data is collected from websites of these companies. Although websites are regarded as secondary data, they are employed in this study because websites are the platforms in which companies can share rich information about themselves. The compiled data is analyzed with content analysis.

RESULTS

In data analysis, thematic networks which systemize the extraction of i) “basic themes” in which lowest-order premises in the text; ii) “organizing themes” in which categories of basic themes grouped together to summarize more abstract principle and lastly iii) “global themes” in which there are super-ordinate themes encapsulating the principle metaphors in the text as a whole (Stirling, 2001: 388) are constructed. Thus, as a result of the content analysis of the data collected from the websites of the given logistics companies, the extent and the nature of the corporate social initiatives adopted by Turkish logistics companies are determined.

To understand the extent of their emphasis on corporate social responsibility, the compiled data is coded and categorized on the basis of main concepts regarding to corporate social responsibility. In this context, in the direction of corporate social responsibility literature, sustainability (e.g., economic, social, legal, ethical, environmental, and management), responsibility (e.g., social, legal, economic, and environmental), environment (e.g., environmental consciousness, environmental logistics, environmental friendly, environmental policy, and environment protection), ethic (e.g., ethical values, code of ethics) , legal (e.g., legal regulations, legal necessity, and legality), and society (e.g., social service, social benefit, and non-governmental institutions) are identified as the main concepts of this approach. Thus, to show the extent of logistics companies’ emphasis on these important concepts, how many times these words are used in their websites is examined and given in the Table 1.

Table 1. Number of CSR Concepts Used in Websites of the Logistics Companies

Concepts / Companies	Sustainability	Responsibility	Environment	Ethic	Legal	Society	Total
Borusan Lojistik	**6**	**6**	**22**	**1**	**1**	**15**	**51**
Ekol Lojistik	**12**	**8**	**33**	**3**	**5**	**5**	**66**
CEVA	**13**	**4**	**5**	**5**	**1**	**2**	**30**
Horoz Lojistik	**1**	**5**	**9**	**3**	**3**	**1**	**22**
Arkas	**3**	**1**	**9**	**3**	**1**	**2**	**19**

In this context, the first logistics company, Borusan Lojistik is also found as one of the logistics companies that concern the societal issues at the most. By positioning themselves as “the green player of a grey industry”, Borusan announces that they conduct all of their activities in an environmental friendly way. Simply put, they state that they adopt socially responsible business practices to protect the trees, sea water, and marine life and save the energy. Moreover, it is found that Borusan engages in corporate philanthropy by partnering with

ÇEKÜL, one of Turkey's major NGOs campaigning in support of cultural values and the environment, and cause-related marketing by planting one tree in their 7 Trees Forest for every 10 runs and 10 containers handled to minimize carbon emissions in their operations. The Waste Recycling System, Waste Reception License, Hazardous Materials Compliance Certification, Green/Eco Port Certification, the Fast Card System to save tons of CO2 emissions every year, and Rotor Blade Adaptor Technology also demonstrate their commitment to the environment.

In addition, compatible with their socially responsible business practices, Borusan also emphasizes the importance of sustainability not only basis of corporate social responsibility but also as an essential part of their business models by appreciating value of the collective contribution and focus on the environment.

Lastly, Borusan announces that they appreciate transparency and accountability principles and ethical business values, and highlights the importance of employee volunteering in activities on education, culture and the arts, the environment, human rights and empowerment of women.

As the second most repetitive logistics company name, Ekol Lojistik also accepts sustainability as its core value and company goal. In the website of the company, it is obviously seen that Ekol emphasizes the economic, social, and environmental sustainability. The credentials such as Gold Sustainable Logistics Certificate, Sedex, OHSAS, EcoVadis also indicate the way how Ekol concerns sustainability in every aspect of their operations. The Intermodal Transportation System of Ekol and Carbon Dioxide Emission Reporting and Reduction are all considered as the result of their environmental concerns. Ekol also announces that it is the first logistics company in Turkey to get involved in the WWF Green Office Program and to obtain the Green Office Certificate. So, all of these are collected under socially responsible business practices of Ekol. Ekol also announces that they supported the adoption campaign of the World Wildlife Fund Turkey (WWF Turkey) with the revenues generated from the scrap waste recycling company. This is one of the cause-related marketing activities of Ekol. Ekol also engages in corporate social marketing activity by supporting the Earth Hour Campaign by WWF to bring attention to global climate change. Ekol also promoted TEMA Nature Education Program by making donations to TEMA within the context of corporate philanthropy. In addition, they engaged in cause marketing by supporting the natural science education of children through sponsorship to celebrate its 25th anniversary in 2016. Lastly, Ekol states that they give importance to corporate community involvement by supporting the Ekol Volunteers who are working for benefits of society. All in all, Ekol is the most outstanding logistics company, who gives importance to corporate social responsibility.

CEVA is the third logistics company whose name is mostly given. As well as in the website of Borusan and Ekol, CEVA states that they emphasize the importance of sustainability in delivering long term value to its customers, employees, suppliers, investors and the society as a whole. Although there is less information about corporate social responsibility initiatives of CEVA in their website, it is concluded that CEVA has some socially responsible business practices particularly for their employees.

The fourth logistics company is the Horoz Lojistik. When the website of Horoz is examined in detail, it is seen that their corporate social responsibility understanding is generally limited to corporate philanthropy. Thanks to its educational foundation, HOREV, Horoz contributes to society by giving scholarship to children and investing in educational institutions and dormitories. However, a very little information is given about their environmental and ethical policy and business practices, when the website of the Horoz Lojistik is compared with the websites of Borusan, Ekol, and CEVA.

Arkas is the last logistics company. When the website of the company is examined, it is seen that there are several socially responsible business practices of Arkas such as Sustainable Environment Management Program. In addition, Arkas announces that they engage in several corporate philanthropy activities such as book donation campaigns to schools and supply aid campaigns to NGOs like EÇEV, intensively. Consequently, on the basis of the examination of websites of each company, the structure of the thematic network is summarized in Figure 1.

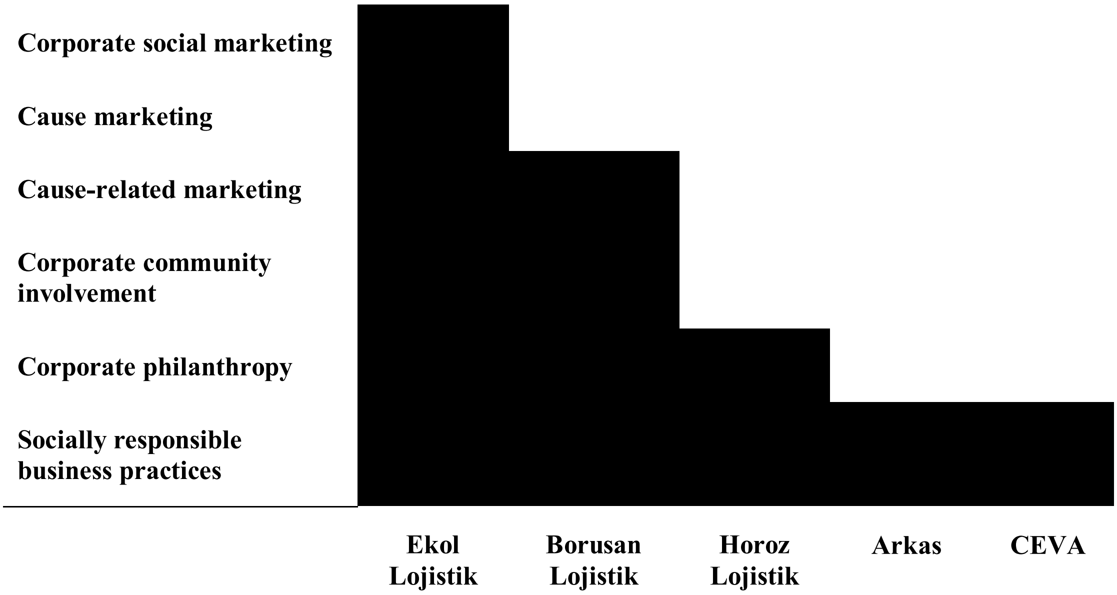

Figure 1. Corporate Social Initiatives of Turkish Logistics Companies

CONCLUSIONS

Logistics managers adopt a total responsibility approach for several reasons. One can be that total responsibility approach gives a chance to increase the visibility of the logistics function both internally and externally to the firm (Poist, 1989). The findings of the study also supports this argument because the logistics companies (e.g., Borusan and Ekol) which engage in corporate social responsibility activities intensively are the ones whose names are more likely to be come into the minds of students. So, it can be concluded that the more logistics companies adopt corporate responsibility activities, the more people can be aware of these companies. In that case, the findings of this exploratory study suggest that the extent of corporate social responsibility activities of logistics companies is regarded as the antecedents of their brand awareness. In further studies, this relationship between CSR activities and brand awareness can be empirically tested.

However, it is difficult to say that there is a positive relationship between the nature of the corporate social responsibility activities of these companies and their brand awareness because the data used in the study does not allow deriving such conclusions. So, the data used in the study can be regarded as the biggest limitation of the study. In further studies, the in-depth interview with managers of these companies and customers can be conducted to provide much more insight about the effect of the extent and nature of corporate social responsibility activities of logistics companies on several issues such as their financial performance or positive consumer attitudes, as well.

All in all, it can be concluded that in the future, along with the prominent effort to balancing profits and societal goals, logistics managers may place greater emphasis on managing societal relations in a more proactive in logistical decision making. So, it is expected that the findings of the study contribute to logistics literature by extending the corporate societal marketing approach beyond marketing to logistics, and logistics practice by providing several managerial insights to logistics firms to design their future logistics strategies with more corporate social responsibility.

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MULTI-CRITERIA DISASSEMBLY-TO-ORDER SYSTEM FOR COMPONENTS AND MATERIALS WITH LIMITED SUPPLY, STOCHASTIC YIELDS AND QUANTITY DISCOUNT

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Abstract *− To save consumption of natural resources, it is essential to promote reuse and recycling of assembly products environmentally friendly and economically. For reuse and recycling, end-of-life (EOL) products are received from multiple suppliers with quantity discount. Then, the EOL products are separated into each component by disassembly operations. Each EOL product is consisted of different components and involved stochastic disassembly yields due to uncertainties of EOL statuses. In order to satisfy the components and materials demands environmentally friendly and economically, a disassembly-to-order (DTO) system should be designed to achieve multi-criteria such as profit, purchase EOL products, outside procurement components and disposal costs. However, the maximizing profit does not always ensure the minimizing those costs since the profit is defined as a difference between the sales of components and materials revenues and a sum of a variety of costs including disassembly, holding, recycling costs. Therefore, the research question is how to determine the number of purchased EOL products for disassembly from each supplier and of processed components for reuse and recycling in order to fulfill the demands of components and materials while achieving multiple criteria simultaneously.*

This study proposes a solving method for the multi-criteria DTO system problem, which determines the optimal purchased combinations of different EOL products in order to satisfy the demands of components and materials with the stochastic disassembly yields, by using linear physical programming (LPP). By adopting LPP, a decision maker is removed from the weight allocation processes for solving a multi-criteria problem with single objective function. The proposed DTO system is formulated by using LPP to find satisfied solution. A numerical experiments are conducted to demonstrate a design method..

Keywords − Linear physical programming, End-of-life products, Multi-criteria decision making problem, Reverse supply chain, Recycling

INTRODUCTION

The depletion of natural resources has been more serious since the demands for assembly products have been increased as the economic growth in emerging countries is increasing. To satisfy the increasing material demands for the assembly products, the reuse and recycling should be promoted economically. After an usage phase, the end-of-life (EOL) products are collected with different statuses. The different statuses lead the different disassembly stochastic yields. The collected EOL products are disassembled to retrieve each component for reuse or recycling. The disassembly is a first step for reuse and recycling and an essential phase. That is because each component needs different inspection for reuse and material recycling requires each different process for each material. With regarding to the other process for reuse and recycling, purchasing EOL products from suppliers, procurement additional components from the outside suppliers, disposal and demands for reuse components and recycle materials should be considered to establish the reuse and recycling economically (Kongar & Gupta, 2009; Massoud and Gupta, 2010; Joshi & Gupta, 2017; Ondemir & Gupta 2014). Moreover, it should consider the different supply capacity of EOL products and the different discount of purchasing EOL products for each supplier. Then, that the whole processes for reuse and recycling become complicated.

Therefore, it needs to establish disassembly-to-order (DTO) system economically to promote the reuse component and recycle material. The DTO system can be defined to determine the number of EOL products to

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be ordered to fulfill a certain demand for components and/or materials (Kongar & Gupta, 2009). The DTO system can be considered as a multi-criteria decision making (MCDM) problem since it has multiple goals such as maximizing total profit, while minimizing purchased, procurement and disposal costs. As one of the effective ways to solve the MCDM problem, linear physical programing (LPP) developed by Messac et al. (1996) is used to solve previous studies about DTO systems (Kongar & Gupta, 2009; Massoud and Gupta, 2010; Ondemir & Gupta 2014). LPP can evaluate all criteria simultaneously by setting the desirability ranges based on the preference functions instead of weight allocation processes.

Massoud and Gupta (2010) propose the DTO system with limited supply and discount of purchasing EOL cost under stochastic disassembly yields by using LPP. However, the DTO system do not consider recycling material inventory, so that all excesses of recycle materials from the demand for recycle material are sent to a disposal facility directly. Kinoshita et al. (2018) propose a solving method for the DTO system with limited supply and discount of purchasing EOL products under disassembly stochastic yields by LPP. However, Kinoshita et al. (2018) do not consider the differences of types of materials even though the demand for recycle materials depends on the types of materials and each different material requires the different recycling processes.

This study proposes the DTO system, which consider differences of types of materials, with limited supply, discount of purchasing EOL products and the stochastic disassembly yields based on Massoud and Gupta (2010) and Kinoshita et al. (2018) by using LPP. The rest of this article is organized as follows: Section 2 explains overviews and procedures of LPP. Section 3 describes the procedures from purchasing EOL products to satisfying reuse components and recycle materials demands in the DTO system. An numerical example of the DTO system is presented in Section 4. Finally, the summary and future studies are provided in section 5.

OVERVIEW AND PROCEDURE OF LINEAR PHYSICAL PROGRAMMING

This section explains the procedure and advantages of LPP. LPP is a multi-criteria decision making tool and developed by Messac et al. (1996) (Ondemir & Gupta, 2014). One of the advantages of the LPP is that a decision maker (DM) is removed from weight allocation processes (Ondemir & Gupta, 2014). LPP defines an aggregate objective function based on preferences of the DM (Ondemier & Gupta, 2014; Messac et al., 1996). In general, MCDM technique needs to decide mathematical weight for the aggregate objective function (Ondemir & Gupta, 2014). However, it is very difficult for the DM to decide correct mathematical weight to reflect his/her preferences for each criterion even though the DM has substantial knowledge about the problem (Ondemir & Gupta, 2014). Instead of weight allocation processes, LPP requires DM to express his/her desirability ranges based on the preference 4 different classes (Messac et al., 1996). The procedures of LPP is consisted of 3 steps as follows.

Step 1 Select class function for each criterion

LPP has 4 classes and each class comprises soft and hard classes (Messac et al., 1996). The soft classes are defined as Class-1S “Smaller-is-better”, Class-2S “Larger-is-better”, Class-3S “Value-is-better” and Class-4S “Range-is-better” (Messac et al., 1996). In contrast to soft classes, the hard classes are defined as Class-1H “Must be smaller”, Class-2H “Must be larger”, Class-3H “Must be equal”, Class-4H “Must be in range” (Messac et al., 1996). The one class function is selected from those 8 soft and hard classes for each criterion based on the features of the criterion.

Step 2 Set desirability ranges for each criterion based on the class function

Step 2 requires the DM to set desirability ranges based on the class function. The 4 hard classes require the DM to set only acceptable and unacceptable ranges. Thus, the criteria belonged to the hard classes can be formulated as simple constraints. In contrast to the hard classes, the soft classes require the DM to set 6 desirability ranges (Messac et al., 1996) The 6 ranges, namely, ideal, desirable, tolerable, undesirable, highly undesirable and unacceptable are set for each criterion.

Step 3 Calculate mathematical weight for each criterion

To seek the solution by evaluating different criteria simultaneously, the aggregate objective function with the mathematical weight is required. LPP weight algorithm calculates the mathematical weight based on the desirability ranges of the DM. The LPP weight algorithm is operated based on the One vs. Others criteria-rule (OVO rule) (Messac et al., 1996). According to the OVO rule, LPP weight is calculated to prioritize the worst criteria improved firstly.

DEFINITION OF DISASSEMBLY-TO-ORDER SYSTEM WITH LIMITED SUPPLY, STOCHASTIC YIELDS AND QUANTITY DISCOUNT

This section describes the DTO system with limited supply, stochastic disassembly yields and quantity discount The DTO system determines the optimal number of EOL products and components in order to fulfil a certain demand for components and/or materials under a variety of objectives and constraints (Kongar & Gupta, 2009).

The EOL products are provided from multiple suppliers, which have the different supply capacities of the EOL product and offer the discount of purchasing EOL products. The DTO system involves several uncertainties such as quality and a variety of EOL products from different suppliers (Joshi & Gupta, 2017). That leads to disassembly stochastic yields, and makes it difficult to identify the exact number of EOL products and components for each process in the DTO system (Joshi & Gupta, 2017).

Therefore, the proposal DTO system with imited supply, stochastic disassembly yields and quantity discount tries to achieve higher profit by setting 4 objective functions. The 1st objective function is set as maximizing profit since the DTO system needs to establish economically. The profit is defined as a difference between revenues and cost. The 2nd and 3rd objective functions are set as minimizing the purchasing cost for the EOL products from suppliers and procurement cost for the additional components from the outside supplier respectively. Both objective functions are expected not only to minimize cost but also to purchase or procure only needed EOP products or components. The last objective function is set as minimizing disposal cost since the amount of disposal weight should be minimized for material circulation.

Subsection 3.1 explains that the treated revenues and costs in the proposed DTO system. Subsection 3.2 describes the detailed procedures from purchasing EOL products from multiple suppliers to satisfying the demands for reuse components and recycle materials.

Revenue and cost treated in proposed DTO

This study proposes DTO system with limited supply stochastic yields and quality discount based on Massoud & Gupta (2010) and Kinoshita et al. (2018). To fulfill demands of reuse components and recycled materials economically, the DTO system determines the number of EOL products and components for each process such as disassembly, procurement from outside suppliers, recovering material values by recycling and disposal of reused components and recycled materials. Thus, the DTO system contains of 2 types of revenues and 6 types of cost as follows:

- Revenue from reuse component sale
- Revenue from reuse component is earned by selling reuse component. The reuse components are retrieved by non-destructive disassembly from the EOL products. Only part, which passes reuse inspection, can be sold as a reuse component. Each component has a different selling price. Note that the demand of reuse components is fixed.
- Revenue from recycle material sale
- Similar to the revenue of reuse component, revenue from recycle material is earned by selling the recycle material. The material values are retrieved from the components, which do not contain hazardous materials, by recycling processes. The selling price of each recycle material is lower than one of the reuse component. Note that the demand of recycle material is also fixed as well as the reuse components.
- Purchased cost for EOL products from suppliers
- EOL products are purchased from suppliers. Each supplier provides different statuses of EOL products with different cost. The different status of the EOL product leads different stochastic disassembly yield. Hence, the same type of the EOL product purchased from the different suppliers involves the different stochastic disassembly yield. Moreover, the discount of purchased EOL cost is offered from each supplier based on the total purchased cost.
- Disassembly cost
- The disassembly operations are consisted of non-destructive disassembly and destructive disassembly. The non-destructive disassembly is conducted for only reuse components, which are not allowed to be damaged (Joshi & Gupta, 2017). Thus, the non-destructive disassembly cost tends to be expensive because of higher labor cost (Joshi & Gupta, 2017). In contrast, the destructive disassembly is

conducted for recycle materials. The components for recycle materials are removed from the EOL products by crushing. The destructive disassembly cost becomes lower than non-destructive disassembly cost.

- Procurement cost for additional components from an outside supplier
- Since the shortage of supplies for reuse components and recycle materials are not allowed, additional components are procured from an outside supplier. Each component procured from the outside supplier has the different procurement cost.
- Inventory cost
- The inventory cost occurs to hold the reuse component and recycle material respectively. When the number of reuse components and recycle materials is greater than ones of demand, the excesses of reuse components and recycle materials are sent to the inventory respectively. The holding cost for reuse components becomes more expensive than one of the recycling materials since reuse components should be stored under good storage conditions to keep their functions (Kinoshita et al., 2018).
- Recycling cost
- Recycling is conducted for the recovery of scrap materials from EOL products (Lambert and Gupta, 2005). Each recycle material requires the different recycling processes to recover it values from the EOL products. Thus, each recycle material has the different recycling cost. On the other hand, the proposed DTO system contains in-plant and out-plant recycling facilities. The in-plant recycling facility has the processing capacity for each recycle material. Thus, if the demand of recycle material is greater than processing capacity at the in-plant recycling facility, the components for recycle materials are sent to the out-plant recycling facility to fulfill the demand of the recycle material. Note that the recycle cost at an in-plant facility is cheaper than one at an out-plant facility.
- Disposal cost
- The disposal cost is consisted of 3 types of disposal cost. One disposal cost is for reuse components. If the inventory for reuse components becomes full, the excesses of reuse components are disposed with the disposal cost for reuse components. The second one is disposal for hazardous components. The hazardous components cannot be neither reused nor recycled. Those components are disposed with hazardous disposal cost. The last one is disposal cost for recycle materials. Similar to the reuse components, the excesses of recycle materials from the inventory capacity of the recycle materials are disposed with the disposal cost for recycle material.

Procedures from purchasing EOL products to satisfying the demands for reuse components and recycle materials

This subsection subscribes procedures from purchaing EOL products to satisfying the demands of reuse components and recycle materials in the DTO system. The overview of proposed DTO system is illustrated as shown in Figure 1.

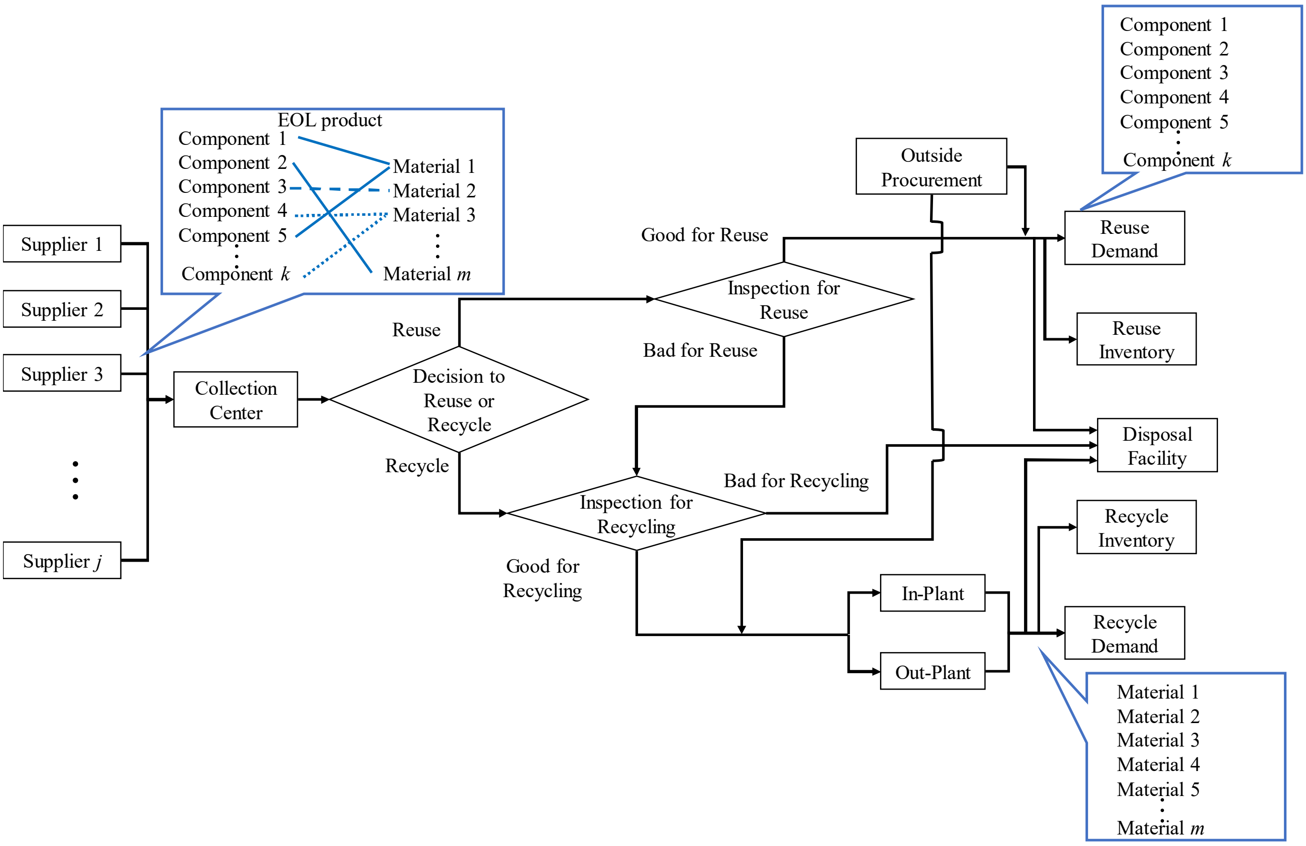

Figure 1. Overview of DTO system, which consider differences of types of materials, with limited supply, discount of purchasing EOL products and the stochastic disassembly yields

First, the different EOL products are purchased from multiple suppliers and sent to a collection center. Each EOL product contains of different components, which contains different materials as shown in Figure 1. There are different demand for each component. On the other hand, the recycle material demand depends on the types of materials as shown in Figure 1. Each supplier has the supply capacity of each EOL products, and offers the discount of purchased cost for the EOL products. Additionally, the multiple types of EOL products are provided from multiple suppliers with different statuses and costs. The different status of the EOL products causes to the different disassembly yields, which determines whether the components can be reused or not. Only components, which can be reused, are removed by non-destructive disassembly operations and sent to the inspection for reuse. On the other hand, the other parts are removed by destructive disassembly operations such as crushing for recycle materials.

Next, the components sent to the inspection for reuse is examined whether the components can be sold as reuse ones or not. The components with good condition can pass the inspection for reuse, and are sold to satisfy the demand of reuse components. Since the supply shortage for reuse components is not allowed, additional components can be procured from an outside supplier to fulfill the demand for reuse components. In a case that the supply of reuse component exceeds the demand for reuse components, the reuse components are sent to the inventory for the reuse components. If the storage for reuse components becomes full, the excesses of reuse components from the capacity at the inventory are sent to a disposal facility.

On the other hand, the components with bad condition are sent to the inspection for recycle materials. The components with bad condition for reuse and components removed by non-destructive disassembly are examined whether they contain hazardous materials or not at the inspection for recycle materials. The components with bad condition for recycle materials are disposed with hazardous disposal cost.

In contrast, the components with good for the recycle material are sent to a recycling facility. There are in-plant and out-plant recycling facilities in the proposed DTO system. The components for the recycle materials are sent to the in-plant recycling facility firstly. Then, the rest of component for the recycle materials are sent to the out-plant recycling facility, if the number of components sent to the in-plant recycling facility reaches the processing capacity. Similar to the reuse components, since the supply shortage of recycle materials is not allowed, the additional components for the recycle materials can be procured from the outside supplier. The excesses of recycle materials from the demand for recycle materials are sent to the storage for the recycle materials. In a case that the inventory for the recycle materials reaches the inventory capacity, the excesses of the recycle materials are sent to the disposal facility.

NUMERICAL EXAMPLE

A numerical example is demonstrated in this section. First, subsection 4.1 explains input data for each process and calculated LPP weight based on the desirability ranges for each criterion. Next, subsection 4.2 shows the results of the numerical example.

Input data of the numerical example

This subsection explains the input date for each process and calculated LPP weight in the DTO system. It is assumed that 3 different EOL products with 8 components are provided from 2 different suppliers with different cost, which offer different discount based on the total purchased prices as shown in Table 1. Also, it is assumed that each supplier has supply capacity for each EOL product as shown in Table 2. Additionally, the different disassembly yields for each component are set as shown in Table 3. Moreover, it is assumed that 3 different materials are contained of the components such as M1, M2 and M3 as shown in Table 4. Table 5 shows the demand, selling price and costs for each component.

With regarding to other input data, the recycling cost for each material at in-plant and out-plant facilities are set as $3.0 and $4.6 respectively. Additionally, capacities of in-plant recycling facility, inventory for reuse components and recycle materials are set 700, 70 and 150 respectively.

Table 1. Discount schedule and rate for EOL product suppliers

Supplier	Discount Schedule	Discount rate
Supplier 1	[0,6000)	0.0%
	[6000,10000)	4.0%
	[10000,15000)	6.0%
	<=15000	8.0%
Supplier 2	[0,4000)	0.0%
	[4000,8000)	3.0%
	[8000,12000)	5.0%
	<=12000	7.0%

Table 2. Purchase price and supply capacity for each EOL products

Supplier	1			2		
EOL product	1	2	3	1	2	3
Purchase Price	29	30	28	29	27	27
Capacity	300	250	300	250	280	250

Table 3. Disassembly yields of different types of EOL products for each supplier

Component		A	B	C	D	E	F	G	H	I	J
Supplier 1	Product 1	0.00	0.74	0.90	0.61	0.83	0.58	0.00	0.98	0.72	0.76
Supplier 2		0.00	0.68	0.52	0.82	0.86	0.77	0.00	0.83	0.59	0.90
Supplier 1	Product 2	0.74	0.00	0.90	0.61	0.83	0.58	0.98	0.72	0.00	0.76
Supplier 2		0.68	0.00	0.52	0.82	0.86	0.77	0.83	0.59	0.00	0.90
Supplier 1	Product 3	0.74	0.90	0.61	0.00	0.00	0.83	0.58	0.98	0.72	0.76
Supplier 2		0.68	0.52	0.82	0.00	0.00	0.86	0.77	0.83	0.59	0.90

Table 4. Demand, selling price and costs for each material type

Material type	Demand for recycle	Selling price of material	Inventory cost for material	Disposal cost for recycle material
M1	1250	15	3.30	2.3
M2	1120	14	3.40	2.5
M3	1320	12	3.50	2.2

Table 5. Demand, selling price and costs for each component

Component type	Material type of component	Demand for reuse	Selling price of component	Reuse percentage	Recycle percentage	Disassembly cost		Procurement cost for additional components	Inventory cost for component	Disposal cost	
						Non-destructive	Destructive			Disposal component	Hazardous component
A	M1	370	18	0.80	0.97	1.4	1.1	10	3.9	2.9	3.2
B	M2	400	20	0.77	0.88	1.6	1.0	9	3.8	2.4	3.2
C	M3	420	21	0.84	0.95	1.4	1.1	9	4.0	1.8	3.2
D	M1	390	19	0.79	0.94	1.5	1.0	9	3.8	2.7	3.2
E	M2	380	18	0.87	0.89	1.5	1.2	9	3.9	2.8	3.2
F	M3	400	19	0.76	0.90	1.5	1.0	8	4.0	2.6	3.2
G	M2	410	18	0.83	0.92	1.6	1.0	9	3.7	2.7	3.2
H	M1	430	21	0.88	0.93	1.5	1.2	7	3.7	1.8	3.2
I	M3	430	21	0.75	0.96	1.6	1.0	10	3.9	1.9	3.2
J	M3	380	18	0.85	0.98	1.5	1.1	8	4.0	2.2	3.2

The DTO system is designed to maximize total profit, while minimize purchased EOL, procurement additional components and disposal costs. The maximizing total profit is belonged to Class-2S "Larger-is-better". On the other hand, all other criteria belong to Class-1S "Smaller-is-better". Therefore, the desirability ranges based on the preference function are set as shown in Table 6. Based on the desirability ranges as shown in Table 6, LPP weight algorithm calculates the weight as shown in Table 7. The LPP weight algorithm code was written in C language.

Table 6. Desirability ranges based on the preference function

Desirability ranges	Profit	Procurement Cost	Purchase Cost	Disposal Cost
Ideal	>=75000	10000<=	18000<=	680<=
Desirable	[72000,75000)	(10000,11500]	(18000,19000]	(680,700]
Tolerable	[68000,72000)	(11500,13000]	(19000,20000]	(700,720]
Undesirable	[65000,68000)	(13000,14000]	(20000,21500]	(720,750]
Highly undesirable	[63000,65000)	(14000,15000]	(21500,23000]	(750,800]
Unacceptable	<63000	15000>	23000>	800>

Table 7. Calculated LPP weight

Objectives	$\tilde{w}_{i,2}$	$\tilde{w}_{i,3}$	$\tilde{w}_{i,4}$	$\tilde{w}_{i,5}$
Profit	0.033	0.049	0.281	1.434
Purchase Cost for EOL Product	0.067	0.153	0.869	2.505
Procurement Cost for Component	0.100	0.230	0.396	1.670
Disposal Cost	5.000	11.500	19.800	35.574

Design example of DTO by using LPP

This subsection shows results of the numerical example of DTO system by using LPP. The numerical experiment was conducted on the same laptop PC (Windows 10 with Intel(R) Core(TM) i5-7200U CPU@2.50GHz) by using optimization solver named glpk. Table 8 shows the results of the numerical example. The aspiration levels of profit, purchased cost for EOL products, procurement cost for additional components and disposal cost become tolerable undesirable, undesirable and desirable respectively. The purchased prices from suppliers 1 and 2 became 11,726 and 9,234 respectively. Thus, the discount for the total purchasing cost were adapted such as 6% and 5% respectively. Then, the total purchasing prices for suppliers 1 and 2 after discount became 11,022.44 and 8,772.3respectively.

Table 8. Values and aspiration levels for each criterion

Objectives	Value	Aspiration level
Profit	69824.1	tolerable
Purchase Cost for EOL Product	13002	undesirable
Procurement Cost for Component	20960	undesirable
Disposal Cost	688.6	desirable

SUMMARY

This study proposed that the DTO system with consideration of differences of material types under the stochastic disassembly yields by using LPP and demonstrated the design example. Future studies should take account into disassembly precedence relationships of EOL products, remanufacturing of EOL products, and volumes of components at inventory.

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FORECASTING IN REVERSE LOGISTICS: GREY PREDICTION MODEL FOR REUSED MATERIALS

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Abstract- *End of life phase activities including recycling, reusing, remanufacturing, and reconditioning of used products and materials are becoming crucial for green logistics practices. In general, reuse provides a flow of goods back to the manufacturer from the users, i.e, reverse logistics. In reverse logistics, strategic decision-making for reused materials are needed to be conducted. These decisions are for the future, and the level of uncertainty of these decisions are very high. Therefore, proper estimation is essential for reused products to minimize these uncertainties in reverse logistics activities. These uncertainties regarding the quantity, timing and quality level of returned products in "reverse logistics" systems make it difficult to determine the location, capacity determination, production planning and inventory decisions. In order to overcome these difficulties and to reduce the uncertainties relatively, it is necessary to determine the time and the amount of returns or amount of reused materials to deal with uncertainties and risks of business management in reverse logistics. This study especially focuses on one of a growing problem, e-waste, and Grey prediction method is used to predict the amount of reused products for Turkey. By doing this, it is aimed to reduce uncertainty and to improve Turkey's future policies about e-waste.*
At the end of the study, it analyzes the changes in the amount of e-waste in Turkey and discusses the results will lead to future studies.

Keywords – E-Waste, Forecasting, Grey Method, Reuse, Reverse Logistics

INTRODUCTION

Electronic waste (e-waste) is a growing global problem, and it gain more attention due to environmental and economic concerns. The number of unused computers, telephones, televisions and devices has doubled between 2009 and 2014, reaching 42 million tons worldwide (Robinson, 2009). E-waste is the fastest growing type of waste in terms of environmental effect on the world. There are many valuable materials that can be gained from recycling activities of e-waste, however, the harmful substances in the e-waste need to be treated before the e-waste is destroyed (Kumar, et al. 2017).

These tremendous environmental and economic effects lead the importance of end of life phase treatment of products. From this point, reverse logistics activities including recycling, reuse, remanufacturing and reconditioning gain more attention. Reverse logistics starts from collection of products from the end users and managing these returned products through the activities i.e. recycling, remanufacturing, repairing and disposing (Govindan et al., 2015). Therefore, e-waste recycling industry is solely based on reverse logistics activities.

Moreover, rapid technological improvements and consequently, shrinking product life cycles are also a trigger in the increase of amount of e-waste. Especially in developing countries e-waste is a significant problem due to poor treatment processes. In order to manage the reverse logistics activities, proper roadmaps are essential, where prediction of the amount of e-waste must be the first step of these roadmaps.

From this point of view, this study aims to predict the amount of e-waste for the next 6 years after 2015 in Turkey, by using Grey prediction method, in order to deal with the potential environmental impacts and to gain economic advantages.

After the introduction part, firstly literature related to e-waste is discussed. Secondly, Grey prediction method is explained. After that, implementation of the study, and discussion and conclusion are presented respectively.

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ELECTRONIC WASTE

There are lots of articles about e-waste generation or e-waste estimation in the literature. Nguyen et al. (2009) made a research about forecasting the amount of waste of five types of electronic appliances as color televisions, refrigerators, washing machines, air conditioners, and PCs in Vietnam. They tried to estimate future amount of e-waste by using survey method with users of electronic appliances. Also, there are lots of works about e-waste by using Material Flow Analysis (MFA) to predict amount of e-waste in different countries (Jain et al., 2006; Yoshida et al., 2009; Zhang et al., 2011; Dwivedy et al., 2010).Similarly, Oguchi et al. (2008) focused on finding the quantity of ICT products in Japan by using product flow analysis.

Moreover, Yang et al., (2009) worked on prediction of the quantity of obsolete computers by using a logistic model. Kim et al., (2013) predicted the quantity of e-waste for 8 products in South Korea by using questionnaire and population balance model. On the other hand, there are many studies using market supply method which, includes production and sales data to predict the amount of e-waste in different countries (Liu et al., 2006; Barman et al., 2012; Chung et al., 2011).

In 2009, Walk predicted the amount of The CRT Devices in Germany between 1995-2020 by using a case study and following Weibull distribution. Petridis et al. (2015), studied on calculating computer waste in Western and Eastern Europe, Asia-Pacific, Japan-Australia- New Zealand, North and South America by using a mathematical model. Moreover, Mmereki et al. (2012) estimated the amount of e-waste in Botswana by using Stanford Method. Similarly, Mmereki et al. (2015) made a prediction about quantity of e-waste in Botswana by using GM (1,1) Model. In 2007, Xiang et al. used a different approach which is Grey Fuzzy Dynamic Model to estimate solid waste in China. In Table 1 literature summary of articles about e-waste and e-waste prediction are given.

Table 1. Literature Summary of E-Waste Prediction

Author(s)	Method	Focused Area
Babu et al. (2007)	Desk Research – Overview	Overview of Electrical and E-Waste Recycling
Barman et al. (2017)	Market Supply	Estimation of E-Waste in Guwahati
Demajorovic et al. (2016)	Survey	E-Waste in Reverse Logistics
Jain et al. (2006)	MFA (Material Flow Analysis)	Estimation of E-Waste in Delphi
Khurrum et al. (2011)	Linear Regression Technique	Review of E-Waste Problem
Kim et al. (2013)	Population Balance Model &Questionnaire	Estimation of E-Waste For 8 Products in South Korea
Kumar et al. (2017)	Desk Research – Overview	E-Waste Recycling Legislation
Ladou et al. (2008)	Desk Research – Overview	Export of E-Waste
Nguyen et al. (2009)	Questionnaire	Estimation of E-Waste in Vietnam
Oguchi et al. (2008)	Product Flow Analysis	Estimation of ICT Product in Japan
Othman et al. (2015)	Questionnaire	E-Waste Disposal (Residential Areas)
Petridis et al. (2015)	Mathematical Modeling	Calculating Computer Waste in Western and Eastern Europe, Asia/Pacific, Japan/Australia/ New Zealand, North and South America
Reinhard et al. (2009)	Desk Research – Overview	E-Waste Recovery and Recycling
Resmi et al. (2017)	EMARP	E-WASTE MANAGEMENT IN REFURBISHMENT INDUSTRIES
Walk (2009)	Case Study	Estimation of The CRT Devices in Germany
Yang et al. (2009)	Logistic Model	Forecasting Computer Waste in US
Yedla (2015)	SYE-Waste Model	E-Waste Estimation (Material Flow)

Yoshida et al. (2009)	MFA (Material Flow Analysis)	Forecasting Discarded Computers in Japan
Yu et al. (2010)	Logistic Model	Obsolete PCs in Global
Zhang et al. (2011)	MFA(Material Flow Analysis)	Prediction of Obsolete Household Products in China
Zu et al. (2012)	Grey Prediction	Prediction of E-Waste in China
Mmereki et al. (2012)	Stanford Method	Estimation of E-Waste in Botswana
Mmereki et al. (2015)	GM (1,1)	Estimation of E-Waste in Botswana
Xiang et al. (2007)	Grey Fuzzy Dynamic Model	Forecasting Solid Waste in China

By considering the literature review, deciding how much electronic waste can be reused and how much can be destroyed will play a decisive role for companies in the near future. The rapid increase in electronic waste shows that in the near future all companies in this sector will need reverse logistics. Also, researchers and authorities should create a global e-waste flow system that encompasses the entire life cycle of electrical products, including production of material, use, and reverse logistics which include recycling, reuse remanufacturing, and reconditioning (Wang et al. 2016).

For this system to be established, the amount of future e-waste must be determined. Therefore, it is important to estimate the amount of e-waste to analyze the impact of this rapid increase on the environment and to be able to create collection policies based on quantity. In the following section, Grey Prediction method is explained.

GREY METHOD

Ju-long Deng developed grey system theory in 1982 (Slavek et al., 2012). Grey system defines incomplete and missing information. Grey system theory provides a multidisciplinary approach that can work in cases where information is incomplete and inadequate (Xiang et al. 2007). The grey model has demonstrated the practicality of using an inadequate database because it can identify such an unknown system and predict efficiently based on a few variables (Morita et al. 2002). Therefore, it is more practical than other traditional methods (Huang, 1994; Liu et al., 2007 ; Köse et al., 2015 ; Taşçı et al., 2016).

There are six main steps in GM(1,1) model and those are presented below:

Step 1: First stage includes the utilization of initial dataset. The original dataset is shown as:

$$x_{0} = (x_1^0 \,, x_2^0, \ldots\ldots x_n^1) \tag{1}$$

Where x_0 refers to a non-negative sequence and n is indicates the sample size of the dataset. $x_0 k \geq 0$ $k = 1,2,\ldots\ldots,n$

The presented sequence is subjected to the Accumulating Generation Operation (AGO), which refers to the cumulative sum of x0 series, where in the following sequence x1 is found.

Step 2: x_0 series are changes monotonically to increasing x_1 series by using AGO in the second step. Sigma is utilized in the equation, which is shown below, in order to calculate x_1.

$$x_k^1 = \sum_{i=1}^{k} x^0 i \tag{2}$$

$x_1$is found as below, after implementing AGO formula:

$$x_k^1 = x_1^1 \,, x_2^1, \ldots, x_n^1 \tag{3}$$

Step 3: After obtaining x_k^1 series, z_k^1should be found. The generated mean sequencez_k^1ofx_k^1 is presented as follow.

$$z_k^1 = 0.5 x_k^1 + 0.5\, x_{(k-1)}^1 \tag{4}$$

k = 1,2,…..,n

By using the given formula, z_k^1 is found as following:

$$z_k^1 = 0.5x_k^1 + 0.5\, x_{(k-1)}^1 \qquad (5)$$

Step 4: Analytical solution of the corresponding grey equation can be calculated by using parameters a and b, after structuring the required GM model (Chen et al., 2000). In this study, Least Square Method is used to calculate a and b. Equations are given below:

Using Equation 6, all values are substituted as Equation (7).

$$b = x_{(k)}^0 + az_k^1 \qquad (6)$$

$$x_{(2)}^0 = az_2^1 + b$$

$$x_{(3)}^0 = az_3^1 + b$$

$$x_{(n)}^0 = az_n^1 + b \qquad (7)$$

In order to find a and b, below matrices should be structured by using given formula:

$$Y = \begin{matrix} x_2^0 \\ x_3^0 \\ x_n^0 \end{matrix} \qquad B = \begin{matrix} -z_2^1 & 1 \\ -z_3^1 & 1 \\ -z_n^1 & 1 \end{matrix} \qquad (8)$$

After that the matrix method is used to find a and b parameters by Equation (9).

$$\alpha = [a, b]^T = (B^T B)^{-1}(B^T.Y) \qquad (9)$$

Step 5: Grey differential equation is needed to calculate the predicted value of the initial data at time (k + 1).

$$x_{(k+1)}^1 = \left[x_1^0 - \frac{b}{a}\right] e^{-ak} + \frac{b}{a} \qquad (10)$$

Inverse Accumulating Generation Operation is essential in order to control the calculated data by using Equation 13(Kayacan et al., 2010).

Step 6: For the 6th step of GM(1,1) model, future values of the initial data set are found.

$$x_{(k+1)}^0 = x_{(k+1)}^1 - x_k^1 \qquad (11)$$

k = 1,2,…..,n

Step 7: Error Analysis in GM (1,1) Model

In order to determine the error between the predicted and the actual value, error analysis is needed in GM (1,1) model. Given equation should be used when k=l, l+1,…,n-1 (Yılmaz et al., 2013) for calculating percent error average, where, x_k^0 shows the initial value and $\dot{\hat{x}}_k^0$ shows the predicted value of the dataset (Wen, 2004).

$$e(k+1) = \left|\frac{x_{(k+1)}^0 - \dot{\hat{x}}_{(k+1)}^0}{x_{(k+1)}^0}\right| x\ 100\% \qquad (12)$$

IMPLEMENTATION OF THE STUDY

Electronic waste includes toys, entertainment and sporting equipment, medical equipment, monitoring-control equipment and vending machines, as well as large household appliances, small home appliances, telecommunication and telecommunication equipment, consumer equipment, lighting equipment, electrical and electronic equipment (washing machines, TVs, refrigerators, mobile phones, computers and etc. According to Global E-Waste Monitor Report (2017), almost 45 Mt of E-Waste were produced in 2016 and only 20 percent of these wastes could be collected.

Municipalities in Turkey are obliged to collect electronic waste separately by establishing collection centers. Also, electronic waste producers are obliged to establish a system for the collection, processing and disposal of waste. Regarding electronic waste management in Turkey, there are three authorized organizations including ELDAY, TUBISAD and AGID (Öztürk, 2015). Turkey has the young population therefore use of technology continuously increasing in the country (Öztürk, T., 2015).Due to statistical data, in 2016, 426 kg per capita e-waste were generated in Turkey (Eurostat,2018). Exitcom General Manager Murat Ilgar explained that Turkey produces 540,000 tons of electronic waste every year and Turkey has only 21 facilities to process of these e-wastes (Ilgar, 2016).However, more recycling capacity is crucial for e-wastes. As shown in the Graph 1, the number of e-waste in Turkey is increasing. Also, while the number of processing plants were 21 in 2011, the number became 71 in 2016 (National Waste Management in Turkey Report 2016-2023).

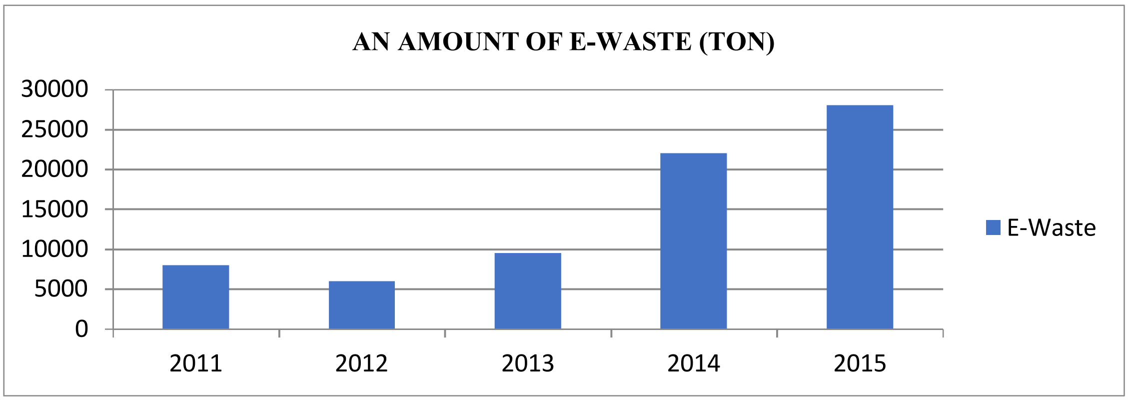

Figure 1. The Number of E-Waste in Turkey (ton) (National Waste Management in Turkey Report , 2016-2023)

Therefore, it is crucial to know the future e-waste amount and the plan of industries or people in the production. The GM (1,1) method is used for estimation, since there was a lack of data on E-waste quantity and quality (Mmereki et al. 2015).The amount of electrical and electronic equipment is predicted by GM(1,1) model for next 6 years after 2015 in Turkey.

Table 2. Actual Values of Amount of E-Waste in Turkey (ton) (National Waste Management, 2023)

2011	2012	2013	2014	2015
8000	6000	9500	22000	28000

The actual values are obtained from National Waste Management in Turkey Report (2016-2023). As shown in the table 2, actual values are increasing year by year.

Table 3. Predicted Values of Amount of E-Waste in Turkey (ton)

2016	2017	2018	2019	2020	2021
46751	74621	119106	190109	303440	484332

The actual non-negative data series called as " $X_{(0)}$"
$X_{(0)} =$ (8000 , 6000, 9500, 22000, 28000)

The new $X_{(1)}$ series is calculated from the cumulative sum of the series $_{(0)}$ which is AGO.
$X^{(1)} =$ (8000, 14000, 23500, 45500, 73500)

In the following sequence z_k^1 of x_k^1 is found as ;
$Z^{(1)}_{(k)}$= (11000, 18750, 34500, 59500)

The Least Square Method is obtained to find a and b values by using Equation (7). In the following part by using Equation (8), X, Y and B matrices are calculated.

$$Y = \begin{vmatrix} 6000 \\ 9500 \\ 22000 \\ 28000 \end{vmatrix} \qquad B = \begin{vmatrix} -11000 & -1 \\ -18750 & -1 \\ -34500 & -1 \\ -59500 & -1 \end{vmatrix}$$

Before using Equation (9), $(B^T.B)^{-1}$ is calculated.

$$(B^T.B) = \begin{vmatrix} 5203062500 & -123750 \\ -123750 & 4 \end{vmatrix}$$

$$(B^T.B)^{-1} = \begin{vmatrix} 0 & 0{,}00002251 \\ 0{,}00002251 & 0{,}9463232 \end{vmatrix}$$

Equation (9) is calculated to find a and b values and the results are as below:
a = -0,47
b = 1909,06
e = 2,7183
The predicted values which are calculated by Equation (11) are shown in the Table 4. In the table, actual and predicted values of an amount of e-waste in Turkey between 2011-2021 and the error analysis for these years.

Table 4. Actual and Predicted Values of An Amount of E-Waste in Turkey ,and the Error Analysis Between 2011-2021.

Years	Actual Value X^0_k	Predicted Value X^1_k	Errors ε (k)
2011	8000	8000	0
2012	6000	7203	1203,00
2013	9500	11497	1996,97
2014	22000	18350	-3649,28
2015	28000	29000	1290,26
2016	-	46751	
2017	-	74621	
2018	-	119106	
2019	-	190109	
2020	-	303440	
2021	-	484332	

As represented in the table 4, the amount of e-waste in Turkey continues to increase until 2021. While the amount of e-waste in 2015 was 29000, it is expected that the amount of e-waste in 2011 will reach 484332. Especially, in after 2017, this increase will accelerate as from 46751 to 74621. In addition, another expected fracture will be after 2019 from 190109 to 303440 tones.

In addition as stated in table 5, error analysis shows that what is the error rate between actual values and predicted values when the prediction is made by grey prediction model. According to values, in 2015, there is 4,61% error margin.

In the following part, Table 5 shows that traditional error results which is defined as Equation (12).

Table 5. Traditional Error Analysis

	Traditional Error Analysis (Δ_k)
2011	0 % (Accepted)
2012	20,05 %
2013	21,02 %
2014	16,59 %
2015	4,61 %

Average Relative Error = $\Delta = \frac{1}{3}\sum_{k=2}^{4} \Delta k =$ 0, 207 %

After calculated traditional error analysis for 2011-2015, average relative error is found as 0,207%. Means that error margin for calculations is 0,207%.

DISCUSSIONS AND CONCLUSIONS

In this study, the amount of e-waste for the next 6 years after 2015 in Turkey is predicted in order to measure the future level of e-waste problem in the country by using Grey prediction model.

As explained in previous sections, e-waste is a growing problem especially in emerging countries. The numerical results of this study are also in line with this fact. As one of an emerging country, in Turkey, currently e-waste is becoming an economic and environmental problem and according to the results of prediction in this study, it is expected that Turkey is going to suffer from e-waste generation. Therefore, reverse logistics activities including collection of e-waste from industrial areas and households, recycling, reusing and remanufacturing according to the type of product and the component is essential. Hence, strategies should be developed by policymakers in order to deal with e-waste. This study can be seen as a basis to expose the impact of e-waste from an emerging country perspective. For future studies, e-waste problem can be analyzed by categorization of the products. Moreover, policies for reducing the amount of e-waste can be established for countries or for the world.

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EVALUATION OF SHIPPING SCHEDULING METHOD CONSIDERING SHORTAGE AND DISPOSAL IN LOGISTICS WAREHOUSE OF APPAREL PRODUCTS

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Abstract *− In apparel supply chain, there are many kinds of products due to differences in color and size, and it is necessary to sell them during the season. On the other hand, the inventory space of stores is limited, so it is important to decide the shipping timing from the logistics warehouse to stores. However, because in the apparel industry the same products aren't sold every season, it is difficult to predict the demand. Therefore, it is better to modify the initial shipping plan after actually selling the product. In many cases, modification of the shipping plan was performed by humans. However, there are many types of apparel products, so there are limits to manually modifying shipping plans. As a way to modify the shipping plan for apparel products, there is Quick Response (QR) which has demand-driven characteristics. QR was first implemented in the middle 1980s by American apparel supply chains (Fisher and Raman (1996), Choi and Sethi (2010)). In the basic QR, a retailer sends POS data to its supplier, who then uses this information to improve demand forecasting and adjust schedules. Tsukagoshi et al. (2016) proposed a flexible ordering strategy at a retailer to change demand with QR. On the other hand, Tanaka et al. (2018) identified that the products whose shipping plan should be modified is a QR type product and it decided the shipping timing on the basis of inventory data in the logistics warehouse. Furthermore, opportunity loss due to shortage can be reduced if similar products are shipped at the same time. However, disposal of remaining apparel products at retailers becomes large, and it causes environmental problems. The aim of this study is to extract shipping pattern and evaluate appropriate timing to modify the initial shipping plan by analyzing. In this study, opportunity loss and disposal are simultaneously considered.*

Keywords − apparel supply chain, environmental factor, just-in-time inventory, shipping *record, shipping schedule*

INTRODUCTION

In recent years, with the diversification of customer needs, manufacturers have been forced to handle many different products. In particular, an individual product in the apparel industry may come in several colors and sizes. Moreover, an increasing number of apparel manufacturers not only sell clothes but also sell general products like bags and shoes (Liu et al., 2013). As a result of this wide variety of products, the apparel industry has more different products to handle than most other industries. Furthermore, there tend to be long lead times before the sales season (Iyer and Bergen, 1997), and as shipper's personnel are influenced by fashion, it is difficult to accurately forecast customer demand and determine the right amount of production (Mostard et al., 2011). In addition, new apparel products are sold every season because their product life cycle is very short (Kim, 2003). These factors all lead to demand uncertainty in the apparel industry that is much greater than that found in an industry that sells only one or a few different products.

An apparel supply chain flows as follows. Under the direction of the manufacturer, products are manufactured at plants and shipped to a logistics warehouse. When the work at the logistics warehouse is completed, the products are shipped to stores at a specific time, where they are ultimately sold to customers (Tanaka et al., 2018). When a customer buys a product, the store registers the sale information as POS data.

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Products that cannot be sold during the sales season are returned from the store to the logistics warehouse, and will be sold in the same season in the following year or discounted at the EC (Electronic Commerce) site and sold. Products that still cannot be sold will eventually be disposed of. However, the apparel industry is the second largest industry in the world and disposal of unsold products can greatly impact the world's resources (Moore and Ausley, 2004). As the amount of unsold products is increasing, disposal is creating an environmental problem (Koch and Domina, 1997). Therefore, in an attempt to minimize the quantity of unsold products, customer demand should be considered when a manufacturer is making production decisions.

The timing and amount of each product shipped is determined as follows. In general, for arrival from plants to the logistics warehouse, the timing and amount of each product shipped is determined in advance, depending on the manufacturer's strategy. For shipments from the logistics warehouse to stores, some products are shipped according to an initial shipping plan and other products are shipped after changes in the initial shipping plan are made based on product sales. Therefore, the shipment of each product can be controlled at the logistics warehouse. When shipments are sent from the logistics warehouse is earlier, pressure is placed on the stores because their inventory space of the stores is limited. In addition, there is the possibility that the product will not be sold and will eventually be returned to the logistics warehouse. On the other hand, when shipments from the logistics warehouse are delayed, stores will experience product shortages and, as a result, they will lose the opportunity to make sales. Therefore, if the amount and availability of products is not based on customer demand, returns or opportunity losses will occur because of unsold or shortages. Consequently, inventory control in terms of determining shipping timing and amount to be shipped from the logistics warehouse to stores is important, and this inventory control role is assumed by the shipper's personnel.

Normally, the shipper's personnel obtain sales information for all products and determine the timing and amount of shipment for each product based on the initial shipping plan. This allows proper inventory allocation and the number of products sold at fixed price will increase. However, if this does not go well, shortages and returned products will increase and the number of products that must be sold at a discount will increase. Therefore, after considering the sales information for all products, the shipper's personnel are required to make decisions about distributing the inventory from the logistics warehouse and should modify the initial shipping plan accordingly. In reality, because there is such a large selection of apparel products and new products are arrived every day, it is difficult to grasp the sales information for all stores and all products. The shipper's personnel cannot consider all of the data and pays attention to inventory allocation of only new products.

Hence, the goal of this study is to build a system to support decision making by shipper's personnel. In this paper, we analyze the shipping records and just-in-time inventory at a logistics warehouse. Sales information is extracted for all products whose shipping plans should be examined and modified if necessary. Specifically, the first is to reduce the number of products to see by limiting the products that shipper's personnel should modify shipping plans. The second is to determine in real time the shipping timing of products whose shipping plan is to be modified. By being able to do them, shipper's personnel can make final shipping decisions while considering the possibility of shortages or disposal.

The next section reviews literature on the methods used in the apparel industry for modifying shipping plans. The third section explains the method proposed in this study for modifying shipping plans. Numerical experiments are carried out and the validity of the proposed method is verified. The final section concludes the paper with some perspectives.

LITERATURE REVIEW

This section summarizes existing literature, and presents a model that utilizes a QR (Quick Response) strategy, as well as a method of forecasting demand for apparel products based on data analysis.

Because of the uncertainty of the demand for apparel products, a strategy has been developed for revising a demand forecast based on the results of trial sales prior to the start of full scale sales. This strategy is called QR and was originally developed as an inventory management strategy. QR made it possible to reduce lead time and quickly respond to market needs (Choi and Sethi, 2010). QR was first implemented in the apparel industry in America in the mid-1980s as a strategy for global response (Fisher and Raman, 1996), but is now a strategy used in various industries. From the standpoint of inventory management, it is possible to collect more information to shorten the lead time and improve the demand forecast (Choi, Zhang, and Cheng, 2018). In basic QR, a retailer sends POS data to its supplier, who then uses this information to improve demand forecasting and adjust schedules (Choi and Sethi, 2010).

A review of the literature suggests a method for improving the accuracy of demand forecasts and reducing shortages or unsold products using the results of data analysis. Tsukagoshi et al. (2016) proposed using a QR inventory management strategy when the replenishment lead time is relatively short compared to the sales period by introducing a monitoring period prior to the normal sales period, and found that it reduced total shortage costs. On the other hand, Tanaka et al. (2018) showed that products whose shipping plans need modification are QR type products and determined shipping timing based on inventory data in the logistics warehouse.

Mostard et al. (2011) proposed a model that predicts demand during the sales period using preliminary order data, which is evaluated by a specialized department when an apparel company needs to order products in the pre-season. Gurnani and Tang (1999) determined retailers' optimal ordering decisions when faced with uncertain costs and random demand for products during the sales season and characterized the conditions for retailers to postpone ordering decisions.

METHOD

This study considers an apparel supply chain as seen in Figure 1. The apparel supply chain consists of multiple plants, one logistics warehouse, one store, and many customers. This study proposes a method for identifying products whose initial shipping plans should be modified based on an analysis of data in the logistics warehouse. Since sales of apparel products tend to occur weekly (Frank et al., 2003), weekly changes are used.

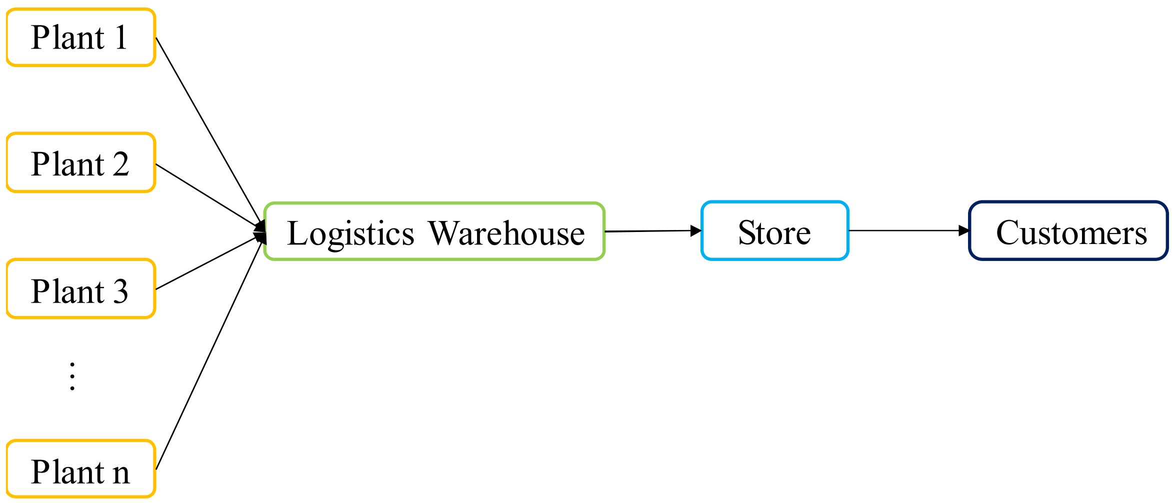

Figure 1. Apparel Supply Chain

Parameters and Variables

The following parameters and variables are used:

N	number of products
T	sales period [weeks]
t	elapsed periods [weeks] (t = 1, …, T)
i	product number (i = 1, …, N)
$d_i(t)$	shipping amount of product i in week t
D_i	total delivery amount of product i
$u_i(t)$	shipping rate in week t of product i
K	number of clusters
T'	investigated sales period
$y_{p,t}$	shipping rate of cluster p in t-th week

Identification Method Using Data at the Logistics Warehouse

In the logistics warehouse, activities related to the products produced by the plant are carried on daily and the instructed product numbers, colors, and sizes in the indicated amounts are shipped. In addition, unsold products are returned from stores to the logistics warehouse during the sales period. The shipper's personnel sets a sales policy for each product, sets up a shipping plan, and determines the timing and amount of shipment. The root of the shipper's personnel decision-making is the sales policy. Therefore, the difference in sales policy leads to extraction of products to be reviewed by shipper's personnel. Since sales policy may be different in product color or size, we first see sales policy with product units, SKU (stock keeping units). In addition, since the sales policy is reflected in the timing and amount of shipment from the logistics warehouse to the shop, the shipping change of each SKU is observed from inventory change in the logistics warehouse.

First, the changes in inventory for certain products in the logistics warehouse are shown in Figure 2. The initial inventory amount shown as week 0 is the arrival amount, and the amount dropped by the next week is the shipment amount. According to Figure 2, there are large differences in the initially arrival amount depending on the product. The amount to be shipped, which is the change amount each week, also changes differently depending on the product. Because of these differences, it is difficult to handle these products using one scale. Therefore, by normalizing the inventory amounts in the logistics warehouse and seeing the changes in shipping amounts, all products can be viewed on the same scale. The first step, shown in (1), is to obtain the shipping amount ui(t) for each product each week.

$u_i(t) = d_i(t)/ D_i$. (1)

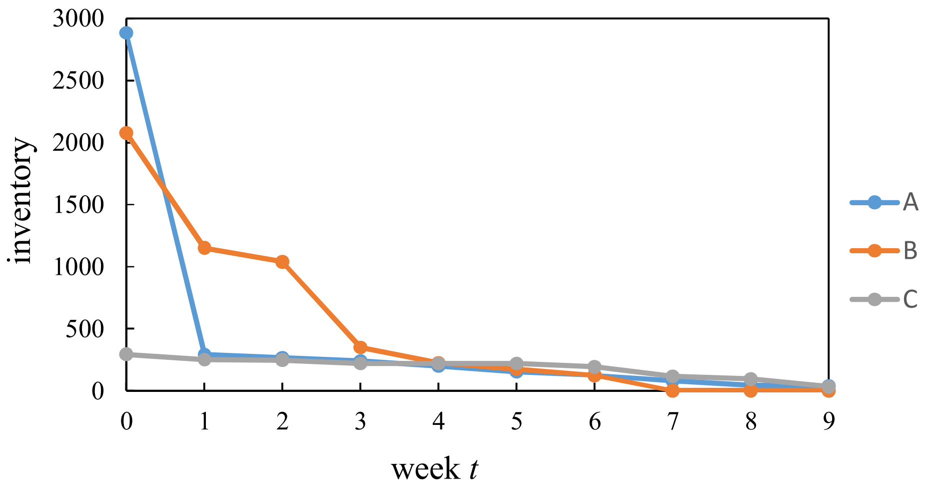

Figure 2. Inventory Changes for Certain Products

Strictly, the sales policy differs for each SKU, but it can be considered to be divided into some types. However, when set to one type, since the sale policies can no longer know, they divided into multiple groups. Therefore, cluster analysis is performed on ui(t), second. Grouping is done using this procedure, according to shipping changes, and the shipper's personnel identify the products to be reviewed. Changes of shipping rates at each week for each group will prompt the pattern extraction of sales policies.

Results and Discussion of the Identification Method Using Data at the Logistics Warehouse

This section describes the results of the calculations using the above procedure. This apparel brand is assumed to sell only clothes and there are 796 products, which are sold in only one season. Originally, this apparel brand deals with more products, but for simplicity this study deals with some products. In addition, cluster analysis was performed on variable t (t = 1, …, 9), with the sample number N=796 using the k-means method. Since the k-means method is a non-hierarchical cluster analysis, it is necessary to set the number of clusters in advance. In this study, the k-means method was performed several times to search explicitly for the number of highly explanatory clusters, and the number of clusters was set to K = 5 as a result. The results are shown as the average values for each cluster in each week. Table 1 presents the results of the cluster analysis and the number of products is shown in Table 2.

Table 1. Average Shipping Rate Each Week for Each Cluster

Cluster	Shipping Rate								
Number	1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week
1	0.937	0.029	0.009	0.009	0.004	0.003	0.003	0.001	0.001
2	0.571	0.112	0.065	0.054	0.046	0.034	0.022	0.025	0.014
3	0.268	0.056	0.478	0.052	0.018	0.006	0.063	0.029	0.012
4	0.205	0.055	0.038	0.491	0.098	0.019	0.022	0.029	0.014
5	0.156	0.040	0.061	0.065	0.055	0.094	0.200	0.149	0.051

Table 2. Number of Products in Each Cluster

Cluster Number	Number of Products	Proportion
1	402	0.505
2	173	0.217
3	103	0.129
4	25	0.031
5	93	0.117
Total	796	1.000

According to Table 1, clusters 1 and 2 have large shipping rate in the first week, and after the second week they decline. This suggests that the products included in clusters 1 and 2 are expected to be sold out in one shipment. This may be due to the sales policy of putting products in a shop front and allowing customers to recognize them. In addition, the shipment of these products is concentrated early in the sales period, and so it is hardly necessary to modify the initial shipping plan. Based on the above characteristics, these are VMD (visual merchandising) type products. VMD is a strategy for getting customers to recognize products by having them exhibit apparel products to sell at stores (Jain et al., 2012).

On the other hand, clusters 3, 4, and 5 show that the shipping rates in the first week are small, and the peak shipping rates occur in the third, fourth, and seventh weeks, respectively. Therefore, it is considered that the products included in clusters 3, 4, and 5 are shipped incrementally. This is a policy where a small amount of product is shipped at the beginning of the sales period, then additional products are shipped after the sales of the products are observed, or selling them for as long as possible. For these reasons, clusters 3, 4, and 5 can be said to be like QR type products. That is, shipping timing and the amount of additional product to be shipped depend on that product's sales from the previous shipment. Hence, in some cases, the initial shipping plan of these products may need to be modified such that the shipping timing is advanced or delayed.

In the case of this brand, the policy is roughly divided into two types. They are a policy to sell products early in sales period and a policy to sell in stages in consideration of sales. The difference between these two policies appears in the shipping rate for the first week. Accordingly, this analysis makes it possible to identify that the products that need their initial shipping plan modified are QR type products like clusters 3, 4, and 5. By looking at the shipping rate in the first week, the products can be divided into VMD type and QR type, and the threshold value is 0.361. Also, as seen in Table 2, since the products in this brand that correspond to the QR type are 27.7% of the total, the data the shipper's personnel need to consider can be greatly reduced.

Determining Shipping Timing for QR Type Products

Although the shipper's personnel can identify the products whose sales information should be examined, they must also decide how to modify the initial shipping plan at each timing. There are two things that are not going as shipping plan, which are selling more than shipping plan or not selling than shipping plan. Therefore, the next thing to do is determining when to modify the initial shipping plan. In order to determine an appropriate shipping timing, if there is no standard in each week, it cannot judge whether it is better or bad than the initial plan. In this case, the average value of each pattern obtained by shipping pattern analysis at each week is taken as a reference. In the case sales are not carried out as planned, it is when the changes of shipment from the logistics warehouse is greatly far away from the basis. Therefore, the timing of modifying the initial shipping plan is when it is far away from the initial shipping plan.

In this research, RMSE (root mean squared error) is used as an index to show how far away from the basis. RMSE is used to evaluate the accuracy of the regression analysis. By using this method it is possible to consider how closely the measured value of the output compares to the predicted value of the output. The closer the RMSE is to 0, the smaller the estimated error, that is, the higher the prediction accuracy. When T' is the investigated period and yp,t is the shipping rate of cluster p and t-th week, RMSE is calculated using (2).

$$RMSE = \sqrt{\frac{1}{T'}\sum_t \left(u_i(t) - y_{p,t}\right)^2}. \qquad (2)$$

However, in the investigation stage, it is not known which shipping pattern each SKU belongs to. Therefore, RMSE is calculated for all patterns of QR type. From the complete calculation, the shipping pattern with the smallest value is taken as the shipping pattern to which the product belongs. In fact, since the shipping pattern has not been determined for the products that are currently on sale, part of the shipping data in the logistics warehouse is used as the test data. By comparing the pattern calculated by RMSE with the actual shipping pattern, the effect of using RMSE is verified.

Numerical Experiment to Determine Shipping Timing

In this numerical experiment, using the previous results, the 221 products determined to be QR type are randomly divided into past data and current data. There are 176 with past data, and 45 with current data.

Table 3 shows the matching rate between the calculation result of RMSE and the actual shipping pattern in each shipping pattern. In Table 3, the matching rate from the second week to the fifth week is shown.

Table 3. The Matching Rate

Week	2nd week	3rd week	4th week	5th week
Pattern 3	0.591	0.955	0.955	0.955
Pattern 4	0.200	0.200	1.000	1.000
Pattern 5	0.611	0.722	0.944	0.944
total	0.605	0.814	0.977	0.977

For Pattern 3, the match rate has increased significantly since 3 weeks. This can be said from the fact that the peak of the shipping rate of Pattern 3 has arrived at the third week. On the other hand, Pattern 4 and Pattern 5 have matching rate exceeding 90% at the 4th week. This is because Pattern 4 has a shipping rate peak at 4th week and Pattern 4 and Pattern 5 can be distinguished at 4th week. From the above, it is possible to specify the pattern by the 4th week and modify the initial shipping timing best.

Table 4 represents a change of the shipping ratio of certain test data. The actual pattern is 3, but in the calculation result by RMSE it is the closest to pattern 3 in the second week and closest to the pattern 4 in the third week. From this change of ratio, it can be considered that this data is closest to the pattern 4 at the third week, because the shipping ratio at the third week is small. Also, due to shipping rates of this product, the shipping rates at the third and fifth weeks exceed 0.200. This is because there is a possibility that the product was insufficient at the ratio shipped at the 3rd week and about same ratio was shipped at the 5th week. By using the RMSE result of the second week, shipment the same proportion as the baseline at the third week makes possible to prevent shortage that may have occurred at the fourth week. On the contrary, when the shipping ratio is higher than the base line, it is possible to reduce the disposal by suppressing the shipment.

In the QR strategy, all remaining products are shipped at the time the sales information is accepted, but by using this method, it is possible to ship according to more actual demand. Specifically, even if sales information is obtained, there is also a case where it is time to recognize sales information instead of immediately shipment products for which sales information has been obtained. For example, there are sales information, but it is far from the base line and the shipping ratio is small. By shipping all products at the same time or by not judging only with one sales information, it will lead to a reduction in disposal at stores.

Table 4. The Change of Shipping Rate of Sample Data

1st week	2nd week	3rd week	4th week	5th week	6th week	7th week	8th week	9th week
0.306	0.044	0.214	0.121	0.228	0.063	0.000	0.000	0.000

CONCLUSION

In order to construct a support system that shipper's personnel should understand as few data as possible, this study proposed and evaluated a method for modifying an initial shipping plan to reduce opportunity losses due to shortages and disposals of apparel products. Concretely, since the shipper's personnel decides the sales policy and makes a shipping plan, we determined whether the shipping plan is to be modified due to differences in sales policy. By analyzing real data in a logistics warehouse, the products whose shipping plans should be modified are identified, and the method proposed in this study is verified with some established scenarios.

The shipper's personnel set up an initial shipping plan based on the sales policy. Therefore this study proposed a method of extracting the sales policy from the shipping rate of the logistics warehouse. In the determination of the shipping timing, the RMSE was used to find out how far the distance from the basic shipping pattern, and the matching rate with the actual shipping pattern was obtained. In addition, the proposed method can consider both shortage and disposal simultaneously than traditional QR.

As a result, the products whose shipping plan is to be modified is QR type products which is shipped several times in sales period, which can be judged from the shipping rate of the first week. In addition, we analyzed the scenario by classifying the products judged as QR into past data and current data. By comparing the result calculated by RMSE and the actual shipping pattern matching rate, 90% of the shipping pattern is known at 4 weeks and it is best timing to modify the initial shipping plan.

For future work, since the intentions of the shipper's personnel are included in the past data, it is necessary to improve the usage of past data, such as analyzing the sales data of each store to further refine the shipping plan. Also, to detect color trends, considering the color changes of other brands will make it possible to obtain results that reflect more realistic trends. Applying the method proposed in this study to other brands could also be considered.

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MACHINE REPLACEMENT SCENARIO ANALYSIS: A CASE STUDY OF FOOD INDUSTRY

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Abstract *– The Machine replacement is one of the major problems for a maintenance department. One of the trends in food consumption is the use of ready-to-eat meals. In Asian countries, most meals are an integration of a major part of rice with minor parts of vegetables and/or meat. For ready-to-eat manufacturers, a rice cooker is an important machine to process rice as a main ingredient. Our objectives were to estimate the lifetime of parts of an automatic rice cooker and to determine when to replace the parts by scenario analysis. We studied the worst cast, best case, average case and simulation in two situations: before and after implementing Total Productive Maintenance (TPM). The input parameters included the lifetime and cost of 30 parts of the rice cooker. The lifetimes of the parts were considered as random variables according to probability distributions determined by a simulation software. The output of the simulation was the total maintenance cost of the parts replacement between one and ten years. Next, the lifetimes of parts were determined based on a scenario such as the minimum, maximum and expected values of lifetimes according to the historical data and supplier data. The result showed that the average case model after TPM implementation is the best estimator with 10.55% difference to the actual maintenance cost. The simulation after TPM implementation was the second best method with 16.97% difference. It implied that the TPM implementation was able to lengthen the part life and results in maintenance cost reduction. In addition, the inventories of parts were categorized by ABC classification. It helped the manufacturer to allocate the resources and monitor the right parts. In summary, the average case analysis was the best estimator to determine when to replace a part how much of the maintenance cost of the rice cooker. In the future, this model could support the manufacturer to decide whether it should invest for different types of machines.*

Keywords – Machine Replacement, Simulation, Scenario Analysis, Total Productive Maintenance, Inventory Classification, Spare Parts Inventory Management

INTRODUCTION

Due to changes in structure and work habits of the traditional family unit, the industry offers a wide range of prepared food (e.g. ready-to-cook and ready-to-eat items) (Park and Capps, 1997). Also in Thailand a transition has taken place in food consumption patterns, especially in big cities, with inhabitants with higher incomes, and the younger generation. Food is selected based on less time and skill to prepare. Home-made meals are replaced by ready-to-cook and ready-to-eat foods bought at food stalls, supermarkets or department stores (Kosulwat, 2002).

This study concentrated on a manufacturer of ready-to-eat meals of which the major raw material is rice. The rice cooker is the main machine to cook rice for all ready-to-eat products in the assortment and therefore is very important. A rice cooker is a consumer durable. It has been estimated that the average lifetime of a rice cooker in Japanese households in 8.5 years (Oguchi et al, 2008). In the past, the maintenance department implemented a basic maintenance plan, some parts were replaced often, leading to a high cost and low productivity. A few years ago, the company started to implement the philosophy of total productive maintenance (TPM) for their machines and equipment (Nakajima, 1988). The storage of parts and equipment needs a policy to keep the parts efficiently. Thus, the objectives of this study were to estimate the distribution of the lifetimes of the rice cooker parts and to decide on the replacement time considering scenario analysis. In addition, an appropriate inventory policy of rice cooker parts based on historical data and TPM implementation was determined.

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Any production system is vulnerable so it fails from time to time. A failed machine needs to be repaired which causes unproductive time. In production systems, the productive time can be increased by introducing stand-by machines or intermediate buffers. For example, consider a flow-line production system, which consists of a linear sequence of several machines. Since the machines cannot perform their operations when they do not receive input or cannot produce output, the entire production system fails if one machine does. A first solution to this problem is to install secondary (standby) machines in parallel with the primary machines that come into operation when a machine fails. Another solutions is to install buffer storage between successive stages of the production line, unlinking these stages and allowing production to continue while the machines are being repaired (Buzacott & Hanifin, 1978; Sörensen & Janssens, 2004). Many aging machines, like a rice cooker, suffer from deterioration. Due to higher operating and maintenance costs, it might be more economical to replace the machine after a certain time of usage (Verheyen, 1979). A review on equipment analysis appears in Hartmann and Tan (2014). Whether a production system consists of a single machine or a network of machines, maintenance of the system is required, i.e. a combination of technical and administrative actions to retain or restore the system into a state in which it can perform as required. The main reason is that poorly maintained machines or equipment leads to random failures causing unavailability for production, which is directly linked to the profitability of a company. Maintenance requires a maintenance strategy, i.e. a systematic approach to upkeep the equipment involving identification, research and execution of repairs, replacement and inspection decisions (Kelly, 1997). Selection of the best maintenance strategy depends on several factors. The company under study has chosen for Total Productive Maintenance (TPM).

Any type of equipment contains several components or parts which are confronted with planned or unplanned maintenance. Unplanned maintenance refers to random failures of the components or parts. Corrective maintenance is the original maintenance strategy appearing in industry (Waeyenbergh & Pintelon, 2002), where maintenance is done whenever a failure occurs. This strategy is acceptable when the consequence of failure is small. Predictive maintenance is a planned maintenance approach where failures of facilities are avoided. This approach tries to forecast lifetime of equipment and recommends a corrective action. The downtime of equipment can be reduced if the preventive maintenance strategies are correctly selected (Mobley, 2002).

METHODOLOGY

The methodology consists of several steps. The first step collected historical data of parts of a rice cooker from the maintenance department including part name, age and cost. For practical reasons, data collection was limited to a period of two years. Next, the distribution of age using situation analysis was determined. Then, the age of parts of a rice cooker wss evaluated in six scenarios using worst case, best case, average case and simulation model as shown in Table 1.

1. Worst case: If a part has been replaced before two years of age, we use the minimum age before replacement. A part that has never been replaced before two years, an age of two years is used.
2. Best case: If a part has been replaced before two years of age, we use the maximum age before replacement. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
3. Average case 1: If a part has been replaced before two years of age, we use the average age. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
4. Average case 2: To estimate the part age after TPM implementation, a part that has been replaced before two years, the average age of the last two replaecment times is used. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
5. Simulation case 1: A part that has been replaced before two years, the age is simulated by means of a historical age distribution. A part that has never been replaced before two years, the supplier is asked to evaluate the age.
6. Simulation case 2: To estimate the part age after TPM implementation, a part that has been replaced before two years, the age is simulated by means of a historical age distribution but by cutting the lowest age. A part that has never been replaced before two years, the supplier is asked to evaluate the age.

Table 1. Situation Analysis of Part Age

Senarios	Age of rice cooker parts (days)	
	Parts ever be replaced before two years	Parts never be replaced before two years
Worst case (W)	Minimum age	2 years
Best case (B)	Maximum age	Evaluate age by a supplier
Average Case (A1)	Average age	Evaluate age by a supplier
Average Case 2 (A2)	Average age of the last two ages	Evaluate age by a supplier
Simulation 1 (S1)	Distribution of age	Evaluate age by a supplier
Simulation 2 (S2)	Distribution of age after cutting lowest age	Evaluate age by a supplier

In the first four scenarios, the part age was assumed to be constant under different situations. A spreadsheet was used to calculate the number of parts used in a period of ten years. The latter two scenarios, a simulation model was built to mimic the part replacement process of 30 parts of a rice cooker using ARENA software version 14.0. We determined the replacement time or the age of parts based on the age estimated from Table 1. The 'Record' module recorded the number of parts arrivals and the replacement cost was calculated. Thirty replications were run for the period of ten years. Then, the total replacement cost estimation of 6 scenarios were compared with the actual cost. Next, the parts inventory was categorized based on its replacement cost for a two years basis using ABC analysis. It helps the maintenance department to prioritize the thirty parts and determine the right policy for parts replacement. Finally, an appropriate inventory policy of each category was proposed.

RESULTS AND DISCUSSION

Part Life Analysis

Some parts of the rice cooker were replaced before two years. The replacement time indicates the life of the part and the distribution of age was determined from the historical data. Since there was limited historical data of part life, we proposed several scenarios and determined the best scenario to be representative of the current situation. For some parts, only two data points were available and the best distribution determined by input analyzer in ARENA software was a Beta-distribution. On the other hand, other parts have never been replaced before two years. It implied that their lifetimes were more than two years. Hence, we asked the suppliers of parts to estimate the life as a constant of lifetime. The first set of parts had an equal lifetime of 730 days or two years i.e. the motor pump, the mechanical seal, the connecting, the solenoid valve, the free roller in feed, the gear motor, the gear box, and the chain tensioner roller. In Arena, we combined the arrival of these parts in the same 'Entity' with a total cost of 99,213 Baht. Next, the second set of parts contained the feeding transportation roller and the curve roller with a total cost of 10,674 Baht. Their lifetimes from supplier estimation was three years or 1,095 days. The third set contained the main driving pocket, the control box, and the gas burner with a total cost of 257,324 baht and estimated life from supplier was 1,825 days or five years. The other parts had a different replacement interval within two years. We observed that there were many parts that the minimum and maximum lifetimes were very different such as the transportation chain, the support bearing for main driving shaft, the transportation free roller type, the main driving unit, the lid supporting, the belt, the main driving shaft, the lid supporting 1 and 2, the gas connecting, the pressure regulator, the key and the shaft. The reason was that the company starts implementing TPM that can extend the lifetimes of the parts.

Simulation Model

First, the simulation model to estimate the number of part replacements was built. There were thee basic modules: create, record and disposal. First, the arrival contained the interarrival time which implied the life of the parts. Next, the record kept the number of parts replaced in a certain time. Finally, the parts departed from the system. In addition, we established the cost of a part as a variable in variable spreadsheet module. The simulation model was made up in the simulation software ARENA version 14.0 (Kelton et al., 2014).

Table 2. Distributions and parameters of part lifetimes of a rice cooker in six scenarios

Parts	Code	Cost (Baht)	Life of rice cooker parts of Scenario (days)					
			W	B	A1	A2	S1	S2
Motor Pump	M9	25,000	730	730	730	730	730	730
Mechanical Seal	M23	1,700	730	730	730	730	730	730
Connecting	M30	270	730	730	730	730	730	730
Solenoid Valve	M21	2,560	730	730	730	730	730	730
Free Roller In Feed	M12	12,883	730	730	730	730	730	730
Gear Motor	M10	25,000	730	730	730	730	730	730
Gear Box	M11	25,000	730	730	730	730	730	730
Chain Tensioner Roller	M17	6,800	730	730	730	730	730	730
Out Feeding Transportation Roller	M29	367	730	1095	1095	1095	1095	1095
Curve Roller	M13	10,306	730	1095	1095	1095	1095	1095
Main Driving Pocket	M6	72,324	730	1825	1825	1825	1825	1825
Control Box	M4	92,500	730	1825	1825	1825	1825	1825
Gas Burner	M3	92,500	730	1825	1825	1825	1825	1825
Transportation Chain	M18	6,762	34	316	146	316	34 + EXPO(89.8)	235 + 82 * BETA(0.226, 0.238)
Support Bearing for Main Driving Shaft	M20	3,480	23	273	122	221	23 + EXPO(68.4)	49 + 224 * BETA(0.226, 0.238)
Transportation Free Roller Type	M7	68,000	223	507	365	365	223 + EXPO(68.4)	223 + EXPO(68.4)
Main Driving Unit	M5	72,324	10	271	104	215.5	TRIA(10, 55, 160)	62 + 209 * BETA(0.226, 0.238)
Soaking Tank	M1	874,000	730	2555	2555	2555	2555	2555
Lid	M8	49,000	304	426	365	365	304 + 122 * BETA(0.112, 0.112)	304 + 122 * BETA(0.112, 0.112)
Lid Supporting 1	M19	3,897	70	448	243	330	70 + EXPO(173)	70 + EXPO(173)
Belt	M2	102,760	191	539	365	365	191 + 348 * BETA(0.112, 0.112)	191 + 348 * BETA(0.112, 0.112)
Main Driving Shaft	M14	9,000	49	414	183	300	49 + EXPO(134)	49 + EXPO(134)
Lid Supporting 2	M22	2,385	49	310	122	252	20 + EXPO(102)	194 + 116 * BETA(0.226, 0.238)
Gas Connecting	M27	1,440	264	466	365	365	264 + 202 * BETA(0.112, 0.112)	264 + 202 * BETA(0.112, 0.112)
Pressure Regulator	M24	1,530	195	535	730	730	730.00	730.00
Pressure Gauge	M26	1,500	163	388	243	284	163 + WEIB(17.7, 0.262)	163 + WEIB(17.7, 0.262)
Shut Valve	M16	8,610	730	1460	1460	1460	1,460.00	1,460.00
Electric Connecting Terminal	M28	1,440	324	406	365	365	324 + 83 * BETA(0.237, 0.226)	324 + 83 * BETA(0.237, 0.226)
Key	M25	1,530	195	535	365	365	195 + 340 * BETA(0.112, 0.112)	195 + 340 * BETA(0.112, 0.112)
Shaft	M15	9,000	49	580	365	365	150 + 430 * BETA(0.112, 0.112)	150 + 430 * BETA(0.112, 0.112)

Output Analysis

In our analysis (and in the figures in this section), the parts of the rice cooker were coded as M1,..,M30 for simple identification. The cost and the number of parts used in six scenarios were shown in Table 3. The maximum cost was 874,000 baht for soaking tank and the minimum cost was 270 baht for connecting. The total cost of parts for a rice cooker was 1,583,868 baht. The result showed that in the worst case scenario, parts which had a record of replacement by two years were replaced often. This could not happen in the actual system. However, it showed how poor the situation could be. Next, for the best case scenario, the parts were assumed to have the maximum lifetime and were replaced the least. This case represented the lower bound of the budget for the rice cooker replacement. The average case before TPM implementation (A1) represented the past situation quite well, however, the average case after TPM implementation (A2) represented the present situation since the lifetime of parts were lengthened due to proper maintenance. The numbe of parts obtained via the simulation models were the average of 30 replication runs. We oberved that the number of parts used in A1 and S1 and A2 and S2 were very similar since the lifetimes were obtained from the same assumption before and after the TPM implementation. Figure 1 visualized the comparison of the number of parts used in the five scenarios except the worst case since it was an extreme case which outranged the other cases.

Table 3. Total Replacement Cost Estimation of 6 Scenarios

Year	Total Replacement Cost Estimationof Scenario (baht)					
	W	B	A1	A2	S1	S2
1	3,114,364	84,951	504,658	332,518	546,677.97	329,466.10
2	7,734,935	518,212	1,194,542	841,583	1,268,976	890,461
3	10,987,186	929,738	1,709,874	1,259,483.60	1,952,651	1,348,652
4	15,600,994	1,197,789	2,408,368	1,706,335	2,736,293	1,926,244
5	18,974,202	1,787,721	3,172,050	2,385,066	3,638,751	2,638,535
6	23,528,213	2,296,947	3,870,907	2,899,624	4,443,652	3,220,644
7	26,847,024	3,356,937	5,251,265	4,121,969	5,982,532	4,582,738
8	31,457,172	3,730,808	5,949,759	4,639,644	6,780,445	5,127,284
9	34,709,483	4,133,334	6,465,091	5,057,545	7,473,966	5,600,916
10	39,382,951	4,715,219	7,412,299	5,764,507	8,478,095	6,403,187

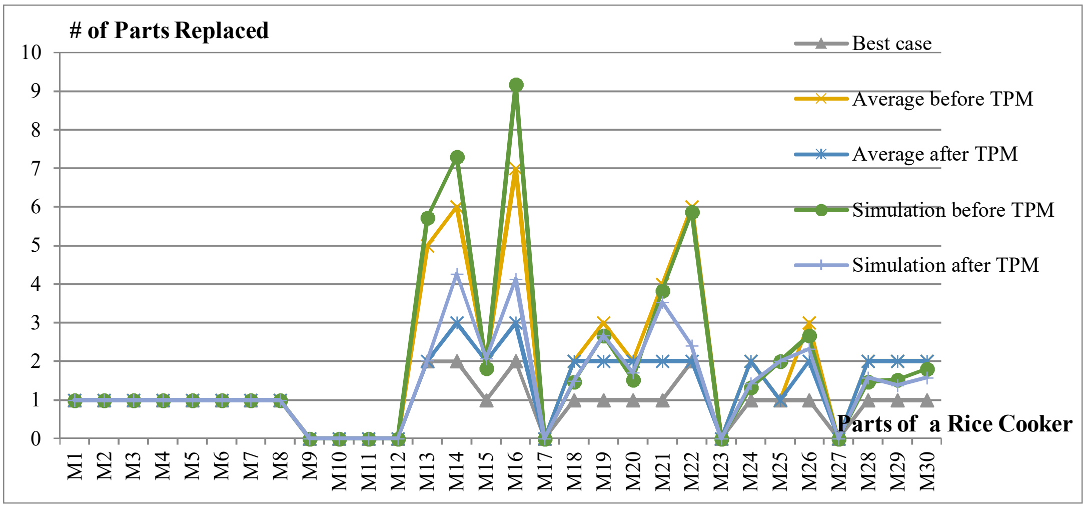

Figure 1. The Estimated Number of Part Used in Six Scenarios for Two Years

The cumulative and average annual replacement costs in a period of 1 to 10 years of six scenarios were shown in Table 3 and Figure 2. This estimation helped the engineering department to determine a strategic budget plan of the rice cooker replacement. The result showed that the replacement cost estimation ranking from the lowest to highest were: (1) best case, (2) average case after TPM implementation, (3) simulation after TPM implementation, (4) average case before TPM implementation, (5) simulation before TPM implementation, and

(6) worst case, respectively. The result seemed to be reasonable since the simulation case included more uncertainty, so the replacement cost was higher than the average case. In addition, it was more economic to replace the parts as fast as possible since the average annual replacement cost estimated showed that the cost was increasing year by year.

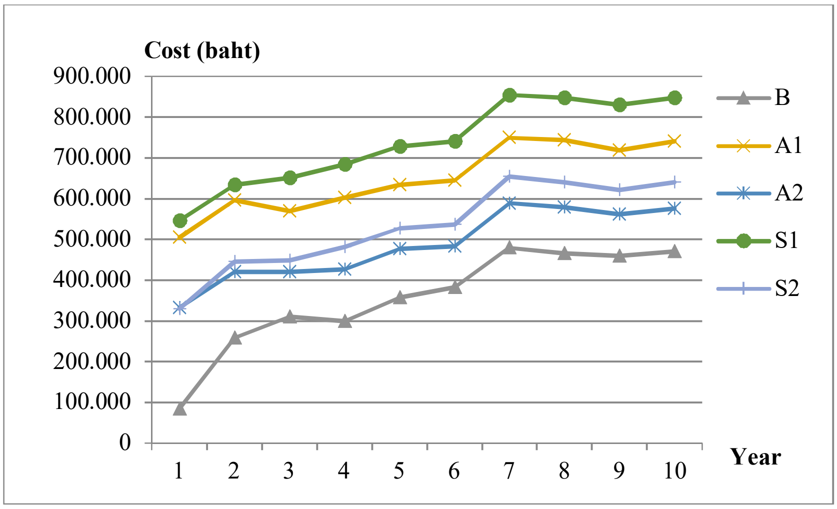

Figure 2. Average Annual Replacement Cost Estimation of Five Scenarios

Part Replacement Cost Comparison

Then, we compared the replacement of rice cooker parts for two years (2009-2010) of six scenarios with the actual cost as shown in Table 4. The actual cost replacement cost for two years was 761,281 baht. The average cost after TPM implementation was the best estimator with 10.55% difference. The simulation after TPM implementation was the second best estimator with 16.97% difference. While the estimators before TPM implementation were poor since the maintenance policy changed. In summary, after TPM implementation, the part life could be estimated by using the average of the recent historical data during TPM implementation. This implied that after TPM implementation, the life of machines or parts are lenghten and the total replacement cost can be reduced.

Table 4. Two-Year Replacement Cost Estimation

Case	Before TPM Implementation		After TPM Implementation	
	Total Replacement Cost (baht)	% Difference	Total Replacement Cost (baht)	% Difference
Worst Case (W)	7,734,935	916.04%	-	-
Best Case (B)	-	-	518,212	-31.93%
Average Case	1,194,542 (A1)	56.91%	**841,583 (A2)**	**10.55%**
Simulation	1,268,976 (S1)	66.69%	890,461 (S2)	16.97%
Actual Cost	-	-	761,281	-

Inventory Control for Spare Parts of the Rice Cooker

Spare parts of the rice cooker will be kept in a store for maintenance or repair. Spare parts for equipment might be expensive and costly to keep in inventory. However, spare parts still need to be kept in inventory to limit equipment unavailability. In case preventive maintenance is implemented, the demand for spare parts appears from two sources: the scheduled maintenance and the demand due to random failures. An ordering policy for this situation is proposed by Vaughan (2005).

In this part, we categorized the parts based on ABC analysis from the estimated replacement cost for two years in six scenarios as in Table 5. The result showed that mainly the types of all thirty parts was almost the same in the A1, A2, S1, S2. The worst and best case scenarios led to slightly different types in some parts. However, we analyzed, based on scenarios A2, which is the best estimator of the replacement. There were parts, of which their lifetime was longer than two years, so they have not been replaced in two years i.e. motor pump, gear motor, gear box, free roller in feed, chain tensioner roller, mechanical seal and gas connecting (M9-M12, M17, M23, and M27). These parts were categorized in type C which implied that the staff could less strict check for the inventory of these types. On the other hand, the parts of type A included the soaking tank, belt, gas burner, control box, and main driving unit which had a high cost, but their lifetimes were about two years. This implied that the staff should strictly inspect these parts. We noticed that, if the staff could raise the life of the shut valve (M16), the replacement cost could be reduced. In addition, we can implement this category interpretation in the maintenance department where the staff should strictly inspect the condition of type A parts and less strict for type B and C, respectively.

Table 5. The Type of Part in Six Scenarios based on ABC Analysis

No.	Index	Scenarios						No.	Index	Scenarios					
		W	B	A1	A2	S1	S2			W	B	A1	A2	S1	S2
1	M1	A	A	A	A	A	A	16	M16	C	B	B	B	A	B
2	M2	A	A	A	A	A	A	17	M17	C	C	C	C	C	C
3	M3	A	A	A	A	A	A	18	M18	C	B	C	C	C	C
4	M4	A	A	A	A	A	A	19	M19	C	B	C	C	C	C
5	M5	A	A	A	A	A	A	20	M20	C	C	C	C	C	C
6	M6	B	B	B	B	B	B	21	M21	C	C	C	C	C	C
7	M7	B	B	B	B	B	B	22	M22	C	B	C	C	C	C
8	M8	B	B	C	B	C	B	23	M23	C	C	C	C	C	C
9	M9	B	C	C	C	C	C	24	M24	C	C	C	C	C	C
10	M10	B	C	C	C	C	C	25	M25	C	C	C	C	C	C
11	M11	B	C	C	C	C	C	26	M26	C	C	C	C	C	C
12	M12	C	C	C	C	C	C	27	M27	C	C	C	C	C	C
13	M13	C	B	C	B	C	C	28	M28	C	C	C	C	C	C
14	M14	C	B	B	B	C	B	29	M29	C	C	C	C	C	C
15	M15	C	B	C	C	C	C	30	M30	C	C	C	C	C	C

CONCLUSION

We estimated the lifetime of parts of an automatic rice cooker and determined when to replace the parts by scenario analysis. We studied the worst cast, best case, average case and simulation for two situations: before and after Total Productive Maintenance (TPM) implementation. The input parameters were the lifetime and cost of parts of a rice cooker. The lifetimes of the parts were random variables according to a probability distribution determined by a simulation software. The output of the simulation was the total maintenance cost of the parts replacement between one and ten years. In other cases, the lifetimes of parts were determined based on a scenario such as minimum, maximum and expected value of lifetimes according to the historical data and supplier data. After TPM implementation, the lifetimes of the machines were lenghtened and the total replacement cost was reduced accordingly and the average case model after TPM implementation was the best estimator. It implied that the TPM implementation was able to lengthen the part life and results in maintenance cost reduction. In addition, the inventory of parts was categorized by means of ABC classification. It helped to allocate the resources to monitor the right parts. In summary, for the company the average case analysis should be implemented to determine when to replace parts and to estimate the maintenance cost of the rice cooker. In the future, this model might be used as a decision support system for investment of different types of machines.

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EFFECT OF ROBUST OPTIMIZATION APPROACH ON MULTI-PLAYER MULTI-OBJECTIVE PRODUCTION PLANNING PROBLEM USING LINEAR PHYSICAL PROGRAMMING

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Abstract *− Each player in the supply chain needs to optimize two or more objectives simultaneously. Furthermore, in decision–making regarding products offered throughout the supply chain, the profit of the entire supply chain is determined by the degree to which each player sets its level. However, the objectives under consideration conflict with each other, and optimizing a solution with respect to a single objective can result in unacceptable results with respect to the other objectives. Goal programming (GP) is one of the methods to optimize two or more mutually opposite linear objective functions with desirable target values simultaneously under the constraints. However, real–life problems often include not only linear functions but also nonlinear functions. Linear physical programming (LPP) has the similar structure of the GP extended to nonlinear. LPP has the piecewise preference functions of them to approximate the nonlinear preference functions by using the several-stage preference ranges. However, LPP has been applied only to multi–objective problems of single decision maker. In this study, a model of multi–player multi–objective decision making is designed by using LPP. Improving the sum of the preference functions of all decision makers can cause the bias of the sums of the preference functions among decision makers. Yatsuka et al. (2018) extended LPP to multi–player with robust optimization to keep balance of the sums of the preference functions. However, both of improving the sum of the preference functions of all decision makers and keeping balance of the sums of the preference functions among decision makers need to be achieved simultaneously. In this study, it is possible to give each decision maker balanced choices by giving a set of solutions satisfied by the decision makers.*

Keywords − Suriawase Process, Linear Physical Programming, Robust Optimization, Multi-player decision making, Multi-objective optimization

INTRODUCTION

There are different parts such as production facilities, logistics warehouses and retail stores in a supply chain. The supply chain involves same products, but it has different optimal production quantities due to their different environments (Shrouf, Ordieres & Miragliotta, 2014; Stock & Selige, 2016). Therefore, it is difficult to find the production quantities that make them satisfied because it is not always possible to make them satisfied without changing initial plans of the ideal ranges of the production quantities (Ilgin & Gupta, 2010; Simchi-Levi, Kaminsky & Simchi-Levi, 2000). Suriawase process is one of the decision making methods of multi-player multi-objective decision making (Inoue et al., 2011; Inoue et al., 2013; Takeishi & Fujimoto, 2001) and in this research Suriawase process is applied to the decision making in the supply chain. In Inoue et al. (2011) shows the quantification of the effects of the modification of the plans, but it is not applied to the modification of the plans of all decision makers. The purpose of this research is to develop the mathematical model of multi-player multi-objective decision making.

This model has two important points. The first is multi-objective optimization, and the second is multi-player decision making. In this study, multi-objective optimization can be solved using goal seeking procedure. Goal programming (GP) (Charnes & Cooper, 1997) and linear physical programming (LPP) (Ilgin & Gupta, 2012; Konger & Gupta, 2009; Messac, 1996; Messac, 1998; Messac, 2015; Messac, Gupta & Akbulut, 1996; Ondemir & Gupta, 2014) are known methods for solving this type of multi-objective optimization. Usually, GP

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is applied to only the problems with liner preference functions. On the other hand, LPP is applied to both linear and nonlinear problems. However, not only GP but also LPP is applied to single decision maker. In this study, LPP is extended to multi-player model. Additionally, it is impossible to reproduce Suriawase process by only using LPP so that extending LPP does not have the effect of the balance of the preference levels among all decision makers. In this study, robust optimization (RO) (Ben-Tal & Nemirovski, 1998; Ben-Tal & Nemirovski, 1999; Bertsimas & Sim, 2004) is applied to multi-player LPP to multi-player LPP so that multi-player LPP has this effect. In Yatsuka et al (2018), multi-player LPP is applied and balance between the decision makers is considered. However, adjustment method of balance between the decision makers is not clear. The second purpose of this study is to adjust the effect of the balance of the preference levels among all decision makers by using RO. Decision makers can get several balanced choices by giving a set of solutions satisfied by all of them.

SURIAWASE PROCESS

The Suriawase process is the decision making method of multi-player multi-objective through the negotiations. In Suriawase process, all decision makers accept an alternative plan by the iterations of the negotiations and the revisions of the requirements of the plan of each decision makers. In other words, it may be impossible to find the plan that makes all decision makers satisfied in the initial ideal plans. However, it is possible to find the acceptable alternative plan of all decision makers. It has five steps as follows.

Step 1: Each decision maker shows the ideal ranges of the objective functions.
Step 2: All decision makers share the ideal ranges shown in Step 1 with each other.
Step 3: If there is a common range of ideal ranges shown in Step 1, proceed to Step 5.
Step 4: After negotiations that among decision makers, a compromise solution is reached.
Step 5: The compromise solution is shown to all decision makers to review the ranges of the objective functions.

In the actual Suriawase process, after Step 5, each decision maker reviews the alternative plan and the above steps are repeated. In this study, we aim to design algorithms to reproduce the above steps.

MULTI-OBJECTIVE OPTIMIZATION

In this study, the method of multi-objective optimization is to make the values of the objective functions of all targets as close to the target values of them as possible. GP and LPP are known as this type of multi-objective optimization.

In GP (Charnes & Cooper, 1997), the preference functions are defined as the functions which shows how far the values of the objective functions are from the target values of the objective functions. By minimizing the sum of the objective functions of all targets, the values of the objective functions of all targets are made close to the target values of them. There are two steps in GP. In the first step, the preference functions of all targets are defined, and the target values and weight coefficients of the objective functions of all targets are given. GP is solved as linear problems. The objective function of target $i(=1,\dots,n)$ is shown as follows by using x_j $(j = 1,\dots,m)$ and their coefficients c_{ij}.

$$\mu_i = \sum_{j=1}^{m} c_{ij} x_j \qquad i = 1,\dots,n \tag{1}$$

Moreover, the target value t_i of the objective function of target i is given and deviational variables d_i^+, d_i^- $(d_i^+, d_i^- \geq 0, d_i^+ \times d_i^- = 0)$ are defined as follows.

$$\mu_i + d_i^+ - d_i^- = t_i \quad i = 1,\dots,n \tag{2}$$

And the preference function z_i of the objective function of target i is calculated in the following equation by using the weight coefficients w_i^+, w_i^-.

$$z_i = w_i^+ d_i^+ + w_i^- d_i^- \quad i = 1,\dots,n \tag{3}$$

These preference functions show how far the value of the objective function of target $i(=1,\dots,n)$ is from the target value t_i. Therefore, because the smaller value of the preference function is better, the values of the objective functions of all targets are made as close to the target values as possible by minimizing the sum of the objective functions of all targets. The formulation of GP is shown as follows.

Objective function:

$$\min \sum_{i=1}^{n} (w_i^+ d_i^+ + w_i^- d_i^-) \tag{4}$$

Subject to:

$$\mu_i + d_i^+ - d_i^- = t_i \qquad i = 1, \dots, n$$
$$\mu_i = \sum_{j=1}^{m} c_{ij} x_j \qquad i = 1, \dots, n$$
$$d_i^+, d_i^- \geq 0, d_i^+ \times d_i^- = 0, \quad i = 1, \dots, n$$

Usually, GP is applied linear problem with liner preference functions. To apply GP to nonlinear problems, the weight coefficients are changed gradually, but the method to change the values of the weight coefficients is not clear. In LPP, the method to change the weight coefficients is shown by setting the several preference levels and their ranges of the values of the objective functions (Ilgin & Gupta, 2012, Messac, Gupta & Akbulut, 1996; Messac, 2015; Ondemir & Gupta, 2014). The preference ranges are given by several-level preference ranges of the objective functions of the targets. The target value and weight coefficients of the objective function of target i of preference level s is shown as t_{is} and w_{is}^+, w_{is}^- respectively. And the difference of target values and weight coefficients between preference level $s-1$ and s are shown as $\tilde{t}_{is}$ and $\tilde{w}_{is}^+, \tilde{w}_{is}^-$. And the values of the preference functions of the same preference level are the same among all targets. The value of the preference function of preference level s is shown as z^s and the difference of the values of the preference functions between preference level $s-1$ and s is shown as $\tilde{z}^s$. By using the parameter β, the preference functions are calculated by following the OVO rule (one vs others rule). OVO rule is the balance of the preference levels among all targets. For example, when the inequality of the preference levels is "Ideal" > "Desirable" > "Tolerable" among ten targets, that all targets are "Desirable" is better than that one target is "Ideal" and nine targets are "Tolerable." Therefore, $\tilde{z}^s$ is established as follows.

$$\tilde{z}^s = \beta(n-1)\tilde{z}^{s-1} \qquad \text{s} = 2, \dots, n_{sc} \tag{5}$$

By using Eq. (5), weight coefficients are calculated in the following algorithm.

Step1: Initial data setting: $\beta = 1.1$, $w_{i1}^+ = 0$, $\tilde{z}^2 =$ small positive number(say 0.1), $i = 0$; $s = 1$;
Step2: $i = i + 1$
Step3: $s = s + 1$
Step4: Calculate $\tilde{z}^s, \tilde{t}_{is}^+, w_{is}^+, \tilde{w}_{is}^+, \tilde{w}_{min}$ as follows

$$\tilde{z}^s = \beta(m-1)\tilde{z}^{s-1} \qquad (s = 3, \dots, n_{sc})$$
$$\tilde{t}_{is}^+ = t_{is}^+ - t_{i(s-1)}^+ \qquad (s = 2, \dots, n_{sc})$$
$$w_{is}^+ = \tilde{z}^s / \tilde{t}_{is}^+ \qquad (s = 2, \dots, n_{sc})$$
$$\tilde{w}_{is}^+ = w_{is}^+ - w_{i(s-1)}^+ \qquad (s = 2, \dots, n_{sc})$$
$$\tilde{w}_{min} = \min_{i,s} \tilde{w}_{is}^+ \qquad (s = 2, \dots, n_{sc})$$

Step5: If $\tilde{w}_{min}$ is smaller than a small positive value (say 0.01), increase β. Then, set $i = 0, s = 1$ and go to Step2.
Step6: If $s \neq n$, go to Step 3.
Step7: If $i = m$, terminate. Otherwise, go to Step 2.

After this algorithm, it is possible to define the preference functions of all targets as follows.

$$\sum_{s=2}^{n_{sc}} (w_{is}^+ d_{is}^+ + w_{is}^- d_{is}^-) \qquad i = 1, \dots, n \tag{6}$$

And the formulation of LPP is as follows.

Objective function:

$$\min \sum_{i=1}^{n} \sum_{s=2}^{n_{sc}} (w_{is}^{+} d_{is}^{+} + w_{is}^{-} d_{is}^{-}) \quad (7)$$

Subject to:

$$\mu_i - d_{is}^{+} \leq t_{i(s-1)}^{+} \quad i = 1, \dots, n, s = 2, \dots, n_{sc}$$
$$\mu_i + d_{is}^{-} \geq t_{i(s-1)}^{-} \quad i = 1, \dots, n, s = 2, \dots, n_{sc}$$
$$d_{is}^{+}, d_{is}^{-} \geq 0, d_{is}^{+} \times d_{is}^{-} = 0, \quad i = 1, \dots, n, s = 2, \dots, n_{sc}$$

However, similarly to GP, LPP is applied to multi-objective optimization with only one decision maker. Therefore, it is necessary to extend LPP to a model with multiple players to reproduce Suriawase process.

MULTI-PLAYER MULTI-OBJECTIVE DECISION MAKING

As mentioned above, LPP is applied to the problems with only one decision maker. So, in this research Suriawase process is reproduced by extending LPP to a model with multiple players. In LPP the values of the objective functions of all targets are made as close to their target values as possible by minimizing the sum of the preference functions of all targets. Therefore, it is possible to extend LPP to a model with multiple players by minimizing the sum of the preference functions of all targets of all decision makers as follows. The weight coefficients are calculated similarly to LPP, but the maximum value of β (β_{max}) among all decision makers is used.

$$\min \sum_{l=1}^{L} \sum_{i=1}^{n} \sum_{s=2}^{n_{sc}} (w_{lis}^{+} d_{lis}^{+} + w_{lis}^{-} d_{lis}^{-}) \quad (8)$$

However, the balances of the sums of the preference functions of all targets among all decision makers are not considered because the sum of the preference functions of all targets of all decision makers is simply summed up and the distinctions among decision makers are not considered. To consider the balances of them, RO is applied to multi-player LPP. In RO, a problem with parameter fluctuation related to the objective function or the constraints is solved and worsening of the solution owing to parameter fluctuation is avoided (Ben-Tal, A. & Nemirovski, A., 1999 and Bertsimas, D. & Sim, M., 2004). The different patterns of the preference ranges of decision makers are regarded as the parameter fluctuation in RO and RO is applied to multi-player LPP. When solving RO, each uncertainty data $\boldsymbol{u}_i$ is expressed as a bounded closed set $\boldsymbol{\mathcal{U}}_i$, and the minimized objective function is expressed using the following formulation.

Objective function:

$$\min_{x} \max_{\boldsymbol{\mathcal{U}}_0} f_0(\boldsymbol{x}, \boldsymbol{u}_0) \quad (9)$$

Subject to:

$$f_i(\boldsymbol{x}, \boldsymbol{u}_i) \leq 0, \forall \boldsymbol{u}_i \in \boldsymbol{\mathcal{U}}_i \; i = 1, \dots, m_1$$
$$g_j(\boldsymbol{x}) \leq 0, \quad j = 1, \dots, m_2$$

In multi-player LPP, RO is used as follows.

$$\min \max_{l} \sum_{i=1}^{n} \sum_{s=2}^{n_{sc}} (w_{lis}^{+} d_{lis}^{+} + w_{lis}^{-} d_{lis}^{-}) \quad (10)$$

It is necessary to obtain a robust solution and simultaneously minimize the sum of the preference functions of all decision makers. Then, the balance between the minimization of the sum of preference functions of all decision makers and the effect of the balance among decision makers is necessary to consider. Therefore, the following objective function can be obtained by using (5) and (6)

$$\sum_{l=1}^{L} \sum_{i=1}^{n} \sum_{s=2}^{n_{sc}} (w_{lis}^{+} d_{lis}^{+} + w_{lis}^{-} d_{lis}^{-}) + \max_{l} \sum_{i=1}^{n} \sum_{s=2}^{n_{sc}} (w_{lis}^{+} d_{lis}^{+} + w_{lis}^{-} d_{lis}^{-}) \quad (11)$$

To adjust the balance between the effects of these two terms, the objective function is shown as follows by using the parameter α.

$$(1-\alpha)\sum_{l=1}^{L}\sum_{i=1}^{n}\sum_{s=2}^{n_{sc}}(w_{lis}^{+}d_{lis}^{+}+w_{lis}^{-}d_{lis}^{-})+\alpha\max_{l}\sum_{i=1}^{n}\sum_{s=2}^{n_{sc}}(w_{lis}^{+}d_{lis}^{+}+w_{lis}^{-}d_{lis}^{-}) \quad (12)$$

And the first term and second term have the different scales, so they are normalized as by using "max LPP" and "max RO." "max LPP" is the maximum of the first term except $(1-\alpha)$, or the first term except $(1-\alpha)$ when $\alpha = 0$. "max RO" is the maximum of the second term except α, or the second term except α when $\alpha = 1$. The objective function of the formulation is modified as follows.

$$\min\left\{(1-\alpha)\left(\sum_{l=1}^{L}\sum_{i=1}^{n}\sum_{s=2}^{n_{sc}}(w_{lis}^{+}d_{lis}^{+}+w_{lis}^{-}d_{lis}^{-})\right)\Big/\text{max LPP} + \alpha\left(\max_{l}\sum_{i=1}^{n}\sum_{s=2}^{n_{sc}}(w_{lis}^{+}d_{lis}^{+}+w_{lis}^{-}d_{lis}^{-})\right)\Big/\text{max RO}\right\} \quad (13)$$

However, in this formulation, minimization and maximization are mixed. Therefore, by adding the variable h and a constraint, the formulation is modified as follows.

Objective function:

$$\min\left\{(1-\alpha)\left(\sum_{l=1}^{L}\sum_{i=1}^{n}\sum_{s=2}^{n_{sc}}(w_{lis}^{+}d_{lis}^{+}+w_{lis}^{-}d_{lis}^{-})\right)\Big/\text{max LPP}+\alpha\, h/\text{max RO}\right\} \quad (14)$$

Subject to:

$$\mu_i - d_{lis}^{+} \le t_{li(s-1)}^{+} \quad l=1,\dots,L, i=1,\dots,n, s=2,\dots,n_{sc}$$
$$\mu_i + d_{lis}^{-} \ge t_{li(s-1)}^{-} \quad l=1,\dots,L, i=1,\dots,n, s=2,\dots,n_{sc}$$
$$h \ge \sum_{i=1}^{n}\sum_{s=2}^{n_{sc}}(w_{lis}^{+}d_{lis}^{+}+w_{lis}^{-}d_{lis}^{-}) \quad l=1,\dots,L$$
$$d_{lis}^{+}, d_{lis}^{-} \ge 0, d_{lis}^{+}\times d_{lis}^{-}=0, \quad l=1,\dots,L, i=1,\dots,n, s=2,\dots,n_{sc}$$

When $\alpha = 0$, only the minimization of the sum of the preference functions of all decision makers is considered. In contrast, when $\alpha = 1$, only the effect of the balance based on RO is considered. Therefore, when $0 < \alpha < 1$, both of them are considered simultaneously. And the value of α of the border between two different solutions shows the change of the balance between the sum of preference functions of all decision makers and the effect of the balance based on RO. Through the following algorithm, the balance between the minimization of the sum of all and the effect of the balance among decision makers is changed. The number of the iterations is shown as n_α.

Step1: The initial situation: $i = 0$
Step2: By using α, normalized multi-player LPP is solved.
Step3: If $i = n_\alpha$, terminate. If not, $i = i + 1$ and $\alpha = \alpha + 1/n_\alpha$.

In this algorithm, the $n_\alpha + 1$ patterns of α are solved. And dislike the model of Yatsuka et al. (2018), this algorithm makes it possible to adjust the balance between two effects. Therefore, the various results of Suriawase process are reproduced by this model and algorithm.

NUMERICAL EXPERIMENT

Numerical experiments were conducted to clarify the difference between multi-player LPP without RO and that with RO. Here, we consider one company that produces and sells two products A and B in a supply chain consisting of a factory, logistics warehouse, and retail store. The profits per unit of A and B are \$12 and \$10, respectively, and the company need to generate a profit of at least \$580. That is, if the numbers of units produced of A and B are expressed as x_A and x_B.

$$12x_A + 10x_B \ge 580$$

Under the above hard constraint, it is necessary to satisfy the preference set of each decision maker to the extent possible. For simplicity, the following two equations are used to represent this numerical example.

$$\mu_1 = x_A, \mu_2 = x_B$$

Table 1. Preference Range of Product A

Level	Facility	Logistics warehouse	Retail store
Ideal	<25	<13	<23
Desirable	25-31	13-17	23-28
Tolerable	31-36	17-24	28-34
Undesirable	36-44	24-34	34-42
Highly Undesirable	44-50	34-50	42-50
Unacceptable	>50	>50	>50

Table 2. Preference Range of Product B

Level	Facility	Logistics warehouse	Retail store
Ideal	<10	<20	<23
Desirable	10-18	20-28	23-26
Tolerable	18-26	28-35	26-33
Undesirable	26-33	35-38	33-36
Highly Undesirable	33-40	38-40	36-40
Unacceptable	>40	>40	>40

Table 1 and 2 show the preference ranges for production amounts x_A, x_B of decision maker $l(l = 1,2,3)$ at each stage of the supply chain; assumes that these values are given in advance. As the result of the weight coefficients algorithm, $\beta_{max} = 3.01$ and **Table 3 and 4** show the weight coefficients.

Table 3. Weight Coefficients of Product A

	Facility	Logistics warehouse	Retail store
Ideal	0.0000	0.0000	0.0000
Desirable	0.0167	0.0250	0.0200
Tolerable	0.0620	0.0443	0.0388
Undesirable	0.1202	0.0961	0.1068
Highly Undesirable	0.4965	0.1862	0.3310

Table 4. Weight Coefficients of Product B

	Facility	Logistics warehouse	Retail store
Ideal	0.0000	0.0000	0.0000
Desirable	0.0125	0.0200	0.0333
Tolerable	0.0388	0.0517	0.0443
Undesirable	0.1373	0.1922	0.3203
Highly Undesirable	0.4256	1.4896	0.3724

And the formulation is shown as follows. In this problem, the smaller production amounts are better, so the only w_{lis}^+, d_{lis}^+ and t_{lis}^+ are used.

Objective function:

$$\min\left\{(1-\alpha)\left(\sum_{l=1}^{L}\sum_{i=1}^{n}\sum_{s=2}^{n_{sc}} w_{lis}^{+} d_{lis}^{+}\right)\Big/ max\ LPP + \alpha\ h/\max \mathrm{RO}\right\}$$

Subject to:

$\mu_i - d^+_{lis} \le t^+_{li(s-1)}, \quad l = 1,2,3, \quad i = 1,2, \quad s = 2,\dots,5$

$$h \ge \sum_{i=1}^{n} \sum_{s=2}^{n_{sc}} w^+_{lis} d^+_{lis} \quad l = 1,2,3$$

$12\mu_1 + 10\mu_2 \le 580$

$d^+_{lis} \ge 0, \quad l = 1,2,3, \quad i = 1,2, \quad s = 2,\dots,5$

Normalized multi-player LPP and its algorithm are performed with $n_\alpha = 10000$ and the results are shown in **Table 5**. "Sum" means the sum of the preference functions of all decision makers. And "max" means the largest sum of preference functions of all targets in this supply chain.

Table 5. Result of All Patterns

Pattern	Solution set		Decision maker			Sum	Max	α	
			Facility	Logistics warehouse	Retail store			lower	Upper
Pattern1	26.7	26.0	0.4383	0.7495	0.4818	1.6696	0.7495	0.000	0.343
Pattern2	25.8	27.0	0.5606	0.6830	0.4912	1.7348	0.6830	0.343	0.608
Pattern3	25.1	27.8	0.6588	0.6570	0.4995	1.8153	0.6588	0.609	1.000

The three patterns are obtained. When the standard of "sum" is defined as the smallest "sum" (when $\alpha = 0$) and the standard of "max" is defined as the smallest "max" (when $\alpha = 1$), **Table 6** shows the change of "sum" and "max" in all patterns.

Table 6. Sum and Max of All Patterns

	Pattern1	Pattern2	Pattern3
Sum	100%	104%	109%
Max	114%	104%	100%

The solution of Patten 1 is equal to the multi-player LPP without the consideration of the balance among decision makers. And Pattern 3 is equal to the multi-player LPP without the consideration of the sum of the preference functions of all decision makers. In contrast to these two patterns, both of the minimization of the sum of all decision makers and the balance among decision makers are considered and the balance between the two effects is kept. Therefore, it is thought that Pattern 2 is the most ideal solution.

CONCLUSION

In this research, based on Suriawase process, the multi-player multi-objective decision making model by extending LPP to multi-player with RO. In Yatsuka et al (2018) the balance between the minimization of the sum of all and the balance among decision makers is not considered, so it is considered in the model of this research. As a result of this consideration, it is possible for all decision makers to get several choices that by giving a set of solutions which make all decision makers satisfied with the proposal model of this research. In this research, the effect of the balance among decision makers is reproduced as the minimization of the maximum sum of the preference functions of one decision maker, but it is needed to be compared with other kinds of methods such as the minimization of the maximum difference among decision makers.

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THE STUDY OF COLD STORAGE AND TEMPERATURE CONTROLLED TRANSPORTATION: A CASE STUDY OF A CHAIN RESTAURANT IN THAILAND

Pannita Chaitangjit[1], *Pornthipa Ongkunaruk*[2]

Abstract *– The safety and quality of agricultural raw materials is important in food service industry because raw materials are temperature sensitive and perishable. Hence, they should be stored in a cold storage and temperature-controlled truck to maintain the quality and safety. This study investigates the current cold chain management of a chain restaurant. The objective is to identify the problems and suggest how to establish the proper cold storages and temperature-controlled trucks. The scope of study is a restaurant having nine branches, two refrigerated containers (20 feet) for storing raw material and three temperature-controlled trucks for sending raw material to each branch. We conduct in-depth interviews with restaurant owner and operators and check the temperature in cold storage and during transportation of raw material by using infrared thermal camera and data logger to identify the problem. Then, we analyze the causes of the problem and suggest solutions for the improvement such as the design of cold storage and delivery platform. In summary, this research will be beneficial to other cold storage and temperature-controlled truck users. It can enhance the cold chain efficiency and food safety as well as energy and cost saving.*

Keywords – Cold Chain Management, Cold Storage, Temperature-Controlled Truck, Restaurant, Energy Saving

INTRODUCTION

Recently, food service becomes an important industry in Thailand. In 2018, the expected market value of restaurant business in Thailand is about 411-415 billion baht with an increasing trend about 4-5% from previous year. In addition, the number of chain restaurants are also increasing due to the impact of expanding of supermarket branch and the improvement of service level and competitiveness of restaurant business (Kasikorn Research Center, 2018). In food service industry, the safety and quality of agricultural raw materials is important because raw materials are temperature sensitive and perishable. Hence, they should use cold chain management to maintain the quality, safety and prolong shelf life of raw materials. (Laguerre et al, 2013). The cold chain management is to properly control temperature, moisture, environment conditions and time throughout processes especially in storage, handling and transportation from an upstream to downstream supply chain (Yuen, 2017; The Postharvest Education Foundation, 2014). The Postharvest Education Foundation (2014) suggested four steps to implement a cold chain management for perishable foods during the postharvest including harvest, collection, packing, processing, storage, transport and marketing until it reaches the final consumer. These steps include 1) pre-cooling system, 2) cold storage, 3) chilling and freezing process and 4) temperature-controlled transportation. Cold chain logistics is the planning and management of the interactions and transitions among stakeholders, in order to keep foods at their optimum temperature for maintenance of quality, food safety and prevention of waste and economic losses. In addition, Kuo and Chen (2010) developed an advanced Multi-Temperature Joint Distribution System for a food cold chain and used multi-temperature truck to deliver the products required different temperature in the same truck. Similarly, Hernandez)2009(stated that in food service distribution there were two parts for monitoring. First, in a distribution center, the temperature in a storage area should have a wide range and can be separated for storing the products at the right temperature and delivery at the right time. Second, in the temperature control truck for delivery products required different temperature, it should separate space to store products in different temperature ranges. In

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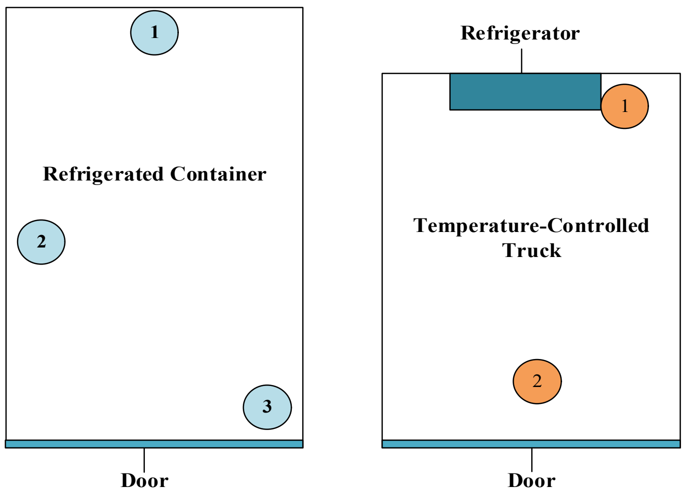
addition, there are good practices to prevent the product from being damaged such as proper handling method, handling equipment, transportation and storage condition, packaging, product position and ventilation (Laguerre et al, 2012; Taylor, 2001; Bertheau et al, 2015; Gogou et al, 2015; Vigneault et al, 2009). The optimal food cold chain management attempts to ensure that all kinds of perishable products with different temperature requirements can be maintained at the best quality condition from the point of supply to the point of consumption, throughout the processes of storage and distribution. The freshness and safety of food are guaranteed in each stage in logistics service so as to maintain the value and quality to satisfy customers (Laguerre et al, 2013; Mercier et al, 2017; Taylor, 2001(. A causal loop diagram is a model used to analyze and identify causes and effect in their systems. It can be used as the tool for enhancing the decision making. An application to identify causes of pollution problem in dairy industry can be found in Aikenhead et al. (2015). The causal loop diagram identified the mechanism of the internal dairy processes and the impact from inefficient use of resources. In addition, it was used to identify the causes of fresh vegetable loss in three major factors i.e. the original quality of vegetables, temperature and compression and impact in the cold chain logistics (Rattanawong & Ongkunaruk, 2017).

This study investigated the current cold chain management of a case study chain restaurant located in Ayutthaya province in central Thailand. The restaurant offers barbecue meat in a Japanese style. The restaurant has nine branches, a central kitchen with two external refrigerated containers (20 feet) at -20°C and an internal cold room for storing raw material. There are three temperature-controlled trucks at -10°C for sending raw material to restaurants. The objective was to identify the problems and suggest how to establish the proper cold storages and temperature-controlled trucks.

METHODOLOGY

First, we conducted in-depth interviews with a chain restaurant owner and operators for analyse the current situation. Next, we drew a swimlane diagram to explain the process of the restaurant. Then, we monitored the temperature in two refrigerated containters and three temperature-controlled trucks by using infrared thermal camera and data logger to identify the problem. In refrigerated containers, three data loggers was placed in three location i.e. inner, central and near the door and an infrared thermal camera is used to check temperature at a wall and raw materials. In a temperature-controlled truck, two data loggers were placed under the refrigerator and near a door as shown in Figure 1. After temperature analysis, we used the causal loop diagram for analysing the causes of the problems. Finally, we suggest solutions to an owner for the improvement.



(a) Refrigerated Container (b) Temperature-Controlled Truck

Figure 1. The Location of Data Logger in Refrigerated Container and Temperature-Controlled Truck

RESULT AND DISCUSSION

Business Process Analysis

A swim lane diagram was drawn to present the sequences, time intervals between activities and relationships of the activities with other functions in a central kitchen and restaurants. The activities were presented in a square box with a number, and the length of the box indicates the time interval between activities. The activity as a box was located in a row indicated the responsible functions of a stakeholder. The arrow identifies the direction of the relationship from one function/stakeholder to another function/stakeholder (Chueprasert et al, 2016). The process is as follows and shown in Figure 2. First, the staff of a restaurant placed an order of raw materials to a purchase department of a central kitchen at night (1). In the morning, the staff of a central kitchen will check the stocks of raw materials. If the stock is not enough, they will buy the raw materials at a nearest market (2). Then, the staff will record the temperature of a refrigerated container which must be less than -18°C in a log book (3). After that, they will prepare the raw materials (4). Next, the raw materials are loaded in a temperature-controlled truck (5). For activity 4 and 5, they spend time about 1 hour. Then, deliver raw material to restaurant (6). After delivery, they will check stock again (7) and plan to ordering raw material from suppliers (8).

Cool Storage Monitoring

We check the temperature in refrigerated container by data logger and the result of temperature shown in Table 1. The lowest temperature at the inner area of refrigerated container is -20.3°C and lower than other area. For the average temperature, we found that the temperature at the inside of refrigerated container is lower than other area too. So if we consider about average temperature in refrigerated container that they should storing the raw material at the inner area and the central area in the refrigerated container because the temperature in that area is suitable for storing raw materials.

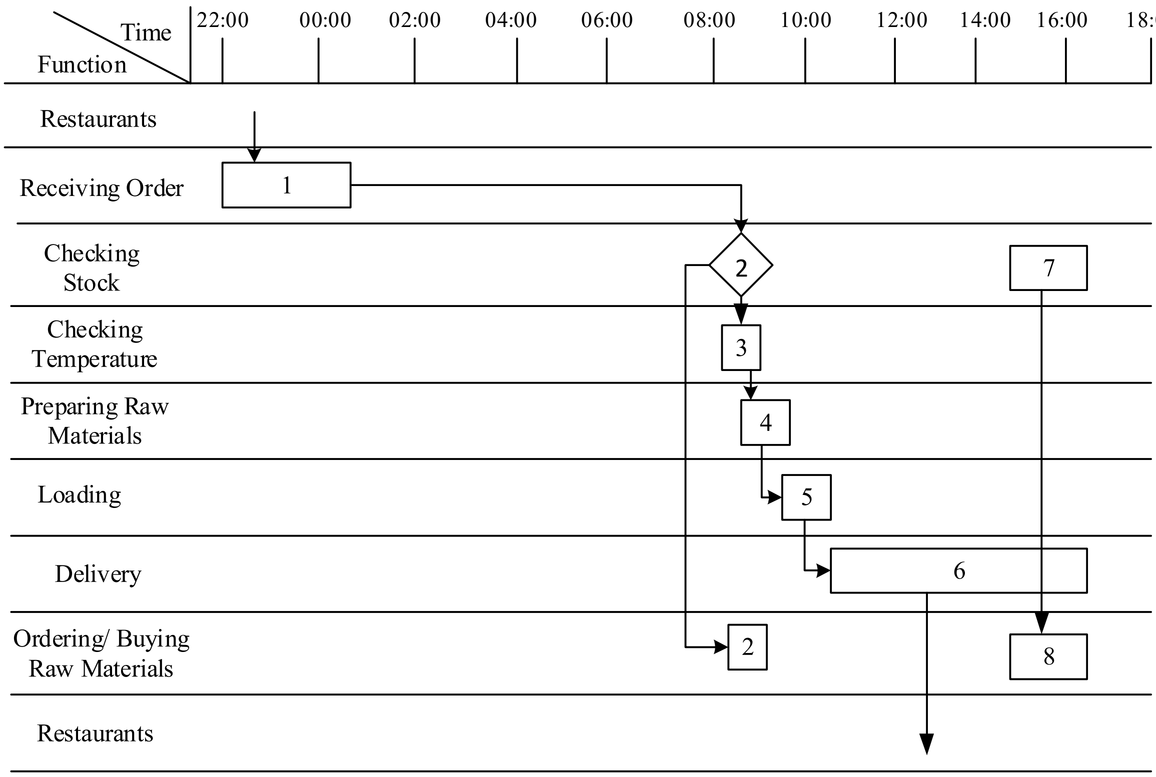


Figure 2. The Swim Lane Diagram of a Central Kitchen

Table 1. Average Temperature in Refrigerated Container at Central Kitchen

The Position of Data Logger	Average Temperature in Refrigerated Container (℃(		
	Minimum	Average	Maximum
Inner area	-20.3	-14.0	4.0
Central area	-16.5	-11.9	-0.4
Front door	-15.6	-7.5	17.1

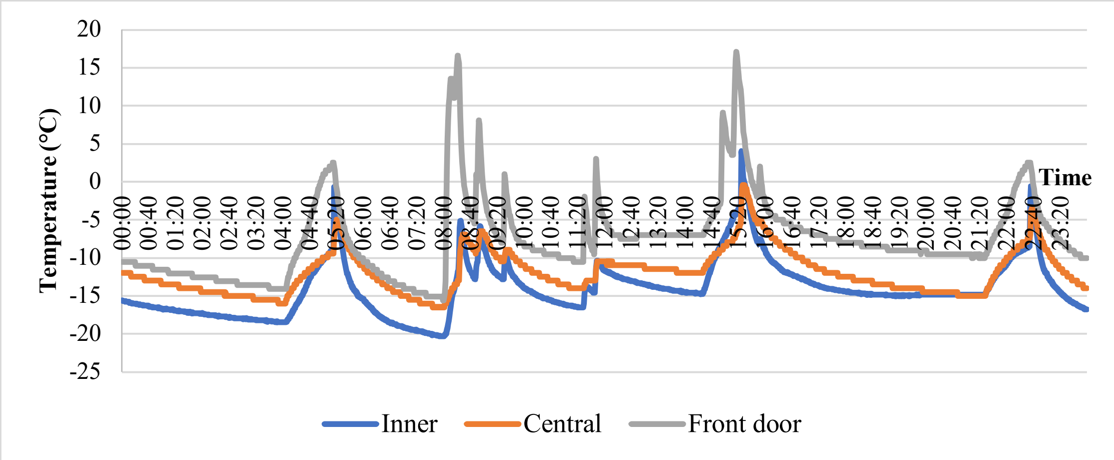
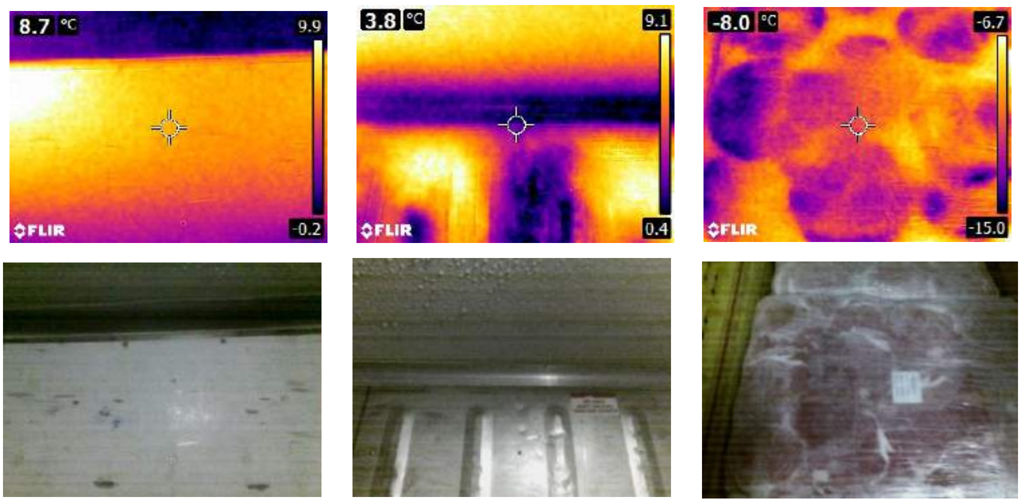


Figure 3. The Temperature in a Refrigerated Container at a Central Kitchen

At night, the temperature in a container is fluctuated between -10°C to -20°C, then the thermostat works at 4 a.m. and the temperature is raised to 0°C within 80 minutes or at about 0.25°C per minute. Then, a freezer is working again and temperature will drop to -20°C within 2.5 hours or around 0.2°C per minute as shown in Figure 3. During the preparation of raw materials, the staff open the door around 15-30 minutes while the external temperature is about 30°C - 40°C. Hence, the temperature at the door area without anteroom is around 10°C - 15°C or the temperature is increased around 2°C to 4°C per minute. For the inner area and central area, the temperature is increase around 1°C to 3°C per minute. When they closed the door, the temperature is dropped to -10°C with an hour. The temperature is decreased around 0.5°C - 1°C per minute after closing the door. It implied that it takes longer time to decrease the temperature to the target level, this results in higher electricity cost. In addition, the most vulnerable location is the door area while the inner area is the coldest.



(a) Inner wall (b) Inside wall (c) Products

Figure 4. The Temperature in Refrigerated Container by Infrared Thermal Camera

Considering the temperature of wall in the refrigerated container by infrared thermal camera as in Figure 4, the temperature of wall is between -0.2°C and 9.9°C which is higher due to improper insulation. However, the temperature of raw material in the refrigerated container is between -8°C to -15°C which is considered as safe condition.

Temperature-Controlled Truck Monitoring

In a temperature-controlled truck, the temperature at the door area is between -7.53°C to 23.40°C as shown in Table 2 and Figure 5 which is mostly lower than the temperature at the under refrigerator area because the cold air blows to that area. However, when staff open the door to unload, the temperature at door area is increased and becomes higher than the other area about 2°C. During unloading, temperature is fluctuated and the raw materials may be damaged. In general, the temperature at door area is 5.83°C which is lower than other area around 3°C. This implied that the air flow is not circulated so the difference of temperature in a temperature-controlled truck is high. Further investigate the other area should be done. In addition, the air circulation should be established. We also found that the staff did not precool a truck before loading. It took 20-30 minutes to decrease temperature from 15°C to 0°C or around 0.5°C per minute.

Table 2. Average Temperature in Temperature-Controlled Truck

The Position of Data Logger	Average Temperature in Temperature-Controlled Truck (℃(		
	Minimum	Average	Maximum
Under the refrigerator	-2.94	8.18	21.82
Near door	-7.53	5.83	23.40

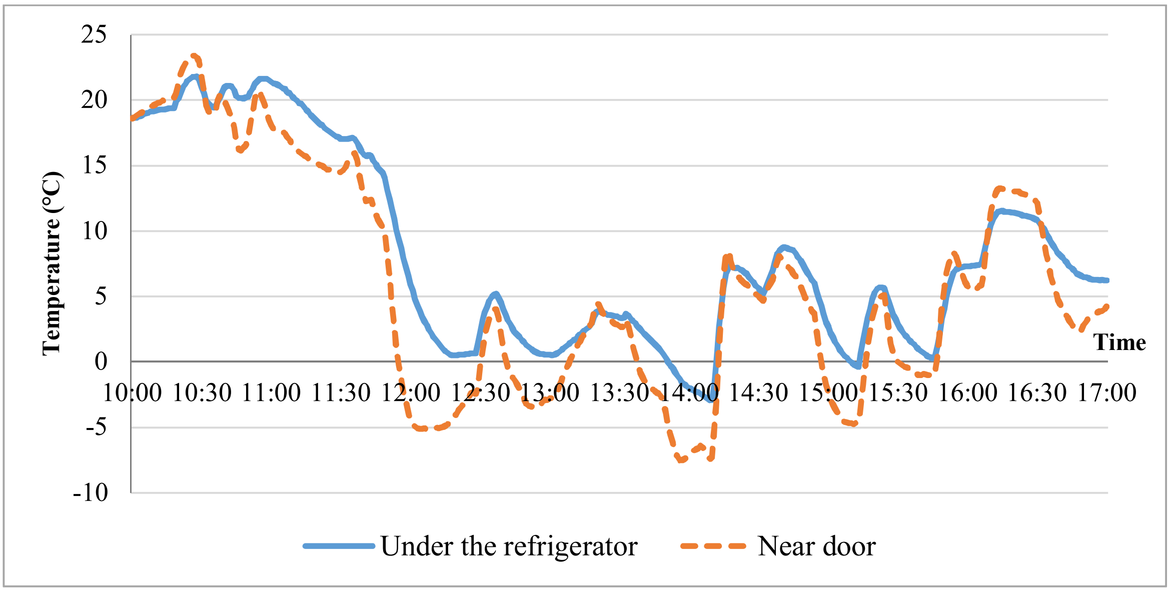


Figure 5. Average Temperature in a Temperature-Controlled Truck

The Identification the Causes of Inefficient Cold Chain Management

After gathering the current practices and the above results, we investigate the causes of the inefficiency of the cold chain management by creating a causal loop diagram as in Figure 6. The plus sign mean the positive effect whereas the minus sign implies the negative effect of the cause. There are four mains causes as follows. First, the lack of collaboration in supply chain, if stakeholder in supply chain has the right attitude to improve the efficiency of the cold chain management and have the common goal among stakeholders and have the agreement from the top management team, then the collaboration will be increased. On the other hand, the number of stakeholders affects the collaboration in the cold chain, the more the difficult. Second, the improper design of cold chain facilities and equipment. There are several causes of improper design of cold chain facilities and equipment such as the quality and quantity of current service providers, capital investment of the users and the knowledge. Third, best practices in a cold chain can improve the efficiency of cold chain management. Starting from the government policy that should provide education in cold chain in universities or institutes, establish the handbook about standard and train the staff about cold chain management. In addition, measurement equipment such as data loggers and infrared cameras to check the temperature all stages in cold chain, with a quality control system and audit system to ensure that the temperature is proper throughout the entire chain. Finally, without implementing the information technology infrastructure which is a foundation of the traceability system, cold chain management cannot be efficient due to big data of temperature and time. To establish the proper factors, the restaurant can enhance the customer service level and save energy.

The Suggestion of Cold Chain Management in Thailand

Using refrigerated container for storing raw material is not effective because there is no insulation and the ambient temperature affects the internal temperature of goods in refrigerated container (Taylor, 2001; Gogou et al, 2015; Vigneault et al, 2009; Yuen, 2017). In loading area, they should create anteroom to reduce the workload of a refrigerator. In addition, they should design the proper layout in cold storage and identify the right amount of raw materials to reduce the picking time and try not to open the door too long to save the energy (Palmer, 2016; Devenish, 2018; Yuen, 2017; Gogou et al, 2015). For temperature-controlled truck, the precooling must be applied for 30 minutes to set up the temperature equal to the storage temperature. The proper design of air circulation should be established. In addition, the door should not open more than 15 minutes. If there are several types of raw materials required keeping in different temperature, it is suggested to separate the area in the storage room and truck. Then, raw materials should be placed and delivered in the appropriate temperature in the entire chain (Taylor, 2001; Bertheau et al, 2015; Hsiao et al, 2017).

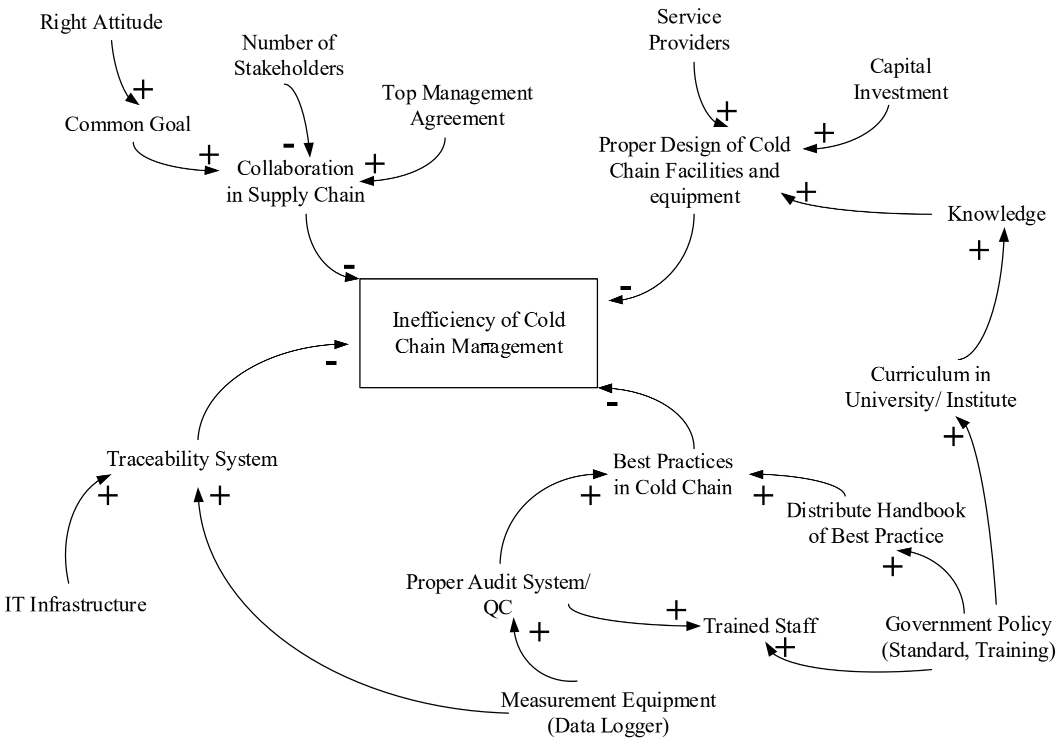


Figure 6. The Causal Loop Diagram of Inefficiency of Cold Chain Management

CONCLUSION

In this study, we explore the current cold chain management in a case study chain restaurant using data loggers and a thermal infrared camera. The problems are using improper insulated materials of refrigerated container, no ante room, long loading time, no precooling and poor air circulation in a temperature-controlled truck. This results in high energy consumption and low quality of raw materials delivered to the restaurants. In addition, the restaurant did not have the data loggers to monitor the temperature in the cold storage and truck. These problems might be found in other chain restaurants in Thailand. Hence, we identified the causes and proposed how to solve the problems in the macro view. In summary, this research will be beneficial to other cold storage and temperature-controlled truck users. It can enhance the cold chain efficiency and food safety as well as energy and cost saving.

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GAP ANALYSIS FOR A FOOD SERVICE VALUE CHAIN IN THAILAND

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Abstract *− At present, food service business in Thailand has an increasing trend about 4-5% from 2017 with the expected volume of 41.1-41.5 billion baht in 2018. Due to life styles change, people prefer to eat out for convenience. Meanwhile, the volume of food delivery is about 26-27 billion baht in 2017 since its service satisfies the customers who need convenience as well. This research aims to analyze the business processes of a Thai restaurant which uses both POS and food delivery service application and to identify the problems and needs for a software platform. First, we conduct the in-depth interviews with a restaurant owner and survey how software is exploited in the restaurant. Next, the Integration Definition for Function Modeling (Idef0) was used to analyze the business processes. We found that there are two separated platforms: point of sale (POS) system and delivery system. The delivery data is not included in POS system, thus the analysis of customers cannot be integrated. Hence, we suggest the government to encourage the software provider to integrate the POS and delivery systems to enhance the information flow and efficient management in forecasting, inventory and production planning.*

Keywords − Food Delivery Service, POS, IDEF0, Restaurant

INTRODUCTION

At present, food service business in Thailand has an increasing trend about 4-5% from 2017 with the expected volume of 41.1-41.5 billion baht in 2018 (Kasikorn Research Center, 2018). The restaurant business is one of the most competitive industries in Thailand (Office of Agricultural Affairs, 2016). Food outlets are everywhere, from small carts dotting every street and pathway to five-star restaurants in some of the world's finest hotels.

Meanwhile, the volume of food delivery is about 26-27 billion baht in 2017 (Kasikorn research center, 2016). There here has been a trend towards delivery service, ordered either via phone or online, that gains an increasing popularity in Thailand due to the behavior adjustment of customers with more need of convenience, quickness, usage usefulness and other motives (Kim, 2011; Littler and Melanthiou, 2006; Saarijärvi et al., 2014; Yeo et al., 2017). The authors consider the 'the last food mile' which can be defined as: "the physical distribution of food occurring in the last part of the food supply chain" (Morganti, 2011) and is usually characterized by small deliveries handled by transport operators, suppliers, wholesalers, distributors, as well as by the eaters themselves (Morganti and Gonzalez-Feliu, 2015).

In addition, Gupta and Paul (2016) noted that Online Food Delivery (OFD) users in Eastern countries like China or Malaysia concentrate more on what businesses offer regarding convenience and time-saving instead of their usage cost. In Western countries like Brazil or England, OFD are also overgrowing, providing added conveniencet to their customers when linked with the relative ease of access afforded by the everywhere of mobile internet devices (Pigatto et al., 2017). Scholars characterized these platforms as an innovation of restaurants or food providers proposed to increase their competitiveness (Yeo et al., 2017; Pigatto et al., 2017; Çavuşoğlu, 2012).

Point of sale (POS) systems facilitate and record business transactions between shops and their clients. They provide better control over business operations. Data captured by POS give details of how much products the end-users brought (Simon, 2008). Using POS data in a retailer system helps the manufacturer to understand the demand of its product and to improve its accuracy demand forecast (Chen and Lee, 2009; Lee et al., 2000).

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According to Williams and Waller (2009), the demand forecast in ready to eat cereal category using the point-of-sale (POS) data was outperform using the order quantity. However, if the bullwhip effect or the non-turn volume which is the promotional activity occurs, then the forecast accuracy using POS will be decreased. Similarly, Trapero, Kourentzes, and Fildes (2012) used the actual data in the UK grocery retailers to forecast for the supplier. They empirically showed that the POS information sharing could improve the demand forecast. Later, Hartzel and Wood (2017) studied the effect of using real time and shared POS in the demand forecasting. They found out that using real time and shared POS can improve the forecast accuracy about 11.2%.

In this study, we proposed Integration Definition for Function Modeling (IDEF0) approach to investigate the implementation of software in restaurants. IDEF0 is a method designed for modeling the decisions, actions, and activities of an organization or system. It uses a box to represent functions within a process and connecting arrows between boxes to show relationships among functions. There are four types of arrows based on their placement; inputs are represented by the arrows flowing into the left hand side of an activity box; outputs are represented by arrows flowing out the right hand side of an activity box; the arrows flowing into the top portion of the box represent constraints or controls on the activities; and the final element presented by arrows flowing into the bottom of the activity box are the mechanisms that carries out the activity. There were applications in Ongkunaruk (2015) who identified problems and proposed how to improve efficiency in the planning, sourcing, production and delivery processes in a raw milk collection centre in Thailand by using IDEF0. Prasertwattanakul and Ongkunaruk (2018) analyzed vertically integrated organic rice company in Thailand using IDEF0. It was used to explore the management system of large scale food service sectors in Thailand (Ongkunaruk and Kessuvan, 2013).

This research aimed to study the stakeholders of food service supply chain in Thailand, then analyze the business processes of a small Thai restaurant chain which used both POS and food delivery service application and identified problems and needs using a gap analysis and proposed how to fill up the gap or improvement. The chain restaurant operates five branches of healthy dishes located in Bangkok, Samutprakan, and Nonthaburi. The stores use a point-of sale system to collect data but do not have their own delivery service. Their customers can order food online through delivery service providers such as Foodpanda, Line Man and Lalamove.

METHODOLOGY

First, we reviewed the literature related to delivery service in food services especially for restaurant business. Second, we performed in-depth interviews with the key restaurant supply chain stakeholders about their roles, key activities and current problems– i.e., suppliers, logistics service providers, restaurants, riders, consumers, point of sale service providers and delivery service providers. Next, we drew a current restaurant supply chain in Thailand for a macro view of relative stakeholders. In addition, we interviewed a case study Thai restaurant and analyzed the business model based using IDEF0. The questions related to all activities implemented in the restaurants, inputs, outputs, mechanisms and controls in those activities and current problems. The solid line represents a current activity (as-is) and a dashed line represents a guideline (to-be). After that, we performed a gap analysis of food service business based on the induction method. Finally, we proposed guidelines to bridge these gaps.

RESULTS AND DISCUSSION

A Generic Restaurant Supply Chain

Form the survey, we graphically presented a restaurant supply chain in Thailand as shown in Figure 1. The solid line indicated the flow of materials among stakeholders while the dashed line indicates the flow of information. There are twelve stakeholders as follows:

- Suppliers: The parties who supply goods or raw materials for restaurants such as farmers, central market, fresh markets and raw material providers.
- Logistics service provides: The third parties who pick up raw materials from markets and deliver to restaurants. These services help suppliers or restaurants who do not have their own vehicles.
- Restaurants: The parties provide food and service for dine-in customers and offer delivery service as well.
- Food delivery manufacturers/home chef: The parties who cook food in their factories or houses and delivery food to the customers who order by phone or online.
- Riders: Persons who pick up food from restaurants by motorbike and deliver it to customers.
- Customers: Consumers who dine-in at a restaurant or order food online using a smartphone or computer.

- Point of sale software providers: The software companies who provide the software or applications for a restaurant to manage the sales transaction. There are several modules according to the requirements of the users. POS can increase the efficiency and accuracy in planning, forecasting, procurement and inventory management as well as the excellent customer service.
- Delivery service providers (aggregators): The parties who provide channel for delivery service to customers by offering the applications in a smartphone or website. They may hire full time or part time riders to fulfill the delivery service. Some providers charge a service fee from customers only such as Lalamove. On the other hand, Food Panda and Now charge both restaurants and customers.
- Directory service providers: They provide information related to restaurants such as location, type of food, rating, and customer review. This service provider has a role to match the customer requirement with a right restaurant.
- Marketing service providers: They gather promotions from member restaurants and share the information to customers through applications. It builds the traffic in a restaurant and the revenue comes from the membership fee paid by restaurants.
- Mobile application service providers: The social network applications such as Line and Facebook. They offer the food ordering system to customers. In addition, it can be used to communicate within group.
- Cloud service providers: The key IT platforms who serve the network service to support business and other providers. They provide data center via internet.

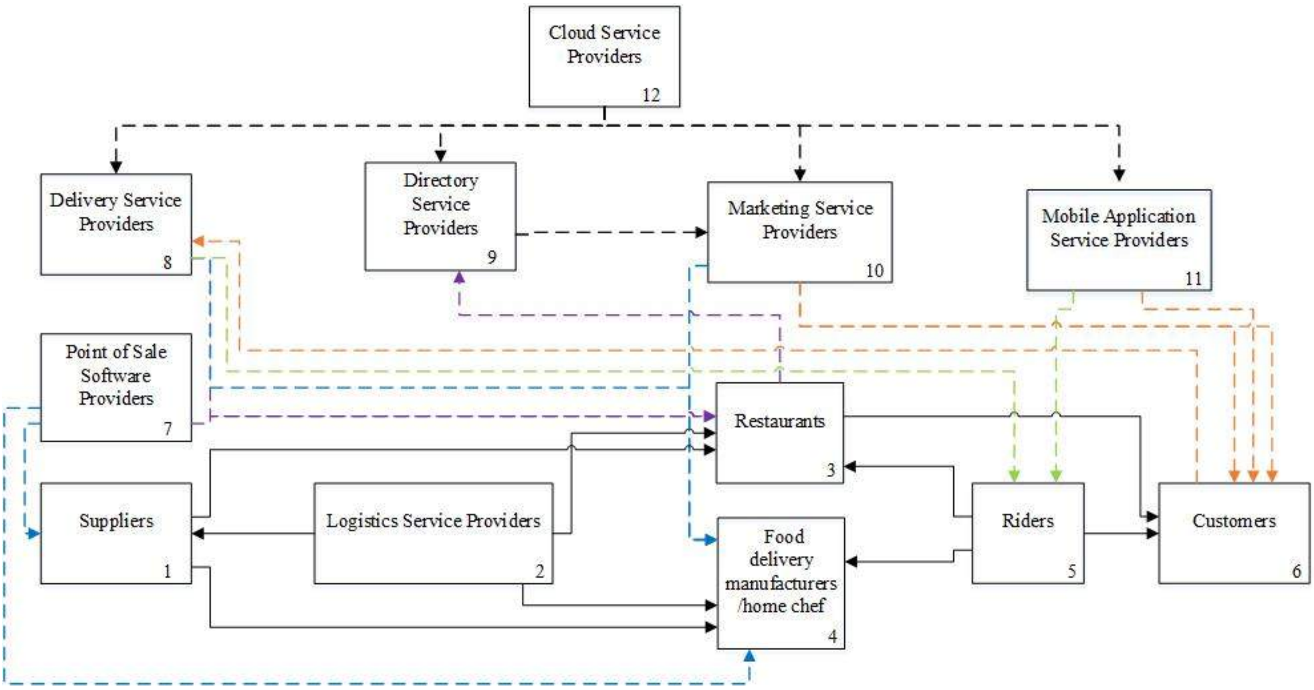

Figure 1. A Restaurant Supply Chain in Thailand

Business Process Analysis of a Thai Restaurant

We focused on the analysis of the business process of a restaurant supply chain at an organization level or level 0 and a main activity level or level 1 as shown in Figure 2 and 3. Initially, suppliers make a contract with farmers with the agreement on the standard and customer specification. After that, suppliers will deliver raw materials and ingredients to a restaurant by a pick-up truck. Suppliers set up time windows to deliver raw materials according to restaurant space at a central kitchen. In a central kitchen, there are raw materials preparation and pre-cooking some menu before sending them to restaurant branches. Staff will check stock at restaurant branches and order based on forecasting from historical data. There are multiple suppliers to serve same type of raw materials to reduce the risk of shortage and monopoly in price. The key procurement decision is when and how much to buy to satisfy the fluctuated demand. The dine-in customer goes to the restaurant directly or reserve the table in advance and pay by cash or credit. Alternatively, the customer can order food online with cash or online payment. Nowadays, the last mile food delivery trends is increasing, together with the growth of service providers such as POS service providers, aggregators, directory service providers, marketing service providers, mobile application service providers and cloud service providers, respectively.

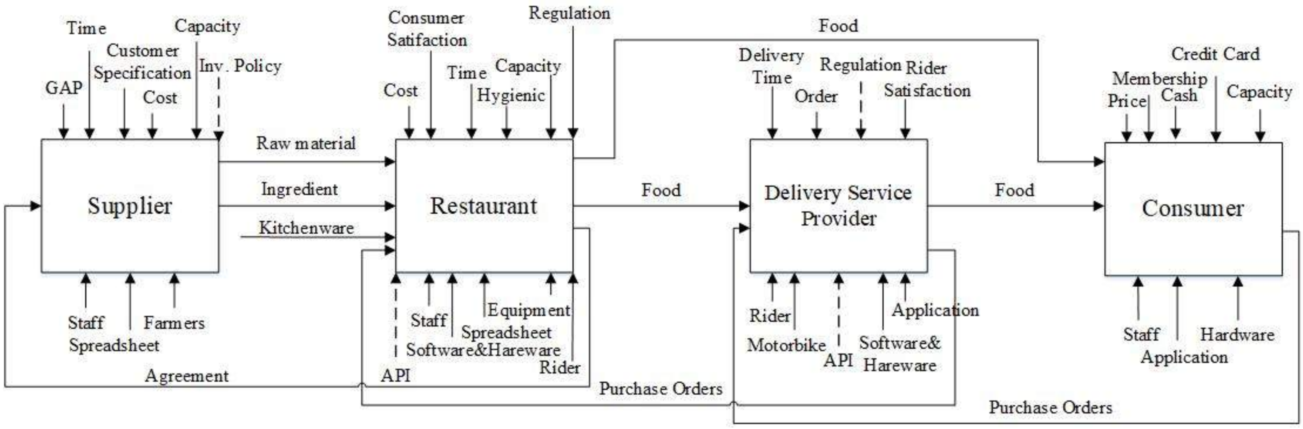

Figure 2. A Business Process of a Thai Restaurant Supply Chain (IDEF0 level 0)

The major activities of a Thai restaurant include plan, source, make, deliver and return as shown in Figure 3. At present, the demand forecast was based on data from POS software in the restaurant only. However, the production is based on both dine-in and delivery customers. The POS data for delivery customers was not aggregated in the POS software. This implied that the current demand forecast was inefficient. More details in delivery activities were shown in Figure 4. A customer ordered food through an application on mobile or computer. Then, an order will be processed by a delivery service provider which will assign the order to a rider. After that, a rider will go to a restaurant and call customer to check whether the order is right. When the customer confirms the order, the rider will confirm an order to restaurant and wait for food. Next, the rider will deliver food to a customer. Finally, the customer pays cash to the rider or online banking. Currently, delivery service providers offer two options for food payment. First, a rider has to pay cash to a restaurant to pick up the food and will receive cash from a customer after delivery. Alternatively, if the restaurant makes a contract with the delivery service provider, the rider do not need to pay, the customer will pay through online payment and the restaurant will be paid afterwards. The drawbacks of the delivery system are as follows. First, the rider must be assigned by the delivery service provider. If the rider reject the order, the new assignment will pass to another rider. In the other system, the rider located in the proximity of restaurant location will bid to take the order, the fastest bidder gets the order. Second, the rider must pay for food in advance to the restaurant. Third, the fragmentation of the POS and delivery software due to different service platforms. Finally, how to cope with high fluctuation in demand and raw material price to maintain the service level in both type of customers.

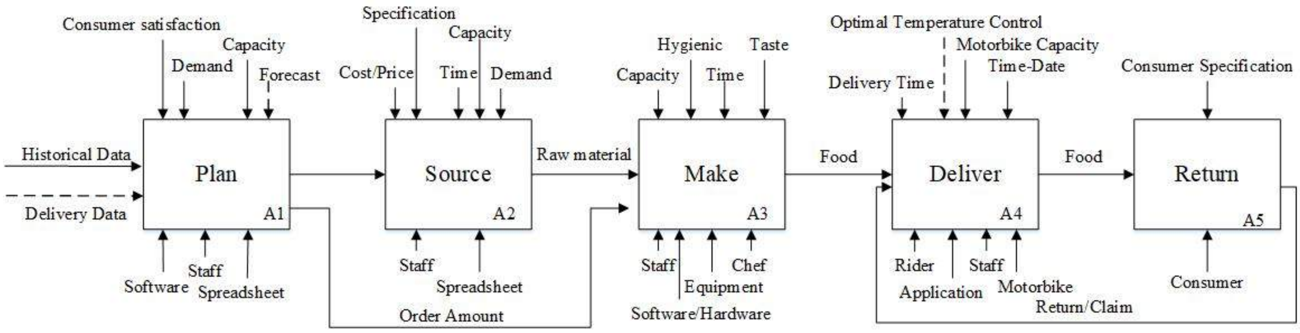

Figure 3. A Business Process of a Thai Restaurant Supply Chain (IDEF0 level 1)

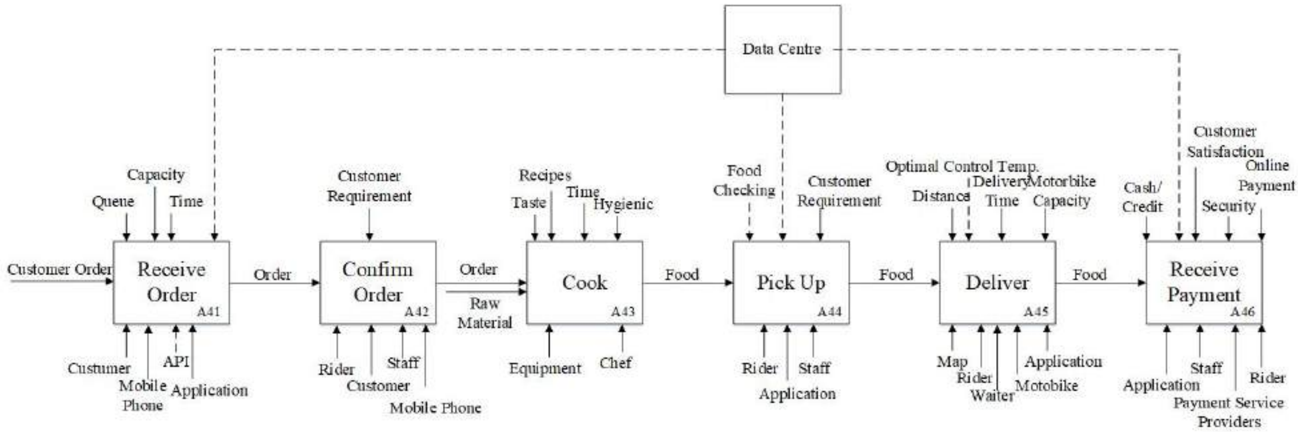

Figure 4. A Business Process of a Thai Restaurant Supply Chain (IDEF0 level 2)

Gap Analysis of Food Delivery Service in Thailand

From the literature review and interview with stakeholders in a restaurant supply chain together with the case study restaurant chain, we performed the gap analysis between the current situation and future need in each activity as shown in Table 1. The major improvement can be in several aspects such as the proper equipment for delivery, good practices for delivery, alternative delivery vehicles, integration of POS and delivery data and data analytics. The business intelligence from integrated data can help support the decision in inventory management, menu engineering and promotion, etc.

Table 1. Gap Analysis of Food Delivery Service

Activities	Important Roles	Current Situation	Gap	Improvement
Food Delivery				
Delivery vehicles	Convenience and responsiveness in food ordering and delivery system.	Several modes of transportation are available including cars, motorcycles, and bicycles.	Traffic congestion in urban areas often delays the delivery.	Drone delivery could be an alternative vehicle to avoid the traffic in the future.
Transport equipment	Containers and delivery boxes help maintain food conditions.	Molded plastic boxes and foil and/or foam inlaid rectangular zipper bag are the most commonly used.	Temperature changes during food delivery, food lit inside its package	Design suitable delivery box using house of quality.
Rider	Fast delivery, clean and safe.	Riders whimsically reject delivery jobs. Cleanliness is not on top of riders' mind.	No food safety and hygienic regulations at present.	Establish standards and regulations to supervise food delivery service. Reward riders who maintain outstanding safety and cleanliness
Application	Connects riders to delivery jobs.	Riders can both bid for jobs or be assigned by the aggregator.	Inability to accept multiple jobs with overlapping routes	Add decision logics to optimize rider-job-route assignment.
Food Online Ordering				
Food ordering system	Satisfying individual customer is the key to success.	Found mistaken orders and wrong conditions	Customers, restaurants and riders do not share real time data	Develop a system that connects and shares detailed order requirements between customers, restaurants and riders

Activities	Important Roles	Current Situation	Gap	Improvement
Food Delivery Payment	Convenience and reliability	Some cases, a rider must advance a payment whereas a customer pay the rider after food delivery	If a rider or customer cancel the order, then the aggregator need to responsible for the cost.	Establish a payment gateway by a reliable payment service provider
Applications	Connects individuals together and provides flow of information	Restaurant operators are required to use to applications, POS and online ordering.	Online ordering application has not yet been connected to POS system.	Develop an application programing interface (API) that can link data from various applications

We proposed a scheme of the online delivery service for a restaurant as shown in Figure 5. There were five stakeholders in the online ordering system of food service business i.e. a data center which connected restaurants, customers and delivery service providers as middlemen. In the future, the big data from the data center can be analyzed and is used as a tool to improve the service for delivery food service industry. Finally, a payment service providers were responsible for payment between customers and restaurants.

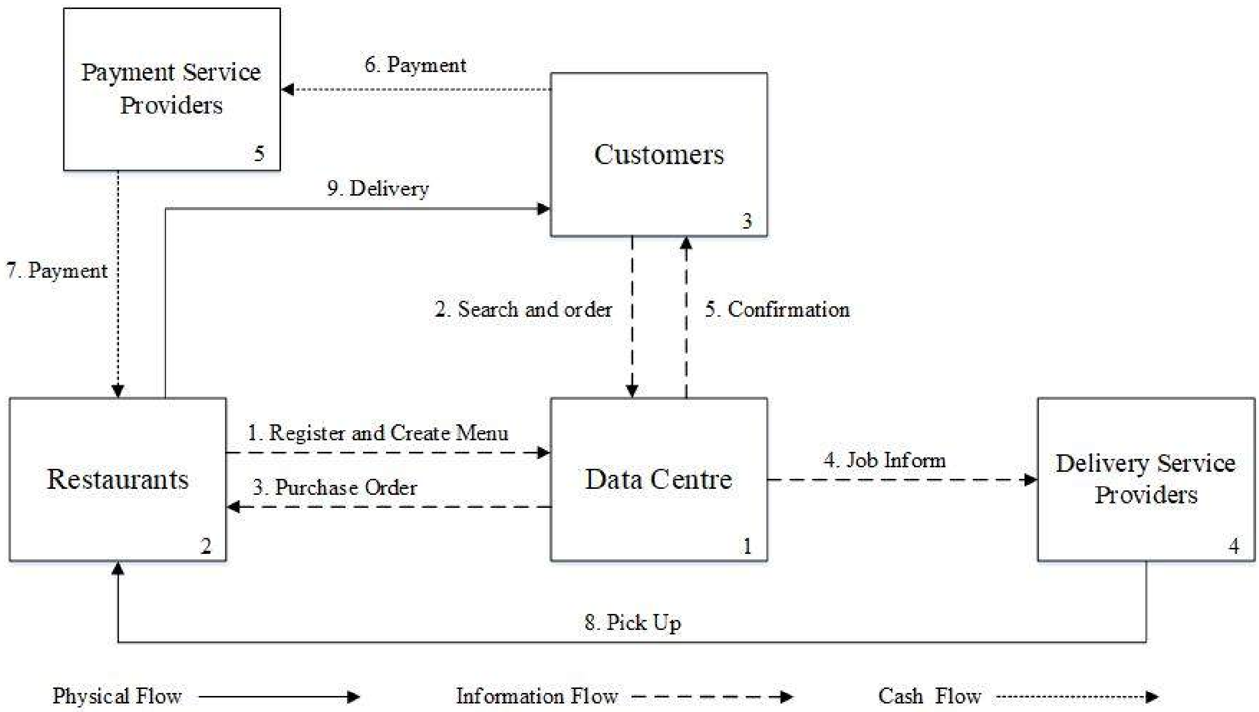

Figure 5. A Schema of Business Process for Online Ordering System Thai Restaurant (supply chain)

CONCLUSION

We analyzed the current restaurant supply chain situation in Thailand and identified the stakeholders who are related to delivery services. Then, we focused on the analysis of the business process of a small chain restaurant using IDEF0 to describe current activities, the control and mechanism. Then, the problems were identified and guidelines for improvement were proposed. In addition, the gap analysis showed that there were some improvements in the macro view such as using API software to integrate the POS and delivery systems to enhance the information flow and efficient management in forecasting, inventory and production planning. The other research in delivery services are vehicle, delivery equipment, applications. In addition, the attitude of the service providers, riders, and restaurant should be established to provide clean and safe food in a short time. In summary, we hope our guideline can be implemented in food service industry in Thailand to increase the downstream supply chain efficiency.

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CLASSIFICATION OF BARRIERS TO ADOPTION OF ELECTRIC VEHICLES AND ELECTRIC FREIGHT VEHICLES

Şükrü İmre[1], Aycan Kaya[2] Dilay Çelebi[3]

Abstract *– Despite their environmental benefits and the incentives provided for the proliferation of Electric Vehicles (EV), the adoption rate of EVs in logistics and transportation systems is well below the potential identified in various projects. A challenge for all actors and policymakers is to define barriers, measures and policies to foster the use of EV in commercial transport. This paper investigates barriers to EV adoption both for passenger and freight transport, based on an extended literature review and provides a classification of those barriers over eight defined types: infrastructure, technology, awareness, operational, charging, political, cost, and vehicle characteristics. The paper also provides a discussion of each barrier and gives research and policy related implications of the findings of the review.*

Keywords – Electric Vehicles, Barriers to Adoption of EVs/EFVs, Electric Freight Vehicles.

INTRODUCTION

Rapid urbanisation in the world foster the use of commercial vehicles on urban roads (Whang & Thoben, 2017). The greenhouse gases and solid particles extracting from these vehicles have significantly distorted the quality of the air. In order to increase air quality and reduce emissions, one of the possible solutions is the development and modification of urban passenger and freight transportation (Quak et al., 2016). In addition, the depletion of fossil fuels and therefore the rise in oil prices and efficient use of information and communication technologies (ICT) are also on the agenda of the transportation sector (Şenlik, 2012). For all these reasons, zero-emission or low emission vehicles such as Electric Vehicles (EVs) and Electric Freight Vehicles (EFVs) are emerging as solutions to the environmental pollution arising from the transportation sector. Moreover, prohibitive decisions taken by European countries regarding petrol/diesel vehicles also encourage the rapid expansion of EVs/EFVs in the near future ("Dizel Araçlar", 2018).

The studies on the development of EV's on the world has gained increasing attention since 2012, and an international EV literature has begun to emerge. Much of the research on EV has focused on how to improve the use of EVs on roads compared to Internal Combustion Engines (ICE) to reduce emissions. The adoption and integration of EV are still very low, and EVs, Hybrid EVs and natural gas vehicles constitute 4% of total sales in passenger vehicles and only 1% of light commercial vehicle sales of total vehicle sales in the year 2013 (Whang & Thoben, 2017). While the number of studies is scarce in EVs, EFVs used in urban freight transport are not yet subject to more than a small number of studies.

Even in developed countries around the world, the usage of EVs and EFVs has not reached the desired levels. In this context, there are many barriers to the adaptation of EVs and EFVs. Therefore, this study aims to reveal and classify the barriers encountered in EV and EFV studies in the literature, sector reports and secondary data sources. In this study, the crucial elements and barriers in the adaptation and development of EVs and EFVs are summarized. In section 2, a literature review is provided for EVs and EFVs. The barriers to adoption of EVs and EFVs are explained in section 3. In section 4, the types of barriers are explained. Lastly, the conclusions of the study are discussed in the section 5.

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LITERATURE REVIEW

In order to find the studies investigating barriers to the adaptation of EVs and EFVs, we searched the academic databases as Springer, Science Direct and Google Scholar by using those keywords: EVs, adaption of EVs, Electric Freight Vehicle (EFVs), barriers of EVs.

Labeye et al. (2016) studied the behaviour of EVs' daily usage by identifying dimensions like strategically, tactically and operationally. Because of the specifics of EVs such as limited range of travel and working quieter than other conventional cars, drivers need to develop new driving abilities. At the strategic level, drivers should identify better ways to charge EV's to travel according to the route created at the beginning of the tour. Secondly, at the tactical level, drivers should develop new driving behaviours that compensate for the problems caused by EV being much quieter than other conventional vehicles while interacting with other drivers. Finally, at the operational level, the drivers should adopt to the regenerative braking function to acquire optimum driving behaviour. Another significant result of this study is the need to acquire the skills and knowledge required to use EV, and it is essential that future research on EVs should focus on developing and designing educational resources for EV drivers.

There are many researches in the literature regarding the routing of ICE Vehicles. In these studies, the most suitable route is determined under specific constraints. The vehicle routing studies of EVs differs from the other vehicle routing studies of ICE vehicles because of the limited travel range of EVs. The routing models of EFV also differ from both EVs and conventional vehicles because of the specifics of EFVs such as the need of charge while loading and unloading processes. Clarembaux et al. (2016) aimed to improve control and perception systems for the loading/unloading process by focusing on intelligent units on the vehicle. In the scope of this study, sensor data was gathered around the vehicle, filtering and data processing were performed to classify vehicles, loads and objects around the EFVs. In addition, they determined the appropriate route, and they used simultaneous localisation and mapping (SLAM) simulations to determine the routes closest to the cargo boxes.

While Whang & Thoben (2016) focus on impact factors on freight transport in the adaptation of EFVs, Taefi et al. (2016) focus on policy measures and the lack of communication between policy makers and logistics companies. The survey study of Whang & Thoben (2016) revealed the impact factors of freight transport as mechanical, environmental, chemical and economic factors.

Taefi et al. (2016) identified the gaps in the literature on intra-city freight transport for EFVs. They also identified gaps between policy and practice regarding EFV ownership by conducting reviews with policymakers and EFVs users. In addition, this study found that the total cost of ownership of EFVs remains high despite to financial incentives. In other words, policymakers only encourage and support the growth of EFVs, but they do not take legal actions that contribute to the system for the establishment of the necessary infrastructure for EFVs.

Urban freight transport is one of the most fundamental elements for countries' economic viability (Whang & Thoben 2017). Economic, environmental and social dimensions of sustainability are important aspects of sustainable urban freight transport. Furthermore, there is a need of advances in technology and innovations in order to overcome the barriers to the adaptation of EFVs. Therefore, Whang & Thoben (2017) integrated the technology dimension with the three basic dimensions of sustainability and revealed the factors related to the dimensions affecting EFV's adaptation to urban freight transport. The factors related to economic dimension are the total cost of ownership including investment costs (purchase price and infrastructure), operating costs (fuel costs, electricity costs, maintenance and repair costs) and ownership costs (insurance costs, license and registration costs). Factors of social dimension are improving public image because of the usage of environmental friendly EFVs and accessibility as a negative factor because of the insufficient charging infrastructures, short of repair shops etc. Factors of environmental dimension are related to environmental quality (emissions and noise) and natural resources (energy consumption and the reuse). The factors of technological dimensions are battery limitations, vehicle limitations (payload capacity and accessories) and charging infrastructure limitation and transportation limitations (travel time and distance).

Quak et al. (2016) considered operational, economic and environmental performance as well as policy and government factors in order to illustrate the changes and trends in EFVs. The range of EFVs is an important factor in logistics operations for logistics firms within the scope of technological performance. The technical problems observed in EFV projects examined in this study are; failure in battery support, equipment compatibility problems, long charging times, and the need to customise the charging station for fleet needs. Logistics companies are waiting for EFVs purchase because of the rapid development in technology. This study indicates that EFVs has many advantages in comparison with ICEs, such as fewer parts, no need for a regular oil change, and an energy-generating braking system.

Quak et al. (2016-1) determined the significant factors affecting future EFV procurement by taking opinions of the operators. They found that economic considerations, running cost and reliability are the primary determinants and environmental concerns comes later. Therefore, economic incentives made by the manufacturers of EFVs and the governments will support the adoption of EFVs. Furthermore, other types of supportive policies to provide operational advantages are access to low emission areas, permission to park on unloaded areas, permission to enter pedestrian areas, use of bus lanes (Quak et al., 2016-1). On the other hand, Quak et al. (2016-2) conducted a SWOT analysis of EFVs compared to ICEs. The results of this analysis show that the strengths of EFVs are low fuel costs, low environmental impact, working in silence, positive acceptance by the public and the weaknesses of EFVs are high procurement costs, limited loading capacity, limited and expensive after-sales support. In addition, the results indicate that opportunities are higher ranges of new vehicles, decrease in battery price, availability of public charging points and threats are low oil prices, increasing energy prices, unclear regulation, and better environmental performances of vehicles running on alternative fuels. Rizet et al. (2016) investigated the carbon emissions and total travel distance if the "Low emissions zone" regulation, which prohibits diesel vehicles in specific zones, is applied in the big urban areas that more than 100,000 habitants live. They constructed two scenarios based on the different weight of payload of EVs. The results of the study show that with the help of "Low emissions zone" regulation, carbon emissions may be reduced by nearly 60% while increasing total travel distance of nearly 9%. On the other hand, the payload weight of the EVs should be increased to compete with the diesel or another type of pollutant vehicles.

Meisel & Merfeld (2018) identified the major barrier to adopt EVs as consumer concerns about the economic benefits of EVs. Therefore, they defined e-vehicle services such as microgrid operation, energy trading and vehicle sharing and in this concept, they proposed economic incentives to increase adoption of EVs. Yan (2018) investigated the economic and environmental effects of tax incentives on adoption of battery EVs in Europe by using cost-benefit analyses and ordinary least square regressions. The results of the study show that instead of tax incentives, providing incentives to for R&D efforts in vehicle/battery technologies will be more effective to increase adoption of EVs. Westin et al. (2018) investigated the important factors such as socio-demographic attributes, geographic conditions, car interest, personal and social norms and environmental concern affecting adoption of EVs in Sweden by conducting a survey study. The results of the study show that the most important factor affecting EVs ownership is personal norm. Furthermore, age and education level has positive effect on EVs ownership. In terms of geographic conditions, adoption of EVs is more in the metropolitan areas and touristic regions. Egner & Trosvik (2018) examined the effect of local policy instruments, public procurement and public charging infrastructure on adoption of EVs in Sweden. The results of their study show that public procurement of battery EVs made by urban municipalities and public charging infrastructures have positive effect on EVs ownership. Globisch et al. (2018) investigated the factors affecting adoption of EVs in commercial pool car fleets with the help of TAM (Technology Acceptance Model). They conducted a survey study with actual EV drivers and analyzed the data by using SEM (Structural Equation Modelling). The results of the study show that perceived organizational usefulness and subjective norms are the most important factors on adoption of EVs in commercial fleet. The following table summarises the literature survey. The studies are categorised into the subject, methodology, application area, type of transportation, data type, vehicle type and applied region as shown in Table 1. Table 2 gives the methods of studies found in the literature. The most commonly used methods are the literature review, secondary data analysis and questionnaires.

Barriers to Adoption of EVs and EFVs

There are many barriers to adoption of EFVs. In the literature, almost all of the studies about EV/EFVs mentioned this kind of barriers. Despite the high investments in EV/EFV made by governments, commercial vehicles are preventing EV/EFV sales due to a significant difference between the total costs of EV/EFV and commercial vehicles. Purchasing cost of EV/EFV is very high (Labeye et al., 2016; Taefi et al., 2016; Wang & Thoben, 2014; Quak et al., 2016; Wang & Thoben, 2017). Because of the high investment costs, high battery costs and recharging requirements, logistics companies do not want to replace ICEs with EFVs (Wang & Thoben, 2017). Moreover, the lack of infrastructure of the charging station is one of the reasons for adoption of EFVs. In addition, because of the new technology of EV/EFV, drivers should need education (Whang & Thoben, 2017). Therefore, logistics companies should provide education for their drivers by paying the costs to improve their driving skills. However, logistics firms do not want to pay the costs, and they do not want to give permissions to the drivers for training. Furthermore, drivers are not willing to take education. All of these factors are the main barriers to EFVs expansion and adaptation (Whang & Thoben, 2017).

Table 1. Summary of Literature Survey

Study	**Subject**	**Methodology**	**Application area**	**Transport type**	**Data type**	**Vehicle type**	**Country**
Kaya (2008)	The general view of Turkey's Transportation Sector	Secondary data	The kinds of all transportation	Passenger and freight transportation	The data and reports of TUIK	The types of all vehicles	Turkey
Şenlik (2012)	The past and future of EVs	Literature review	Road	EV-automobile	Academic papers and sectorial reports	EVs	
Ustabaş (2014)	The micro and macro effects of EVs in the economy of Turkey	Literature review	Road	EV-automobile	Academic papers and sectorial reports	EVs	
Wang & Thoben (2014)	How EFVs adapt inner-city freight transportation	Literature review, questionnaire and simulation	Inner city road	Freight transportation		EFVs	
Clarembaux et al. (2016)	The developing control and sensing systems for park/docking process of EVs	The stages of autonomous driving control architecture and SLAM (Simultaneous localisation and mapping)	Inner city road	Freight transportation	LIDAR (light radar), sensor and laser	EFVs	The European Union
Labeye et al. (2016)	The user behaviour of EVs	Questionnaire and focus group	Inner city road	EV-automobile	The data of questionnaire, focus group, and driver's diary about their travel experience	EVs	France
Rizet et al. (2016)	The researching that exchanges of EVs regarding Diesel Vehicles	Questionnaire	Inner city road	Freight transportation	The data of 3000 French senders, 10000 receivers and questionnaire	EVs	France
Quak et al. (2016)	What are opportunities and barriers of use of EV in logistics	Projects	Road	Electric Freight Mobility	The inputs, progressions and findings of projects	EFVs	
Taşkın (2016)	The examining changes and current state in the transportation sector	Literature review and sectorial reports	The kinds of all transportation	Passenger and freight transportation	Academic publications, sectorial reports, the data of TUIK	The types of all vehicles	Turkey

Table 1-cont. Summary of Literature Survey

Study	Subject	Methodology	Application area	Transportation type	Data type	Vehicle type	Country
Taefi et al. (2016)	The identifying policies for supporting adoption of EFVs	Online questionnaire and multi-criteria decision model	Inner city road	Freight transportation	The data from 10 policymakers and 16 logistics firms	EFVs	Germany
Taefi et al. (2016-2)	The examining initiatives examples of EFV adaptation	Projects	Inner city road	Freight transportation	The inputs, progressions and findings of projects	EFVs	Denmark Germany Holland Sweden UK
Kuppusamy et al.(2017)	The effects of integration EVs to the taxi fleet	Mathematical Decision Model	Inner city road	Passenger transportation		EVs	
Wang &Thoben (2017)	The affecting factors use of EFVs	Literature review	Inner city road	Freight transportation		EFVs	

Table 2. Methods in Literature

Reference	Routing Algorithms	Decision Models	Data processing, classification and filtering	Secondary data	Literature review	Survey	Focus Group	Travel diaries
Kaya (2008)				X				
Şenlik (2012)					X			
Ustabaş (2014)					X			
Clarembaux et al. (2016)	X		X					
Labeye et al. (2016)						X	X	X
Quak et al. (2016)					X			
Taefi et al., (2016)						X		
Taşkın (2016)				X	X			
Taefi et al., (2016)				X				
Whang & Thoben (2014)					X	X		
Wang & Thoben (2017)					X			
Kuppusamy et al. (2017)		X						

One of the barriers to adaptation of EFVs is battery technology and constraints (Labeye et al., 2016; Taefi et al., 2016; Wang & Thoben, 2014; Quak et al., 2016; Wang & Thoben, 2017). The common battery problems mentioned in the literature are EV/EFV's limited range, battery weight, battery safety and security (Whang & Thoben, 2017). In addition, the size of the battery limits the loading area of the vehicle, and the availability of different connectors, different sockets and different payment systems complicate the recharging process. The presence of such structures prevents the spread and adaptation of EFVs.

Limited variety of EFV models and the lack of after-sales support are other barriers. In other words, the limitations of standard vehicle and vehicle types especially in large trucks appear to be one of the factors that prevent adoption of EFVs. Moreover, even though EYA has high torque and acceleration, it is a fast, flexible and comfortable structure in traffic. However lack of repair and spare parts support of EFV manufacturers is seen as a barrier. On the other hand, there are operational barriers and difficulties in EYA. These barriers are long charging time, low load capacity, high EFV sales price and high battery cost. Although the method of renting or exchanging batteries is among the options to reduce the EFV purchase cost and operational costs, the excessive cost of repair caused by the EFVs deterioration is also a barrier for EFV buyers. In addition, it is necessary to train transport operators and drivers for the technical and operational efficiency of EFVs (Quak et al., 2016).

Taefi et al. (2016-2) found that EFV's range of motion was smaller than the suggested km. EFV could not charge between the tours, during loading and unloading periods and there are no quick charging options for EFVs. In addition, the lack of different types of energy limits the range of EFVs. For example, solar panels placed on the roof of EFVs could increase the range of EFVs. On the other hand, this study reveals the lack of repair centers, limited knowledge for repair, low spare part suitability, long repair times and money loss as factors that block the spread and adaptation of EFVs. This study pays attention to the recharge of EFVs in the context of energy supply and infrastructure. Methods of charging include slow charging, fast charging, battery swapping, and inductive charging. Fast charging seems to be an option to increase the efficiency of EFVs, but this shortens the life of the battery. In addition to these, a limited number of charging stations and battery exchanges for large vehicles are among the other barriers. This study also investigates the human factor affecting adoption of EFVs.

In some cases, drivers refuse to use EYAs. Therefore, drivers should be trained about EFVs to ensure optimum use of EFVs. With the help of training, travel range of EFVs can increase by 30%.

Riset et al. (2016) investigated what changes would occur regarding environmental and traffic conditions if EFVs took the place of diesel vehicles. The results show that the carbon dioxide ratio fell within the scope of the scenarios they determined. On the other hand, loading areas of EYA are an essential problem for freight forwarding logistics companies. In addition, the range of EYAs, loading area and the diversity of EYA types are much more limited than diesel vehicles.

Types of Barriers

This paper classifies barriers, which are discussed in the literature. It provides a classification of those barriers into eight types: infrastructure, technology, awareness, operational, charging, political, economic, and vehicle characteristics. Some of these barriers differ according to the characteristics of EF and EFV. Therefore, EV-Automobile and EFV columns are added to Table 3 in order to show which type of vehicle is relevant for which type of barrier.

Infrastructure Barriers

Infrastructure is one of the most mentioned barriers in the literature. Table 3 summarizes some of those barriers discussed. The most emphasised infrastructure barrier is the lack of infrastructure for the charging stations (Steinhilber et al., 2013; Taefi et al., 2016, Quak et al., 2016; Taefi et al., 2016 -2). The inability to establish after-sales service infrastructure is another important barrier (Quak et al., 2016; Taefi et al., 2016-2; Steinhilber et al., 2013). On the other hand, the lack of spare parts and repair centers are among the barriers of infrastructure (Qak et al., 2016; Taefi et al., 2016-2). In addition, the production of limited varieties of EFVs is also viewed as a barrier to adoption of EFVs in terms of logistics firms (Quak et al., 2016).

Technological Barriers

Research and development costs are too high for both EV, battery production and development (Ockwell et al., 2008). This situation prevents almost all related companies/universities from research and development. Also, logistics firms are not considering investing in EFVs because of the rapidly evolving technology (Quak et al., 2016). This emerges as a technological barrier to the spread of EFVs. On the other hand, there is no R&D investment for EVs in developing countries (Şenlik, 2012) and therefore they do not have the technical competence to make the necessary improvements for EVs all the time.

Table 3. Barriers

Types of Barriers	Barriers	EV-Automobile	EFVs	Reference
Infrastructure	The lack of charging stations and its infrastructure	X	X	Steinhilber et al. (2013); Taefi et al. (2016); Quak et al. (2016); Taefi et al. (2016-2)
	The limited types of EFVs production		X	Quak et al. (2016)
	The absence of after sales services	X	X	Quak et al. (2016); Taefi et al. (2016-2); Steinhilber et al. (2013)
	The limited volume of production of EFVs		X	Quak et al. (2016)
	The nonexistence of repair center and spare-parts of EFVs and EVs	X	X	Quak et al. (2016); Taefi et al. (2016-2)
	The long repair times		X	Taefi et al.(2016-2)
	The lack of repair know-how of EFVs and EVs	X	X	Taefi et al. (2016-2)
	The lack of facilities for parking and road infrastructure for EVs	X		Steinhilber et al. (2013)
Technological	The high R&D cost	X		Ockwell et al. (2008)
	The rapidly changing technology		X	Quak et al. (2016)
	The absence investing of R&D and research activities for developing countries	X		Şenlik (2012)
Charging	The limited technology of battery (long charging time)	X	X	Şenlik (2012); Ustabaş (2014); Wang & Thoben (2014); Quak et al. (2016); Taefi et al., (2016-2); Wang & Thoben (2017); Berkeley et al. (2017)
	The different types of battery sockets and battery infrastructure	X	X	Quak et al. (2016); Taefi et al. (2016-2); Wang & Thoben (2017)
	Battery safety	X	X	Quak et al. (2016); Wang & Thoben (2017)
Awareness	The unwillingness of acquiring awareness for EFV or EV's optimum driving		X	Quak et al. (2016); Wang & Thoben (2017)
	The lack of awareness for optimum driving		X	Taefi et al. (2016)(2); Wang & Thoben, 2017
Political	The nonexistence of political criterion	X	X	Taefi et al. (2016)
	The lack of privileges for adaptation of EFVs		X	Quak et al. (2016)
	Policymaker does not focus on EFV/EVs infrastructure and suppliers of EFVs/EVs	X	X	Taefi et al. (2016)
	The lack of environmental regulations	X		Zhang et al. (2011)
	The uncertainties of carbon emission policies	X		Okwell et al. (2008)
	The inadequate of incentives for EFVs/EVs in developing countries	X	X	Ustabaş (2014)
Cost	Total cost of acquiring EV/EFVs	X	X	Şenlik (2012); Ustabaş (2014); Ockwell et al. (2008); Labeye et al. (2016); Taefi et al. (2016); Quak et al. (2016); Wang & Thoben (2014); Quak et al. (2016); Taefi et al. (2016-2); Wang &Thoben (2017)
	Commercial vehicles have lower acquiring costs comparing with EFVs/EVs		X	Taefi et al.(2016); Quak et al.(2016)
	High battery cost	X	X	Labeye et al. (2016); Taefi et al. (2016); Wang & Thoben (2014); Quak et al.(2016); Taefi et al. (2016-2); Wang & Thoben (2017)
	Training cost of EFVs' drivers		X	Taefi et al. (2016-2); Wang & Thoben (2017)
	High repair costs for EVs and EFVs		X	Taefi et al.(2016-2)
Operational	The limited range	X	X	Şenlik, (2012); Ustabaş, (2014); Labeye et al. (2016); Taefi et al. (2016); Wang & Thoben (2014); Quak et al. (2016); Taefi et al. (2016-2); Riset et al. (2016); Wang & Thoben (2017); Berkeley et al.(2017)
	The freight transportation process of logistic firms only focus on ICE vehicles		X	Quak et al. (2016)
Vehicle characteristics	The limited freight capacity in EFVs		X	Quak et al. (2016) ; Riset et al. (2016)

The development of the battery may increase the availability and widespread use of EVs. For this reason, charging action becomes vital for electric vehicles. Many studies in the literature mentioned batteries and charging activities. The battery technology is still limited and therefore the charging time of the EFVs/EVs is very long (Şenlik, 2012; Ustabaş, 2014; Wang & Thoben, 2014; Quak et al., 2016; Taefi et al., 2016-2; Wang & Thoben, 2017; Berkeley et al., 2017). Different battery types and sockets cause ineffective usage of the charging infrastructure (Taefi et al., 2016-2; Wang & Thoben, 2017).

Barriers Related to Awareness

Very few of the articles in the literature mention about awareness and knowledge of EFVs as barriers. Optimal driving of electric vehicles requires education and awareness. Notably there is no awareness for the optimum driving of EFVs (Taefi et al. 2016-2; Wang & Thoben, 2017) and there is reluctance in people to acquire the necessary knowledge (Quak et al., 2016; Wang & Thoben, 2017).

Political Barriers

There are many political obstacles to increasing the adaptation of EFVs and EVs. There is no standardised criteria/measure for the adoption of electric vehicles even in developed countries. Moreover, political activities about the infrastructure of the electric vehicle system have not been identified (Taefi et al., 2016). There are also uncertainties in the environmental regulations (Zhang et al., 2011) and carbon policies (Okwell et al., 2008).

Cost Barriers

Both purchasing costs of electric vehicles and expenses of after-sale services are seen as an essential factor for potential customers. All studies in the literature mentioned about high purchasing cost of electric vehicles as a barrier to the adaptation of EV/EFVs. Furthermore, battery cost and repair cost of EF/EFVs are very high.

Operational Barriers and Vehicle Characteristics

Limited travel range of EFVs is a significant operational barrier that affects logistics companies to adopt EFVs negatively. Furthermore, logistics companies focus on conventional vehicles for their freight transportation process. Vehicles used freight transport have different capacities. However, EFVs has a limited number of capacity options that prevents logistics companies from adding EFVs to their fleet.

CONCLUSION

EVs/EFVs are more environmentally friendly vehicles compared to diesel vehicles, and increasing usage of EVs/EFVs may help to decrease carbon emission and health problems due to air pollution. In spite of the benefits, several obstacles need to be overcome before EVs and EFVs will be widely adopted. In this study, we discuss those barriers over an extended literature review. These barriers are categorized into seven groups as infrastructure, technology, awareness, charging, political, cost, and operational and vehicle characteristics. Specifically, high investment and battery replacement cost, lack of awareness, options for second battery reuse, battery limitations, limited variety of vehicles, limited travel range, recharging infrastructure, and lack of after-sales support are some of the factors that prevent urban usage of EVs/EFVs.

As future research, recommendations to overcome these barriers in Turkey will be discussed over benchmarking of the practices and regulations applied in other countries.

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BAYESIAN DECISION MAKING FOR HYBRID SYSTEM WITH CLASSIFYING RETURNS

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Abstract – *Reverse supply chain comprises sequences of activities required to recover a used product from a customer to manufacturer. Product recovery management deals with the collection of used and discarded products and explores the opportunities to remanufacture the products, reuse the components or recycle the materials. Remanufacturing of used products is one of the most desirable opportunities among the product recovery choices. Remanufacturing is an industrial process in which used products are restored to "like-new" conditions. In this research we consider a hybrid manufacturing/remanufacturing system for a single remanufacturable product and model the hybrid system as an open queueing network (OQN) with a stochastic return of used products and demand. In remanufacturing systems it's critical to coordinate the recovery operation and disposal decisions of the inducted cores satisfy non-stationary demand. The classification of the return products and associated decisions provide substantial cost savings originated from the remanufacturing operations and also it prevents lessen the value of the return products. To this end we utilize Bayesian approach in dealing with return and recovery rate uncertainties of the remanufacturing system. In Bayesian updating procedure recently obtained data is pooled with the formerly existing data about the parameter that we interested. We have analyzed the effect of recovery rate adjustment on the profit function and other system performance measures with various stages of product life cycle of the recoverable product. To capture the full characteristics of the model we utilize the demand and return rates during a typical life cycle of a remanufacturable product.*

Keywords – Bayesian update, queueing network, remanufacturing, reverse supply chain

INTRODUCTION

Environmental regulations, customer consciousness, shorter product life cycles and extensive competition in the global markets directed manufacturers to focus on their supply chains (SC). Integration of used products into the supply chains in various forms of recovery options viz. remanufacturing, reconditioning, refurbishment, reduce whole supply chain costs. Yet, uncertainties in timing, quantity and quality of returned products complicates reverse material flow stem of supply chain and serviceable parts inventory control (Fleishmann et. al., 2000). Product recovery management deals with the collection of used and discarded products and explores the opportunities to remanufacture the products, reuse the components or recycle the materials. Remanufacturing of used products is one of the most desirable opportunities among the product recovery choices. Remanufacturing is an industrial process in which used products are restored to "like-new" conditions. Remanufacturing is not only a direct and preferable way to reduce the amount of waste generated, it also reduces the consumption of new materials and energy resources. Recycling, on the other hand, is a process performed to retrieve the material content of used and non-functioning products without retaining the identity of the original product. Remanufacturing of durable goods has become an important alternative to assembling new products. This is a direct consequence of the implementation of extended manufacturer responsibility, together with the new more rigid legislation and public awareness of the environment. Remanufacturing operations tend to be labor intensive that lead to significant variability in the processing times at various shop floor operations. The uncertainties surrounding the returned products further complicate the modeling and analysis of product recovery problems. As such, forecasting the quantity and the quality levels of used products are difficult. The

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results of these uncertainties include undersupply or obsolescence of inventory, improper remanufacturing plan and loss of competitive edge in the market. The serviceable inventory level coordination between remanufactured products and the new products which are procured from outside further complicates the optimization of the system performance.

In this paper, we consider a hybrid system where manufacturing and remanufacturing operations are occurring together with a single item remanufacturable returns and stochastic demand. We use an open queueing network for remanufacturing system modeling and decomposition principle and expansion methodology to analyze the system. Both demand rate and return rate of cores are following independent normal distribution with known mean and variance. The primary objective of this paper is to use Bayesian methods in dealing with inducted cores quality and recovery rate uncertainties of the used products in the remanufacturing system. In Bayesian analysis the new information is combined with the previously available information. At this point to determine the quality level of returns the prior information (distribution) corresponds to the historical data or the subjective thought of the decision maker about the random parameter of the involved process. The consequential decision or inferential statement (posterior distribution) combined all available information about the uncertain parameter of the interest. We have analyzed the effect of recovery rate adjustment on the profit function with various stages of product life cycle with considering the various quality group of the return product.

LITERATURE REVIEW

Product recovery management deals with the collection of used and discarded products and explores the opportunities to remanufacture the products, reuse the components or recycle the materials. The objective of product recovery management, as stated by (Thierry et. al. 1995) is "to recover as much of the economic (and ecological) value as reasonably possible, thereby reducing the ultimate quantities of waste". The researchers have been building up various models to acquire the essential information for successful product recovery management (Fergusson and Browne 2001; Simon et. al., 2001; Zuidwijk and Krikke, 2001; Akcali and Cetinkaya, 2011). European Working Group on Reverse Logistics made the comprehensive characterization of the process as "the process of planning, implementing and controlling backward flow of materials, in process inventory, packaging and finished goods, from a manufacturing, distribution or use point, to a point of recovery or point of proper disposal". Broad literature in the area of reverse logistics and closed-loop supply chain is examined by Govindan et. al. (2015). Gungor and Gupta (1999) and Ilgin and Gupta (2010) review the literature in the area of environmentally conscious manufacturing and product recovery. Recent books by Lambert and Gupta (2005), Gupta and Lambert (2008) and Gupta (2013) are helpful in understanding the general area of disassembly. The book by Pochampally et al. (2009) explores various areas of reverse logistics and closed-loop supply chains. They evaluate the futurity of used product by Bayesian updating from expert systems approach. Since the inventory control and production planning techniques available for traditional manufacturing lines are not suitable for the remanufacturing environment

Aras et. al. (2004) presented an approach for assessing the impact of quality-based categorization of used products. The authors showed that incorporation of returned product quality in the remanufacturing and disposal decisions can lead to major cost savings for the hybrid systems. Takahashi et al. (2007) considered a decomposition process where recovered products are decomposed and classified into wastes, materials and parts to be used in the process for manufacturing for a Markovian remanufacturing system. Ferguson et. al. (2009) states that remanufacturing firms could increase their profit around 4% by means of categorizing post consumed products. In this paper, we considered returned products recovery rate uncertainty through classifying inducted cores and we utilize Bayesian approach in dealing with return and recovery rate uncertainties of the remanufacturing system. The classification of the return products and associated decisions provide substantial cost savings originated from the remanufacturing operations and also it prevents lessen the value of the return products.

In Bayesian analysis the new information is combined with the previously available information. At this point the prior information (distribution) corresponds to the historical data or the subjective thought of the decision maker about the unknown parameter of the involved process. The consequential decision or inferential statement (posterior distribution) combined all available information about the uncertain parameter of the interest. The performance of the following updates depends on the prior information therefore the determination of prior information is significant. If there isn't any basis of the prior information then the decision maker may consider the non-informative priors about the random variable which represents the unrevealed parameter may obtain any value in its domain equally likely (Hill, 1997; Hill, 1999; Winkler, 2003).

MODEL DESCRIPTION AND ANALYSIS

The structure of the model that we have considered in this paper is depicted in Figure 1. In this paper we assume that both return and demand processes are independent and we consider single remanufacturable item. There are two distinct inventory locations in the system viz. return product inventory comprise post used returned items from consumers and serviceable inventory comprises brand new and recovered products where the stochastic demand is fulfilled. The market environment for the remanufactured products is followed the "make-for-stock" policy. In the make-for-stock environment all customer demand is planned to be met from finished serviceable inventory. Unfulfilled demand is not permitted and considered lost sales.

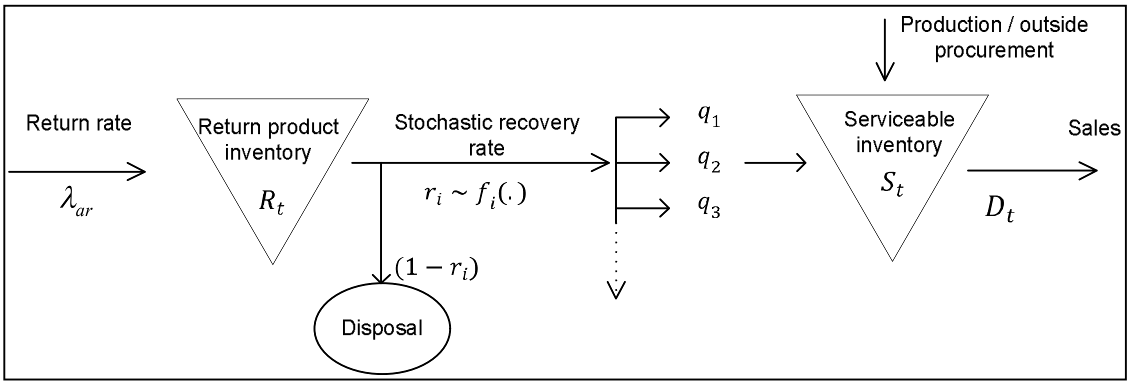

Figure 1. Manufacturing / remanufacturing system with classifying returns

Throughout the paper, for recovery potential we use the term recovery rate (ri) to refer to the acceptable fraction of used parts that satisfies the quality specifications for remanufacturing. Also, it's assumed that recovery rate distributions are independent with the magnitude of the returned rate flow. The p.d.f. and c.d.f. of the re-usable rate of returned items is denoted as f(ri) and F(ri) respectively. The recoverable returns classified as q_1, q_2 and q_3 after disassembly and inspection station, and represents high, average and low quality rate respectively. The aim of the classification at this stage is determining part recovery processes and its associated process time and remanufacturing costs. At this stage disposal rate of the returned items represented by $(1 - r_i)$. We model the remanufacturing system as an open queueing network and use the decomposition principle and expansion methodology to analyze it. To obtain the approximate throughput rates (THi) of each server and the entire remanufacturing network, we utilize the expansion methodology. Details of the method and necessary derivations for production lines can be obtained from (Gupta and Kavuşturucu, 2000).

In Bayesian analysis the new information is combined with the previously available information. If random variable ri (recovery rate) is continuous, the prior and posterior distribution of ri can be represented by density functions. The posterior distribution is the conditional density of ri , given the observed value, y, of the sample statistic.

The posterior density can be written as follows (Winkler, 2003).

$$f(r_i | y_s = y) = \frac{f(r_i) f(y | r_i)}{\int_{-\infty}^{\infty} f(r_i) f(y | r_i) dr_i} \tag{1}$$

The densities $f(r_i | y_s = y)$ and $f(r_i)$ represent the posterior and prior distributions respectively and $f(y | r_i)$ represents the likelihood function.

Selecting the appropriate prior distribution function is the most critical phase of the Bayesian updating. Selecting the applicable prior distribution is the major stage for drawing an inference. In fact the prior information (distribution) corresponds to the historical data or the subjective thought of the decision maker about the unknown parameter of the involved process. The consequential decision or inferential statement (posterior distribution) combined all available information about the uncertain parameter of the process. The performance of the succeeding updates depends on the prior information therefore the determination of prior information is significant. If there isn't any basis of the prior information then the decision maker may consider the non-informative priors about the random variable which represents the unknown (Winkler 2003; Lee 2012 and Robert 2012).

In this study it's assumed that return rate and recovery rate of returned items for each quality grade are normally distributed with known means $\mu_{ar}, \mu_{q1}, \mu_{q2}, \mu_{q3}$ and variances $\sigma_{ar}, \sigma_{q1}, \sigma_{q2}, \sigma_{q3}$ respectively. Then prior density function for core recovery rate can be written as follows;

$$f'(r_i) = (2\pi\sigma_r'^2)^{-1/2} exp\{-1/2\,(r_i - \mu_r')^2/\sigma_r'^2\} \quad (2)$$

when $r_i \sim N(\mu_r', \sigma_r'^2)$

Based on sample data y_s, which is normally distributed (μ_r, σ_r) with mean equal to the parameter that we interested ri.. Then the posterior distribution of core recovery rate ri can be obtained from Bayesian updating with normal prior density as follows (Lee, 2012);

$$f''(r_i|y_s) \propto f'(r_i)\, f(y_s|r_i) \quad (3)$$

$$f''(r_i) = (2\pi\sigma_r^{2''})^{-1/2} exp\{-1/2\,(r_i - \mu_r'')^2/\sigma_r^{2''}\} \text{ when } r_i \sim N(\mu_r'', \sigma_r^{2''}) \quad (4)$$

where,

$$\sigma_r''^2 = 1/(1/\sigma_r'^2 + 1/\sigma_r^2) \quad (5)$$

and

$$\mu_r'' = \sigma_r''^2(\mu_r'/\sigma_r'^2 + y_s/\sigma_r^2) \quad (6)$$

NUMERICAL ANALYSIS AND RESULTS

In this section we examine the effect of classification of the return rate and Bayesian update on the performance of the system. In the model that we studied single production order decision made before the period to persuade the demand. Used products may be returned to the remanufacturing system and they follow a stochastic recovery rate. Unfulfilled demand at the end of the period is considered as lost sales. The primary objective of this paper is obtaining optimal order quantity and associated total system cost in the presence of stochastic return and recovery rate using Bayesian approach. To assess the effect of recovery rate on the remanufacturing system performance we defined the expected cost per period, which comprises of the variable and fixed remanufacturing and outside procurement costs, disassembly, testing, disposal and remanufacturing costs, holding costs for serviceable inventory and lost sales costs. The following notation is used for the steady state cost function.

$E(R_t)$: expected number of returned products per unit of time.
$E(dis.)$: expected number of disposed items per unit of time.
$E(S_t)$: expected on hand inventory level per unit of time.
$E(L_s)$: expected lost sales per unit of time.
$E(Rm_t)$: expected number of remanufactured products .
$E(P_t)$: expected number of procured/manufactured new items.

$$E(TC|r_i) = c_pE(R_t) + c_{dis}E(dis) + c_hE(S_t) + c_lE(L_s) + c_rE(Rm_t) + c_mE(P_t) \quad (7)$$

The cost variables are; purchasing cost of returned products (cp), disassembly cost (cdis), inventory holding cost for serviceable items (ch), lost sales cost for unfulfilled demand (cl), remanufacturing operation cost (cr) and cost of procured / manufactured items (cm). Additionally we examined the effect of Bayesian updating and classification of the return products on various system performance measures viz., average serviceable inventory and process times.

After the disassembly and inspection station it is assumed that there is a stochastic scrap rate of (1-ri) and recoverable items classified in to 3 grades as q_1, q_2 and q_3. The assessment of the performance measures for return rate classification and updating this information are done through the various return and demand rate of the remanufacturable products with the following cost parameters; purchasing cost of returned products (cp=5), disassembly cost (cdis=4), inventory holding cost for serviceable items (ch=1), lost sales cost for unfulfilled demand (cl=5), remanufacturing operation cost (cr=10) and cost of procured / manufactured items (cm=30). In Table 1 and Table 2, performance measures of the remanufacturing system through various combinations of return and demand rates are considered for prior information and posterior probability distribution respectively. Here we presented the comparison of prior and posterior information after updating the prior distribution by normally distributed simulated data with coefficient of variation cv=0.2, 0.4, 0.6 and 0.8 sequentially. Also, we assumed that recovery rate for inducted cores are normally distributed for each return category we and tested the model under various parameters for the return category probability distribution. In Table 1, we consider the recovered items classification distribution as follows; (μ_{q1}, σ_{q1}) =(0.3, 0.1), $(\mu_{q2}, \sigma_{q2}) = (0.5, 0.1)$ and $(\mu_{q3}, \sigma_{q3}) = (0.2, 0.25)$.

Table 1. System performance measures for prior distribution

Return and demand rate	Prior	Prior distribution results		
	c_v	*E(TC)*	*E(WIP)*	*E(PT)*
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.2	38.21	15.26	11.03
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.4	36.78	13.86	10.55
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.6	35.18	11.03	9.82
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.8	33.80	10.65	9.24
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.2	42.35	10.41	10.67
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.4	41.11	9.59	10.23
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.6	39.72	8.20	9.82
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.8	36.64	7.39	9.26

Table 2. System performance measures for posterior distribution

Return and demand rate	Prior	Posterior distribution results		
	c_v	*E(TC)*	*E(WIP)*	*E(PT)*
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.2	35.24	14.34	8.82
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.4	33.56	12.78	8.29
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.6	32.73	10.38	7.56
$(\lambda_{ar}, D_t) = (0.7, 0.5)$	0.8	31.94	9.67	7.02
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.2	33.76	10.02	10.12
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.4	32.70	9.27	9.56
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.6	30.59	7.85	8.13
$(\lambda_{ar}, D_t) = (0.4, 0.8)$	0.8	29.94	7.54	7.96

CONCLUSIONS

In this paper, we consider a hybrid system where manufacturing and remanufacturing operations are occurring together with a single item remanufacturable returns and stochastic demand. We use an open queueing network for remanufacturing system modeling and decomposition principle and expansion methodology to analyze the system. We have analyzed the effect of recovery rate adjustment on the profit function with various stages of product life cycle with considering the various quality group of the return product by means of Bayesian updating. Numerical analysis shows that cost savings with Bayesian update is significant with low return rate and high demand rate. Also, Bayesian update with quality grading and high coefficient of variation reduce the total system cost significantly and other system performances e.g. process time and serviceable inventory.

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A LITERATURE REVIEW ON SUCCCESS FACTORS AND METHODS USED IN WAREHOUSE LOCATION SELECTION

Ramazan Eyup Gergin[1], Iskender Peker[2]

Abstract *– The fact that the production and consumption amounts are different from each other gives a dynamic feature to the concept of storage. In addition, an effective storage activity hinges upon the selection of the right warehouse location that takes into account capital and labor investments; minimizes the transportation cost and time. The aim of this study is to investigate the preliminary researches in the selection of the warehouse location selection and to present information on which success factors and methods are preferred. Within this scope, many academic studies have been examined by filtering various databases. According to the results of the study, the most used methods in warehouse location selection are multi-criteria decision making methods such as AHP, ANP and TOPSIS; and the most commonly used success factor is determined as the cost-based factors.*

Keywords – Literature Review, Location Selection, Success Factors, Warehouse

INTRODUCTION

Increasing competitive pressures and performance requirements cause logistics activities to become more important, and companies need logistics to gain competitive advantage and build sustainable customer relationships. In recent years, this need felt by companies has increased their commitment to logistics and supply chain management.

One of the key activities of logistics and supply chain management is storage. Storage includes all movements of goods in the warehouse or distribution, including receipt, storage, order collection, accumulation, sorting, and distribution (Onut et al., 2008). The warehouse is the intermediate point that plays a strategic role in the realization of an entire sequence of operations which is from the raw material stage to the production environment and distribution to the consumption centers (Keskin, 2008). In real life, the concept of storage will keep updating as production and consumption quantities are constantly differentiated. In addition to this global aspect of warehousing, the fact that warehouses usually require large capital investments and labor costs, and the need to minimize transportation cost and time (Cakmak et al., 2012) make the choice of storage location more strategic.

In this study, a research has been carried out in which the method and success factors used in warehouse location selection are investigated in depth. In addition, explanatory information is given about the years of these studies and the scientific journals they published. For this purpose, literature review has been included in the following section of the study. In the last section, the results and suggestions about the study are included.

LITERATURE REVIEW

Warehouse site selection has become a matter of interest for many researchers up till today (Maharjan et al., 2017). In this study, preliminary studies on warehouse location selection are examined in three sub-titles which are journals/conferences they published, success factors and methods they used, respectively. The studies in the research have been compiled by using the search system of Gumushane University database. In addition, some national articles have been searched and explored from different databases such as Google Scholar, YOK theses, ULAKBİM Social Sciences. The keywords "Warehouse Location Selection", "Warehouse Location Decision", "Storage Location Selection", and "Storage Location Decision" are used when the related works are scanned. Books have not been included into the study. The study only focuses on the optimal location selection of warehouses. The explanatory information on the studies is summarized in Table 1.

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Table1. Explanatory Information on the Studies

Author (Year)	*Journals/Conferences/Thesis*	*Methods*
Korpela and Tuominen (1996)	International Journal of Production Economics	AHP
Hidaka and Okano (1997)	Proceedings of the 29th Conference on Winter Simulation	Ballon Search
Kratica et al. (1998)	XV. ECPD International Conference on Material Handling and Warehousing	Genetic Algorithm
Vlachopoulou et al. (2001)	International Journal of Production Economics	Geographical Decision Support System
Drezner et al. (2003)	IMA Journal of Management Mathematics	Mathematical Modeling
Colson and Dorigo (2004)	European Journal of Operational Research	MCDM
Michel and Hentenryck (2004)	European Journal of Operational Research	TABU Search
Oum and Park (2004)	Transportation Research Part E	Mean and Chi-Square Test
Zevgolis et al. (2004)	Tunneling and Underground Space Technology	Evaluation of Cost Analysis and Investment Plans
Sharma and Berry (2007)	European Journal of Operational Research	Lineer Programming
Liu et al (2008)	Supply Chain Management: An International Journal	AHP
Chen (2009)	International Journal of Business and Management	Centrobaric Method and AHP
Qu and Chou (2009)	Expert Systems with Applications	Fuzzy Logic
Beltran et al. (2010)	Journal of Environmental Management	ANP
Cura (2010)	Computers & Industrial Engineering	Intuitive Local Search
Demirel et al. (2010)	Expert Systems with Applications	Choquet Integral
Ekmekcioglu et al. (2010)	Waste Management	AHP/TOPSIS
Kuo (2011)	Expert Systems with Applications	AHP/ ANP/ Fuzzy DEMATEL
Ozcan et al. (2011)	Expert Systems with Applications	Simos Procedure/ TOPSIS ELECTRE/GRA
Ozesenli (2011)	Doctoral Thesis	Mixed Integer Modeling
Yılmaz et al. (2011)	XI. ISPR	Genetic Algorithm
Bu et al. (2012)	Procedia - Social and Behavioral Sciences	AHP/ TOPSIS/ Entropy
Ashrafzadeh et al. (2012)	Interdisciplinary Journal of Contemporary Research in Business	Fuzzy TOPSIS
Caka (2012)	Master Thesis	Choquet Integral
Aktepe and Ersoz (2014)	Journal Of Industrial Engineering	AHP/ VIKOR/ MOORA
Durmus and Turk (2014)	European Planning Studies	Logistics Regression
Garcia et al. (2014)	Computers and Electronics in Agriculture	AHP
Rath and Gutjahr (2014)	Computers &Operations Research	Mixed Integer Linear Programming
Segura et al. (2014)	Transportation Research Procedia	P-Medyan Myopik Algorithm
Dey et al. (2015)	International Journal of Management Science and Engineering Management	TOPSIS/ BAT/ MOORA
Chotithammaporn et al. (2015)	Procedia - Social and Behavioral Sciences	Mean / Standard Deviation
Huang et al. (2015)	Computers &OperationsResearch	Nonlinear Mixed Integer Programming
Jayant (2015)	Advances in Industrial Engineering and Management	VIKOR/TOPSIS/GRA
Karmaker and Saha (2015)	Decision Science Letters	AHP/ TOPSIS
Monthatipkul (2016)	Kasetsart Journal of Social Sciences	Nonlinear Mathematical Modeling
Ozbek and Erol (2016)	JEBPIR	AHP/BAT/COPRAS/MOORA
Yılmaz and Kabak (2016)	IFAC-PapersOnLine	Multi-Purpose Decision Model
Bjorklund et al. (2017)	Research in Transportation Economics	Identifying Critical Factors
Dey et al. (2017)	Computers & Industrial Engineering	SAW/ MOORA/TOPSIS VIKOR/ ELECTRE II COPRAS/PROMETHEE
He et al. (2017)	Transportation Research Part D	Fuzzy AHP/ Fuzzy Entropy/ Fuzzy TOPSIS
Golda and Izdebski (2017)	Procedia Engineering	Genetic Algorithm
Maharjan and Hanaoka (2017)	Transportation Research Procedia	Mathematical Modeling

The information gathered from the studies is summarized in the following sub-titles.

Journals/Conferences

The Journals / Conferences in which studies are published are presented in Figure 1.

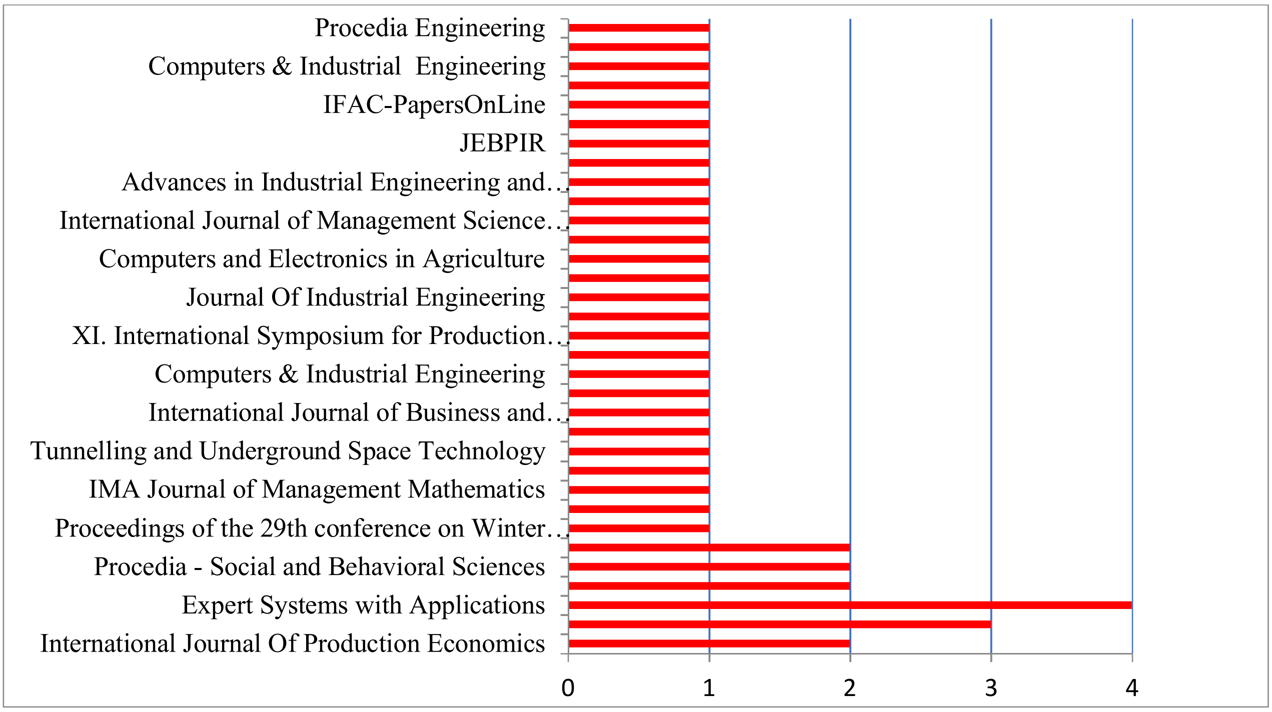

Figure 1. Journals/Conferences

According to Graph 1, it can be said that the studies have taken place in 33 different journal / conferences. "Expert Systems with Applications," and "European Journal of Operational Research" are the most commonly published journals.

Success Factors of Warehouse Location Selection

Findings related to success factors are presented in Table 2.

Table 2. Success Factors of Optimal Warehouse Location Selection

Author (Year)	**Success Factors**	
Korpela and Tuominen (1996)	*Reliability*	**Obedience*truth*transportation*Plant/Equipment*Personnel Abilitys *Non damage handling*
	Flexibility	**Special requests *Urgent Deliveries*Capacity*
	Strategic Alignment	**Strategic Alliances *Strategic Alignment *Collaboration*
Hidaka and Okano (1997)	**Transportation Costs *Warehouse Candidate Locations *Warehouse Fixed Costs*	
Kratica et al. (1998)	**Candidate Warehouse Location *Consumers *Fixed Costs *Customer Request*	
Vlachopoulou et al. (2001)	** Customer Population *Spending Power *Quality of Transportation Links *Competition *Store Size *Parking Facilities *On-Site *Warehouse Management Cost *Distribution Cost*	
Drezner et al. (2003)	**Unit Product Price *Unit Shipping Cost *Variable Order Cost *Holding Cost Ratio *Stock holding Cost Ratio *Reorder Cost Ratio*	
Colson and Dorigo (2004)	*Buildings*	**Storage Volume (m^3) *Insulated Roof and Walls *Existing Offices in the Area *Distance to road*Railway Connection *Waterway Connection *Daily hour of work*
	Customs	**Customs in the area *Bonded Warehouse *Artificial Warehouse*
	Logistics	**Stores Account *Inventory Management *Using Barcode or Label *Computer Systems *RF Communication * Repackaging *Order Management *Transportation /Distribution*
	Handling	**Mixed Transmission*Electric Forklift *Diesel/Gasoline Forklift * Loading / Unloading Docks *Dock Levelling *Automatic Dock *Semi-Trailer Docks*

Michel and Hentenryck (2004)		** Fixed Cost * Transportation Costs*
Oum and Park (2004)		** Transportation Connection and Market Access * Transportation Facilities * Labor and Other Costs * Land Availability and Price * corporation income tax incentive *BIT/E-Business Infrastructure *Logistics Services Providers and Costs *Income Tax for Foreign Labors*
Zevgolis et al. (2004)	*Site Selection*	**Field Selection *Substructure * Underground Gap Transformation*
	Financial Analysis	** surface land acquisition * Underground Area Creation *Waterproof *Floor*Networks * Fire Protection and Security *Systems *Offices*Ramps* Unforeseen Costs*
Sharma and Berry (2007)		** Warehouse Location Cost * Transportation Cost*
Liu et al. (2008)	*Technical Ability*	** Performance Standards * Ascension and Transfers * Forecast Management *Telecommunication *Training *Knowledge and Ability *Products *Incentives *Quality Management *Loss of employe*
	Experience	**Background *Property Diversity *Financial Power *Facilities * Professional cooperation *Staff Relationships *Emergency Plan*
	External Abilities	**International Infrastructure *Language Skills *Facility Security *Environmental Risk-Safety Assessment*
Chen (2009)		**Distribution of Sales Place *Transportation *Land *Political Environment *Natural Environment*
Qu and Chou (2009)		**Service *Transportation and Distribution Systems *Market Potential *Cultural Issues *Environmental Factors *Infrastructure*
Beltran et al. (2010)	*Facility Usage Costs*	**Distance to Waste Water Treatment Plant *Distance to another Waste Collection Plant *Distance to Waste Landfill *Municipalities and Waste Disposal*
	Facilities and Infrastructure	**Access *Water *Flow and Sewerage Systems *Power *Paths*
	Environmental problems	**Water Resources *Visual Impact *Affected Community *Topography *Cattle Routes *Archaeological Areas *Flood Areas *Protected Areas*
	Legal Requirements	**Land Planning *Facilities and Infrastructure *Environmental Issues *Near Municipalities*
Cura (2010)		**Fixed Cost *Transportation Cost*
Demirel et al (2010)	*Costs*	**Labor Force *Transportation *Tax Incentives and Structures *Financial Incentives *Handling Costs*
	Workforce Specificity	**Labor Force Ability *Access to Labor*
	Infrastructure	**Presence of Transportation Modes *Telecommunication Systems *Quality and Reliability of Transportation Modes*
	Markets	**Customer proximity *Proximity to suppliers / producers *Delivery times and response*
	Macro Environment	**Government Policies *Industrial Regulation Laws *Reconstruction and Construction Plan*
Ekmekcioglu et al. (2010)		**Hydrology *Adjacent land use *Climate *Flora and fauna *Site capacity *Road access *Cost*
Kuo (2011)	*Convenience*	**Knowledge Capabilities *One Point Service *Proper Handling Extension*
	Cost	**Port / Warehouse Facilities *Transfer Time *Port Rates*
	Port Conditions	**Port Operation System *Position Resistance*
	Operation Capacity	**Density of Shipping Lines *Import / Export Volume*
Özcan et al. (2011)		**Unit Price *Stock Holding Capacity *Store Average Distance *Average Distance to Main Suppliers *Movement Flexibility*
Özesenli (2011)		**Raw Material *Supplier *Production Facilities *Distribution Centers *Customers*
Yilmaz et al. (2011)		**Distances of Warehouses to Demand Areas*
Bu et al. (2012)		**Average Transportation Time *Fixed Costs *Average Freight Transmission Cost *Maximum Number of Trucks *Maximum Number of Loaders*
Ashrafzadeh et al. (2012)		**Labor Cost *Transportation Cost *Handling Cost *Land Cost *Telecommunication Systems *Proximity to Customers *Proximity to Suppliers or Producer *Delivery Time and Responsibility*
Caka (2012)	*Cost*	**Labor Cost *Shipment Cost *Storage Cost*
	Workforce	**Qualification Personnel *Value Added Activity Capacity*
	Environmental Factors	**Market Proximity *Transportation Alternatives *Legal Procedures and Company Reliability*
	Infrastructure	**Capacity *Storage and Transportation Systems *Shipment Capacity *Storage Conditions*
Aktepe and Ersoz (2014)		**Sales *Ratio Between Wholesale and Retail Sales *Finding the Way *Cost of Warehouse Leasing *Number of Competitors * Potential Growth*
Durmus and Turk (2014)		**Accessibility *Market Size *Clusters *Distance to City Center *Rents and Customs*

Garcia et al. (2014)	*Accessibility*	**Terrain Roads *Sea Roads *Railways*
	Security	**Robbery Loss Ratio *Organized Crime Existence *Security Personnel *Security Systems*
	Warehouse Needs	**Qualified Workforce *Machinery and Equipment *Energy *Land *Services*
	Accept	**People's Acceptance *Government Acceptance*
	Costs	**Materials *Distribution *Daily Pay and Salaries *Energy *Insurance*
	Distance	**Distance between Personnel and Warehouse *Distance Between Growing Area and Warehouses *Distance to between Warehouse and Customers*
Rath and Gutjahr (2014)	**Facilities *Consumers *Potential Warehouses *Customer Demand *Capacity *Time *Vehicle Capacity *Unit Storage Cost *Warehouse Settlement Cost *Unit Transportation Cost *Total Upper Floor Amount of Plant*	
Segura et al. (2014)	**Demand Point *Operational Costs Between Demand Point and Candidate Location *Number of Facility to be Found*	
Dey et al. (2015)	*Costs*	**Labor Costs *Transportation Costs *Tax Incentives and Tax Structure *Financial Incentives *Transportation Costs*
	Workforce Characteristics	**Qualified Workforce *Workforce Existence*
	Infrastructure	**Presence of Transportation Modes *Telecommunication Systems *Quality and Reliability of Transportation Modes*
	Markets	**Proximity to customers *Proximity to suppliers or producers *Delivery times and responses*
	Macro Environment	**Government Policies *Industrial Regulations and Laws *Zoning and Construction Plans*
Chotithammaporn et al. (2015)	**Technical *Land *Communication Network *Infrastructure *Materials *Economy *Social *Marketing *Other*	
Huang et al. (2015)	**Suppliers *Facilities *Candidate Areas *Average Storage Period *Unit Area Construction and Operation Cost *Fixed Cost of Warehouse*	
Jayant (2015)	**Unit Price *Stock Holding Capacity *Average Distance *Average Distance to Main Suppliers *Movement Flexibility*	
Karmaker and Saha (2015)	*Responsiveness*	**Delivery Time and responding *Providing Related Information*
	Transportation Conditions	**Transportation Quality *Existence of Transportation Modes *Telecommunication*
	Cost-Related Factors	**Land Cost *Handling Cost *Labor Cost *Transportation Cost*
	Location Properties	**Land Access *Quality and Reliability of Facilities *Proximity to Producer *Proximity to Consumer*
	Convenient Business Environment	**Talented Worker *Finding Workforce*
Monthatipkul (2016)	**Consumer *Vendor *Diesel Price *Average Ship Size of the Dealer*	
Özbek and Erol (2016)	**Unit Price *Stock Holding Capacity *Average Distance *Main Supplier Average Distance *Movement Flexibility*	
Yilmaz and Kabak (2016)	**Demand *Local Distribution Center Procurement *Distance Between Local Distribution Center and Demand Point*	
Bjönklund et al. (2017)	**Variable Costs *Business Model Development and Customization *Community Acceptance as a Customer *Creation of New Services *Logistics and Supply Chain Management Competence *Advantage of Advanced IT and Systems*	
Dey et al. (2017)	**Availability of Markets *Accessibility *Location Condition *Cost*	
He et al. (2017)	*Economy*	**Land Acquisition Value *Expansion Facility *Access *On-time Delivery *Resource Availability *Tax Policy*
	Society	**Impact on Traffic Accidents *Impact on Residents Near *Contribution to the Development of Leading Industry *Harmonization with Regional Economic Planning*
	Environment	**Impact on Ecological Landscape *Environmental Protection Level *Natural Conditions*
Golda and Izdebski (2017)	**Transportation Costs *Fuel Costs *Additional Costs Related to Warehouse *Distance and Relation of Warehouse to Railway and Highway Infrastructure*	
Maharjan and Hanaoka (2017)	**Demand Point *Candidate Point *Distance *Accessibility *Development Index *Disaster Safety Index*	

Based on Table 2, when the success factors used in the studies are examined, it can be stated that the cost-related factors are the front plan. In addition Infrastructure, Transportation, Transportation, Workforce, Transportation Modes and Handling success factors are often preferred.

Appropriate Methods of Warehouse Location Selection

The methods used in the studies are shown in graphic 2. According to Figure 2, it can be stated that Multi Criteria Decision Making (MCDM) methods are preferred more than the others.

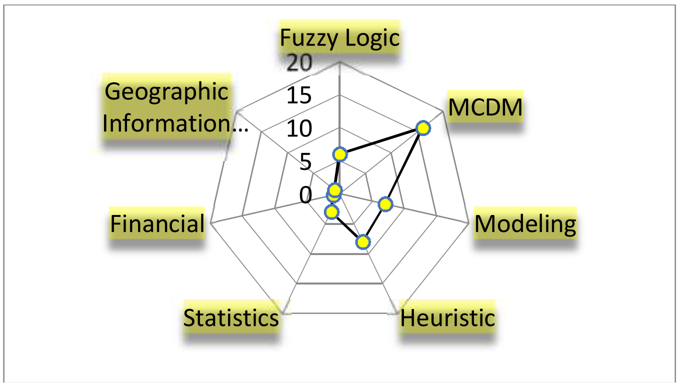

Figure 2. Spread of Studies By Methods

As can be seen in Figure 3, there has been a significant increase in recent years in the studies related to the warehouse location selection process.

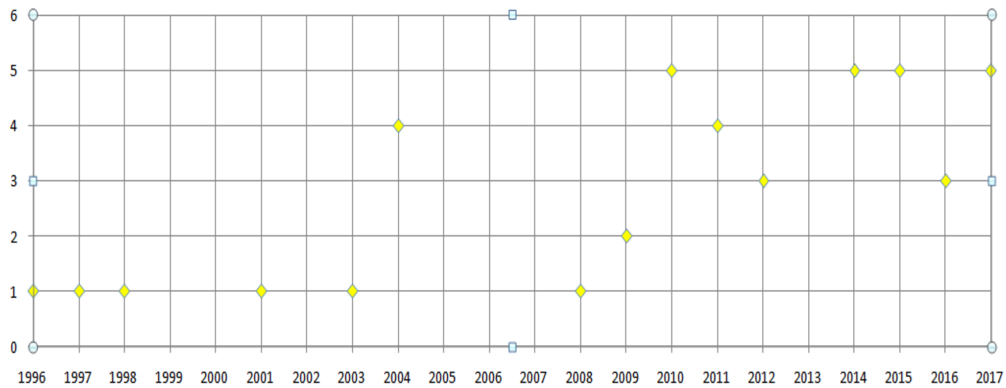

Figure 3. Spread of Studies by Years

Figure 4 shows the spread of the methods on a yearly basis.

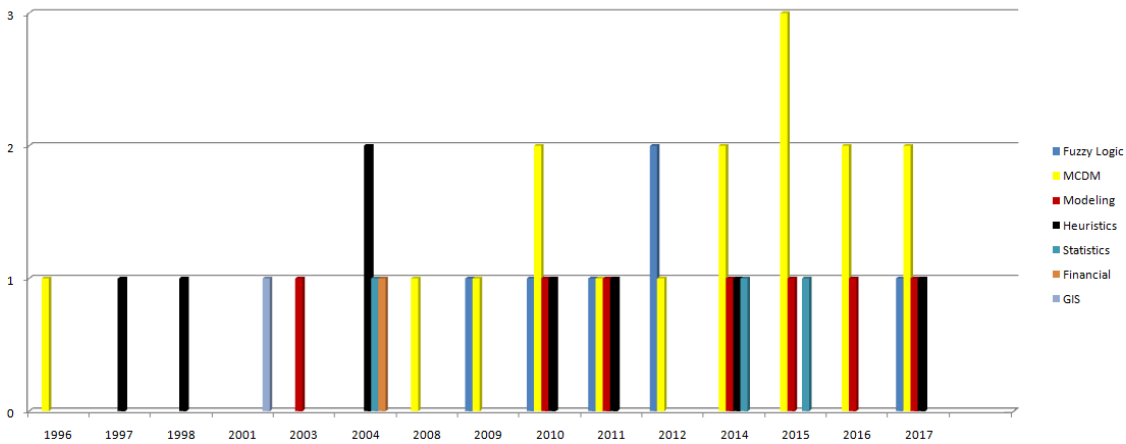

Figure 4. Spread of Methods on a Yearly Basis

According to the graph above, it has been determined that MCDM methods are frequently preferred in recent years and many studies they have been used as a support method in determining the weights of success factors. When the studies are evaluated in general, it is seen that the most widely used method related to warehouse location selection is MCDM methods. The most commonly used methods after the MCDM methods are determined as heuristic methods, ant the methods containing modeling and fuzzy logic, respectively.

CONCLUSION

The success of storage, which is one of the critical activities of logistics and supply chain management, depends on the appropriate location selection of the warehouse (Cakmak et al., 2012). The aim of the current study is to analyze in depth the research conducted regarding the warehouse location selection which is an important task for the optimization of logistics systems (Demirel et al., 2010).

The increase in the number of warehouse location studies by years shows that the warehouse location selection process is important and the awareness of this importance increases. "Expert Systems with Applications" has been identified as the most widely available resource among the published sources of the studies examined in the research. This result is an important indicator of scientific journals in which researchers of warehouse site selection studies can publish their work. The most commonly used success factor in the studies is the "Costs" related factors. The fact that depots usually need large capital investments and labor costs (Cakmak et al., 2012) can be expressed as the main reason for the frequent use of success factors in costs. Other success factors most used in the studies are; Infrastructure, Transportation, Transportation, Workforce, Transportation Modes, and Handling. MCDM methods are mostly used in studies related to warehouse location selection. When the related literature is examined, it is revealed that the MCDM methods are the most integrated methods with other methods. In addition, when the most preferred methods among the methods of MCDM are considered, it can be said that AHP, ANP, and TOPSIS are in the forefront, respectively. This tendency towards MCDM can be explained with the influence of qualitative and quantitative variables in warehouse location selection. In that, the MCDM methods gives the ability to evaluate qualitative and quantitative variables together with the expert opinions.

The study was based on the database of Gumushane University and a year restriction was not used. In future studies, firstly, studies can be done based on journals and expanded databases, and a more in-depth research can be carried out by reaching the studies made during specified years. Moreover, since the warehouse location selection is closely related to the warehouse design, success factors which can be planned together with warehouse design with warehouse location can be developed in future studies. Finally, Geographical Information Systems (GIS) and MCDM methods in warehouse location; methods as Simulation in warehouse design can be preferred.

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A LITERATURE REVIEW ON AIRCRAFT MAINTENANCE ROUTING PROBLEM

Tolga Temucin[1], Gulfem Tuzkaya[2], Ozalp Vayvay[3]

Abstract *– The airline industry which is projected to grow at an annual average rate of 3.7% globally in the period of 2016-2034 is a challenging sector for companies that want to have a market share. The strong position in the market can be achieved by reducing many of the costs, such as personnel expenses, fuel expenses, professional service purchases, aircraft rent and depreciation expenses, airport fees, maintenance material costs. Because these costs are a consequence of the problems (flight scheduling, fleet assignment, aircraft maintenance routing, crew scheduling, and etc.) encountered in the airline industry, OR professionals both within and outside of airlines have been working on the development of methods for obtaining optimal solutions to these problems since the 1950s. In this context there are numerous academic studies related to airline operations in literature. Although one can refer to surveys related to airline operations, it isn't sufficient to cover the rich literature of airline scheduling, especially for the last decade. So, this study's aim is to remove this shortcoming by reviewing the papers concerning airline operations published between 2010 and 2017 and to focus on the studies within these papers especially related to aircraft maintenance routing problem.*

Keywords – Aircraft maintenance routing problem, airline operations, airline scheduling

INTRODUCTION

Airline industry is one of the areas where in the last decade, development of the aviation industry has shown significant growth. This incredible progress makes the aviation industry challenging and forces airline companies to produce a range of solutions to reduce operational costs. These costs can be diversified based on different airline operations such as flight scheduling (schedule preparation), fleet assignment, aircraft (maintenance) routing (tail assignment), crew scheduling, disruption recovery, etc. Although such operations have been studied for several decades, the challenge remains fresh due to high complexity of airline networks and increasing size of industry[1].

Although one can refer to the surveys of Etschmaier and Mathaisel (1985), Bergh et al (2013), Gopalakrishnan and Johnson (2005), Clarke (1998) for flight scheduling, fleet assignment, aircraft maintenance routing and crew scheduling problems as well as irregular airline operations, respectively, these valuable studies are not sufficient to cover the rich literature of airline scheduling, especially for the last decade. In this context, this study's aim is to remove this shortcoming by reviewing the papers concerning airline operations published between 2010 and 2017 and to focus on the studies within these papers especially related with aircraft maintenance routing problem because of the reasons below.

- As Maintenance, Repair and Overhaul (MRO) costs are equivalent to 12% of operational costs[2], lack of coordination and planning in MRO activities can cause great losses. For example, in 2010, 65.000 U.S. airline flights could not take off because the aircraft did not receive proper MRO, resulting in $28.2 million as a penalty cost against 25 U.S. airlines[3].
- The lack of coordination and planning in MRO activities also adversely affects the reliability of airline companies. Between 1994 and 2004, 42% of the fatal accidents in the U.S. were caused by maintenance errors[4].

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- Cost items such as human cost (loss of life), reputation cost and monetary loss have caused the aviation industry to focus on maintenance operations lately. Otherwise, the increasing number of planes and passenger capacity would have opened the door for greater catastrophes. Over the last 10 years, the airline industry has improved its overall safety performance 54%. The accident rate in 2016 was 1.61 accidents per million flights, compared with 3.53 nearly a decade earlier, in 2007, and fully 10% lower than in 2015[5].

SURVEY METHODOLOGY

Before searching for the studies throughout the literature, the topics which are considered within the aforementioned survey papers are assessed to create a scheme. During the review, ScienceDirect, Springer, IEEE, Emerald and Google Scholar databases had been investigated to search for the keywords such as “flight scheduling”, “crew scheduling”, “crew routing”, “airline scheduling”, “airline planning”, “fleet assignment”, “aircraft routing”, “aircraft maintenance”, “aircraft fleeting”, “aircraft schedule”, etc. At the end of the research, 82 papers which were published in international journals or conference proceedings during the 2010-2017 period had been identified. Finally, these papers had been analyzed, classified, and recorded under the classification scheme.

PRELIMINARY FINDINGS

This section will focus on two topics. The first issue is the determination of areas where work is concentrated. The second issue is about an analysis of the distribution of papers by publication year which will disclose the trend in airline scheduling.

Focused Area(s)

Airline industry is a very competitive environment. To have a huge market share in such an environment, airlines struggle to reduce their costs which will let them to propose low-priced tickets which will eventually cause passengers to be satisfied. Airlines can accomplish this by focusing on one or more than one substantial sub-problem in airline scheduling. Within this review, we have classified the problems encountered in airline industry into 6 main sub-groups, namely flight scheduling problem (FSP), fleet assignment problem (FAP), aircraft maintenance routing problem (AMRP), crew scheduling problem (CSP), aircraft scheduling (routing) problem (ASP) and schedule recovery problem (SRP). In fact, all of these problems take into account the smaller but different areas of the main problem.

The flight scheduling problem considers the construction of a feasible flight network by selecting a set of origin-destination pairs, assigning the flight times and determining the operating frequencies. The resulting flight network is used as input to the fleet assignment problem, which assigns a fleet type to each individual flight leg. The main goals of the fleet assignment are the maximization of the captured and recaptured passengers, maximization of revenue and through revenue (additional revenue stemming from the premium passengers pay for the comfort of staying on the same plane) and minimization of the operating cost. Feasibility constraints for the fleet assignment process include flow constraints, balance constraints, availability constraints and flight coverage constraints (Abara, 1989). The aircraft maintenance routing problem deals with arranging routes for the aircrafts so that the maintenance regulation constraints are not violated while the crew scheduling problem tries to handle the assignments of crew members to each aircraft (Başdere and Bilge, 2014). The aircraft scheduling (routing) problem is a version of aircraft maintenance routing problem which does not take into account the maintenance regulation constraints such as maintenance in every D days, person-power / man-power / work force availability and maintenance base/station capacity constraints. This planning process involves the determination of the sequence of flight legs to be flown by each individual aircraft so as to cover each flight exactly once (Al-Thani et al, 2016). There is a close relationship between these sub-problem types, so that, the output of a problem is used as the input of another. On the other hand, schedule recovery problem can be defined as the problem of modifying the flight and aircraft schedules to compensate the presence of irregular operations that result in the temporary or permanent unavailability of aircraft (Vos et al, 2015).

Additionally, during our study, we encountered with some other subjects which are mainly related with maintenance issues. These are maintenance tracking information systems (MTIS), safety issues (SI), maintenance personnel (MP) and ergonomic assessment (EA). These four issues are summarized below.

- *Maintenance tracking information system* is a necessary part of a good maintenance program. Such a system makes the maintenance program more effective and reduces its cost in the long run. A suitable system allows the maintenance manager to gather data to support maintenance decisions. It includes equipment failure data that may be fed back to designers or manufacturers, used for process hazard evaluation, or sent to the purchasing department to support changes to specifications or to support the selection or avoidance of particular vendors or equipment types. The maintenance information system is also a valuable resource for the planning department to use when preparing job packages for future maintenance work[6].

- *Safety issues* is the group of studies where the aim is to investigate the challenges to the implementation of the Safety Management Systems (SMSs).
- *Maintenance personnel* is the group of studies which deals with the problems of maintenance personnel where the last subject is about ergonomics.

Traditionally airlines can study the chosen areas step by step which will cause a minor reduction in costs while simplifying the overall process. On the other hand, they can prefer to study the chosen areas simultaneously (the integrated approach) which will cause a higher reduction in costs while making the process more complex. Table 1 presents the sub-problem(s) which is/are dealt with within each paper published between 2015 and 2017.

Analysis in this topic expresses that;

- Percentage of articles related with FSP, FAP, and CSP is almost same (respectively, 15%, 14%, and 16%). On the other hand, the percentage of AMRP-related articles (27%) is almost twice as high as that of FSP, FAP and CSP.
- The percentage of maintenance related articles is equal to 47% of all articles. This shows the importance given to maintenance in airline scheduling.
- AMRP is the most frequently studied subject in the maintenance related articles (55.32%).
- More than one topic worked together in 15 of 82 articles (18.9%).

Table 1. Sub-problem(s) within Each Paper Published Between 2015 and 2017

						MAINTENANCE RELATED SUBJECTS					
	FSP	FAP	CSP	SRP	ASP	AMRP	MTIS	SI	MP	EA	OTHERS
Vos et al (2015)				X							
De Bruecker et al (2015)									X		
Gerede (2015a)								X			
Gerede (2015b)								X			
Zhang et al (2015)				X							
Sun (2015)	X										
Murça and Müller (2015)					X						
Hu et al (2015)				X							
Shanmugam and Robert (2015)											X
Liang et al (2015)						X					
Kasava et al (2015)											X
Irwin and Streilein (2015)										X	
Gürkan et al (2016)	X	X				X					
Dong et al (2016)	X	X									
Irvine et al (2016)						X					
Kang et al (2016)		X									
Mohamed et al (2016a)			X			X					
Al-Thani et al (2016)						X					
Lijima and Nishi (2016)			X								
Liu et al (2016)		X				X					
Passenier et al (2016)								X			
Sarhani et al (2016)						X					
Colbacchini et al (2016)							X				
Mohamed et al (2016b)			X			X					
Jamili (2017)		X				X					
Bayliss et al (2017)			X								

						MAINTENANCE RELATED SUBJECTS					
	FSP	FAP	CSP	SRP	ASP	AMRP	MTIS	SI	MP	EA	OTHERS
Parmentier and Meunier (2017)			X			X					
Safaei and Jardine (2017)						X					
Kasirzadeh et al (2017)			X								
Abdelghany et al (2017)	X										
Yang et al (2017)		X									
Kenan et al (2017)	X	X									
Qin et al (2017)						X					
Mofokeng and Marnewick (2017)											X
Ma et al (2017)		X									
Özener et al (2017)		X	X								
Eltoukhy et al (2017)						X					

FSP: Flight Scheduling Problem, **FAP**: Fleet Assignment Problem, **CSP**: Crew Scheduling Problem, **SRP**: Schedule Recovery Problem, **ASP**: Aircraft Scheduling Problem, **AMRP**: Aircraft Maintenance Routing Problem, **MTIS**: Maintenance Tracking Information Systems, **SI**: Safety Issues, **MP**: Maintenance Personnel, **EA**: Ergonomic Assessment.

Distribution of Papers by Publication Year

Figure 1 shows the studies examined in terms of their interests and publication year.

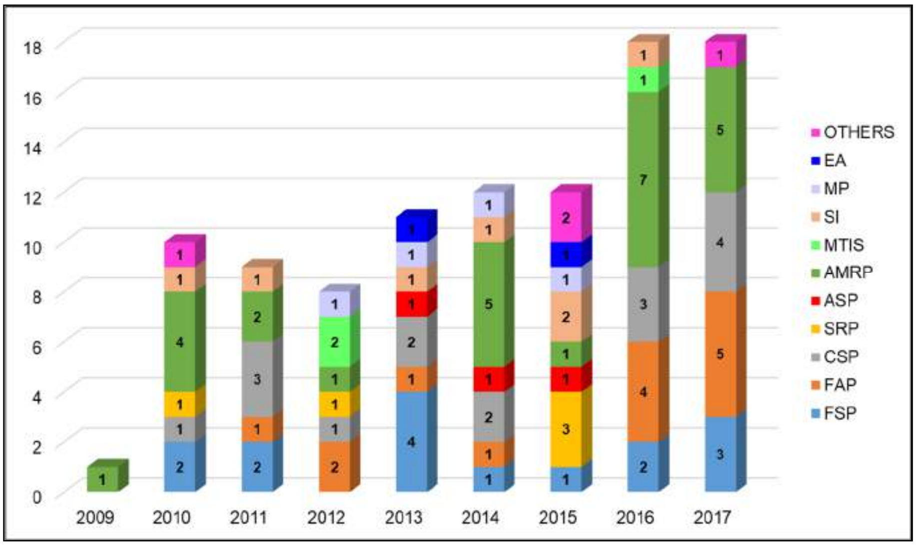

Figure 1. Studies Examined in Terms of Their Interests and Publication Year.

Figure 1 expresses that;

- The number of studies on airline scheduling is increased year by year.
- Almost every year AMRP (in 8 of 9 years), FSP (in 7 of 9 years) and CSP (in 7 of 9 years) topics have been studied.
- When 2009-2013 and 2014-2017 periods are compared with each other, it is observed that the number of studies on AMRP is increased by 225% and the number of studies on FAP is increased by 250%.

AIRCRAFT MAINTENANCE ROUTING PROBLEM

As shown in section 3, the AMRP is the mostly studied area by the academics for airline scheduling process. As noted earlier, the main reasons for this situation are that MRO costs constitute 12% of operational costs and that lack of coordination and planning in MRO activities damages the reliability of airline companies. Hence, AMRP related studies will be the focus of this section. These studies will be examined in 4 sub-chapters. In the first two sub-chapters basic AMRP features such as the maintenance type interested and time horizon used in the published papers will be determined. In the third sub-chapter general characteristics of solution methods will be explained. Finally, in the last sub-chapter objectives and maintenance constraints used during the AMRP studies are introduced.

Type of Maintenance

This section is devoted to determine which types of maintenance are mostly included in the studies. Although there is no real consistency in literature about the definitions of maintenance, Bergh et al (2013) provided a framework which is presented in Table 2 by using the most common definitions. According to them, aircraft maintenance can be divided into scheduled/preventive/routine maintenance and unscheduled/non-routine maintenance with respect to uncertainty which is indicated by the rows in the table. The columns refer to the intensity of the workload, starting from short-term (i.e., frequent and light) until long-term (heavy) maintenance.

Maintenance types in the reviewed studies are classified based on the taxonomy provided by Bergh et al (2013) which leads to the bold numbers in parentheses in Table 2 showing the total number of studies in each maintenance category.

Table 2. Taxonomy for Aircraft Maintenance (Bergh et al, 2013) and the Total Number of Studies for Each Maintenance Category

<table>
<tr><td rowspan="2"></td><td colspan="3">Lay-over maintenance or light maintenance</td><td colspan="2">Heavy maintenance
(2)</td></tr>
<tr><td>Line maintenance
(2)</td><td colspan="2">Line or hangar maintenance
(1)</td><td colspan="2">Hangar maintenance
(1)</td></tr>
<tr><td rowspan="3">*SCHEDULED or PREVENTIVE or ROUTINE*
(4)</td><td>Short-term checks
(7)</td><td colspan="2">Mid-term or regular checks
(3)</td><td colspan="2">Long-term checks
(4)</td></tr>
<tr><td rowspan="2">Pre-flight, transit, daily checks
(2)</td><td>A-check
(9)</td><td>B-check
(5)</td><td>C-check
(4)</td><td>D-check
(5)</td></tr>
<tr><td>Av-check, M-check</td><td></td><td>Balance checks</td><td></td></tr>
<tr><td rowspan="2">*UNSCHEDULED or NON-ROUTINE*
(2)</td><td>*Predictive or on-condition maintenance*</td><td colspan="2">*Predictive or on-condition maintenance*</td><td colspan="2">*Predictive or on-condition maintenance*</td></tr>
<tr><td>*Corrective or emergency maintenance*
(1)</td><td colspan="2">*Corrective or emergency maintenance*</td><td colspan="2">*Corrective or emergency maintenance*</td></tr>
</table>

Time/Planning Horizon/Period

Two conclusions can be drawn from Table 2.

- Maintenance types which are mentioned in the articles mostly belong to the scheduled/preventive/routine maintenance class. This type of maintenance is often stated as a preventive form of maintenance which ensures the aircraft is airworthy, conducted at pre-set intervals.
- Maintenance types which are studied in the articles mostly belong to short-term (light) maintenance class. A- and B-checks are short-term checks. The A-check occurs most frequently and has to be performed about every 65 flight hours, or approximately once a week. This check comprises the inspection of landing gear, engines and control surfaces. B-check is performed slightly less frequently, about every 300 to 600 hours. This involves a more extensive visual inspection and also lubrication of all moving parts.

If the AMRP related studies are examined, one can determine that only three types of time horizon is used in the studies, namely 1 day, 4 days and 7 days.

The longest time horizon (7 days) is the most preferred one with %53. There are two different opinions about 7 days time horizon. According to one opinion, 7 days planning period becomes more of a planning horizon that is too optimistic for the frequent disruptions that plague the airline industry. Additionally, with a longer time horizon, one could also argue for including "non-high-time" aircraft, i.e., those aircraft with remaining legal flying hours of two days or more. However, maintaining these aircraft earlier than necessary is counterproductive to the goal of maximizing the utilization of aircraft green time and consumes scarce maintenance slot and man-hour resources needed for the high-time aircraft. On the other hand (the second opinion), the solution to a problem with a longer time horizon may indeed better utilize the remaining flying hours of the aircraft by delaying the maintenance of some high-time aircraft beyond the current day but still within the legal limits (Aslamiah et al, 2010). Studies that agree with the second opinion and that use 7 days time horizon are Diaz-Ramirez et al (2014), Liang et al (2015), Başdere and Bilge (2014), Mohamed et al (2016a), Mohamed et al (2016b), Al-Thani et al (2016), Parmentier and Meunier (2017), Safaei and Jardine (2017), and Afsar et al (2009).

The second most used planning period is 1 day with %41. The weekly time horizon of the model is fairly long for the operational perspective (Başdere and Bilge, 2014). The expression used by Aslamiah et al (2010) supports this: The horizon may in fact be shorter than a day since a disruption might occur in the middle of the day, necessitating a recovery for the remainder of the flight leg network with the given start locations for the aircraft. Studies adopting this view are Gürkan et al (2016), Maher et al (2014), Jamili (2017), Liu et al (2016), Sarhani et al (2016), Orhan et al (2011) and Aslamiah et al (2010).

Unlike the above-mentioned studies, Eltoukhy et al (2017) modelled the OAMRP with a 4 days planning period.

General Characteristics of Solution Methods

Frequently occuring stochastic events in the airline industry may affect the states of the aircrafts in the fleet and such events generally increase the operational costs or even create infeasibilities in the existing route assignments. Hence AMRP is required to be solved very frequently in order to respond to such changes; therefore, developing a fast and responsive solution method becomes an essential task (Başdere and Bilge, 2014). However AMRP is a NP-Hard problem (Al-Thani et al, 2016) for which exact methods are not likely to find effective solutions in a reasonable computational time for large-scale instances. Therefore in most cases, (meta-)heuristic approaches are used to cope with these problems. Figure 2 summarizes usage rate of each solution method in reviewed AMRP studies.

Figure 2 corresponds to the below. As can be seen, heuristic and meta-heuristic solution methods are used in 60% of current studies. The mostly used meta-heuristic approaches are Genetic Algorithm in Yang and Yang (2012); Particle Swarm Optimization Algorithm in Mohamed et al (2016a), Sarhani et al (2016); Variable Neighborhood Search Algorithm in Al-Thani et al (2016); Simulated Annealing Algorithm in Afsar et al (2009).

Additionally, Branch and Bound Algorithm, Branch and Price Algorithm, Column Generation Algorithm are some of the methods used as exact methods; while Dantzig-Wolfe Decomposition, Benders' Decomposition are some of the decomposition methods used in AMRP studies.

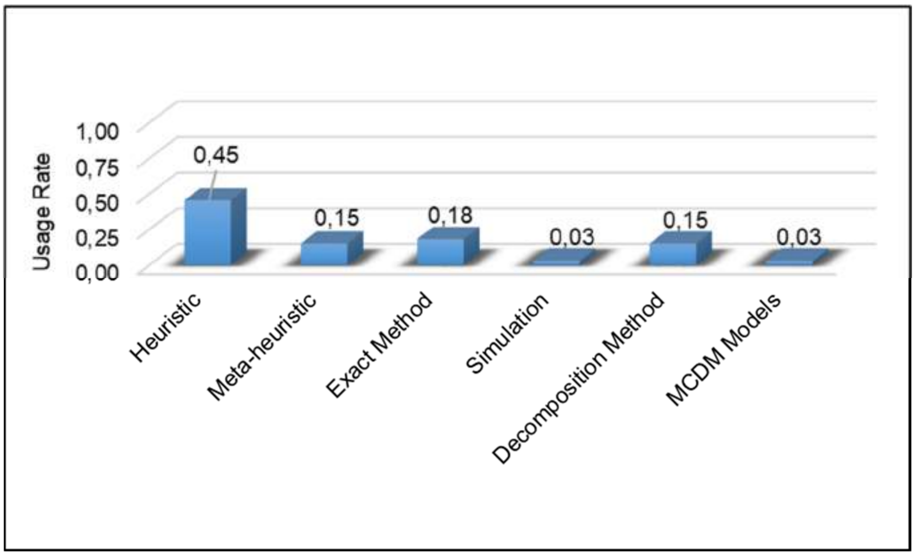

Figure 2. Usage Rate of Each Solution Method Used in AMRP Related Studies.

Common Objectives & Maintenance Based Constraints within AMRP Related Studies

According to the studies;

- 50% of the surveyed studies use operational cost minimization and its components as an objective function.
- Minimization of the unused legal flying times, profit maximization and minimization of the aircraft routing cost are the most used objectives.
- "Maintenance every D days", "person-power / man-power / work force availability" and "maintenance base/station capacity" are the most used maintenance based constraints in studies.

CONCLUSIONS AND FUTURE REMARKS

In this review, trend in studies related to airline operations such as disruption recovery, flight scheduling, fleet assignment, aircraft (maintenance) routing, crew scheduling is examined through a survey of 82 papers which were published between 2010 and 2017. As a result of this examination, the following conclusions are reached.

- The number of studies on airline scheduling is increased year by year.
- Almost every year AMRP, FSP and CSP topics have been studied.
- Percentage of articles related to FSP, FAP, and CSP is almost same (respectively, 15%, 14%, and 16%) where the percentage of AMRP-related articles (27%) is almost twice as high as that of FSP, FAP and CSP.
- The percentage of maintenance related articles is equal to 47% of all articles.
- AMRP is the most frequently studied subject in the maintenance related articles (55.32%).
- When 2009-2013 and 2014-2017 periods are compared with each other, it is observed that the number of studies on AMRP is increased by 225% and the number of studies on FAP is increased by 250%.

Facts summarized above showed that a more in-depth study of AMRP-related studies is required to enhance our knowledge level from some aspects. Hence, in the second part of this study, AMRP-related studies are examined in 4 sub-chapters. In the first two sub-chapters basic AMRP features such as the maintenance type interested and time horizon used in the published papers are determined. In the third sub-chapter general characteristics of solution methods is explained. Finally, in the last sub-chapter objectives and maintenance constraints used during the AMRP studies are introduced. As a result of this detailed examination, the following conclusions can be considered as future directions for studying.

- Although stochastic events such as severe weather changes, equipment failures, variable maintenance times, or even new regulations often cause corruption on aircraft maintenance routing plans, still there are not enough studies which compensate this deficiency neither in modelling nor in solution approaches.
- Transportation is one aspect we cannot do without in this day and age. However, the current transportation systems come along with a wide range of problems including global warming, environmental degradation, health implications (physical, emotional, mental, spiritual), and emission of greenhouse gases. In fact, the transport sector attributes to 23% of the globe's greenhouse gas emission resulting from burning of fossil fuels[7]. So, during the development of AMRP models, more studies should take into account the fuel consumption and CO2 emission cost within operational costs.

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THE IMPACT OF ORBIT DEPENDENT RETURN RATE ON THE CONTROL POLICIES OF A HYBRID PRODUCTION SYSTEM

Seval Ata[1], Murat Fadıloğlu[2], Aybek Korugan[3]

Abstract *− In this study we consider a hybrid production system that manufactures new products and remanufactures used products. Product demands arise following a Poisson process and do not differentiate between new products and remanufactured products. Each product is returned to the hybrid system with a positive probability following a random usage time. The return rate is a function of the return probability as well as the number of items in use. The system decides when to produce new products or to accept returned products. Our objective is to investigate the impact of knowing the number of products in use on the production and admission control. To this end, we construct a stochastic dynamic programming and analyze the system numerically.*

Keywords − hybrid systems, Markov decision processes, optimal production control

INTRODUCTION

In recent decades product remanufacturing has become a profitable business. The profitability of remanufacturing comes from the relatively low effort required to restore cores. On the other hand, the uncertainty in quality, quantity and timing of collected cores introduces a new kind of complexity to production planning. The essential function of a production system is to supply the demand in a timely manner while keeping the lowest possible inventory levels. In traditional production systems demand process is the major source of uncertainty while remanufacturing systems encounter both demand and return uncertainties. Furthermore, the link between satisfied demand and the return flows increases the complexity of these processes. Therefore, production and inventory control policies have to be updated for remanufacturing systems.

The majority of inventory control models that consider the uncertain demand and return processes assume that these processes are independent of each other. A single echelon continuous review inventory system was first modeled using an M/M/1/N queue by Heyman (1977), where returns are assumed to arrive following a Poisson process, demands occur one by one that follows an independent exponentially distributed time and are satisfied as long as there is a returned product in the queue. Returns are accepted in the system if the inventory of returns does not exceed N and are disposed otherwise. The objective is to determine the optimal inventory level N that minimizes the total inventory cost using a push production control. The model includes disposal option but does not consider the production and remanufacturing lead times. Muckstadt and Isaac (1981) introduced constant lead times as an extension but ignored the disposal activity for a continuous review (Q, r) policy inventory model with an optimal order quantity Q and a safety stock r. The results obtained from the single-echelon model were applied to a two-echelon model. Van der Laan et al (1996b) considered various periodic review inventory control mechanisms by including the disposal option to the single-echelon model in Muckstadt and Isaac (1981). They compared the inventory policies with and without disposal and showed that disposal is a necessary action for cost minimization. Van der Laan et al (1996a), analyzed three different inventory control policies with core disposals and showed that a four-parameter control policy is optimal. In Van der Laan et al (1999) the authors analyzed the effects of lead-time duration and lead-time variability on total expected costs numerically and showed that the pull control strategy is more cost effective than the push control strategy for hybrid production systems without disposal option. Fleischmann et al (2002) considered a basic uncapacitated (s, Q) continuous review inventory system with independent Poisson demands and returns that is similar to the case without returns. They included returns in the model by allowing both positive and

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negative demand. They showed that conventional (s, Q) policies remain optimal when introducing Poisson item return flows. In a further study, Fleischmann and Kuik (2003), proposed an optimization algorithm for the same system to compute the control parameters for an order up to level (s, S) policy.

Van der Laan and Salomon (1997) extended the control mechanisms in Van der Laan et al (1996b), by adding disposal of returns. They also considered the capacity of returns to generate new demand. They conducted a numerical study and showed that disposal of returns is necessary to achieve maximum system efficiency since it reduces variability. In Van der Laan et al (1996b), system assumptions are more general even though their control strategies rely on Muckstadt and Isaac (1981). They allow non-zero fixed remanufacturing costs and separate holding costs for remanufacturables and serviceables. To investigate the effect of lead time, they assumed deterministic lead time for both manufacturing and remanufacturing, rather than a deterministic manufacturing lead time and stochastic lead time resulting from limited remanufacturing capacity. Yuan and Cheung (1998) used queueing perspective and proposed an (s, S) inventory control model with correlated demand and returns but without including disposal option. They assumed Poisson demand, exponential return lead time and instantaneous procurement lead time. At the end of return lead time, items are returned or kept by customer with a given probability. They developed an algorithm to compute the optimal replenishment parameters and analyzed the impact of partial returns. Toktay et al (2000) considered an industry problem in the Kodak single use camera remanufacturing case. They constructed a closed queueing model to study the effects of various system parameters such as informational structure, procurement delay, demand rate, and length of the product's life cycle. Bayındır et al (2003) considered a remanufacturing system as a queueing network, including production capacity of facility to find the ratio of returned products. In their next study, Bayındır et al (2005) relaxed the as good as new assumption of remanufactured products by considering two customer classes and two product classes as new and remanufactured with common capacity constraint. They modeled the system for an (S-1, S) inventory control policy and downward product substitution, where a remanufactured demand may be satisfied by a new product. The main aim is to investigate the system conditions, under which utilization of remanufacturing option provides profit improvement. Behret and Korugan (2009) provided a detailed hybrid manufacturing/remanufacturing model using queueing networks that considered the quality grades of returns and remanufacturing processing and lead times dependent on quality grades along with independent demand rates and manufacturing lead times. They have explored optimal values of a push type control for returns and finished goods inventories. Korugan and Gupta (2014) considered an adaptive kanban control procedure for a hybrid remanufacturing/manufacturing system, where the number of kanbans increase and decrease based on the intensity of arrivals. Here kanbans balance the manufacturing and remanufacturing capacities.

In periodic review stochastic period models there are some studies including remanufacturing processes. Simpson (1978) modeled a system with items arriving at a separate remanufacturing facility. These items can be disposed of or held for some time before they are remanufactured. Thus, he studied the tradeoff between material savings due to reuse versus additional inventory carrying costs and proved optimality of a three-parameter control policy to control order, repair, and disposal with independent demand and return rates but without fixed costs and lead times. Inderfurth (1997) showed this policy to be optimal also in the case of non-stochastic and identical non-zero lead times for procurement and remanufacturing processes. He compared the lead times for the two processes and concludes that the deviation between the two lead times is a critical factor for the simplicity or complexity of the optimal policy. Buchanan and Abad (1998) assumed that returns are a stochastic fraction of the number of items in the market for each period and the time until return is exponentially distributed. They derived an optimal procurement policy depending on the on-hand inventory and the number of items in the market for a finite horizon. Another periodic review inventory model considering dependency between returns and demand was proposed by Kiesmüller and van der Laan (2001). In this study, order up-to policy followed and both the demand and the return streams follow a Poisson distribution and returns depend on previous demands. All lead times are constant and returned items are either remanufactured or disposed with a constant probability with a finite planning horizon. Authors compared the case of dependent returns with the case of independent returns and numerically showed that the average cost is smaller in the dependent case. In a series of multi-echelon systems considering independent demand and returns, DeCroix et al (2005) allowed demand to be negative and they proved that a base-stock echelon is still optimal. As an alternative to the echelon base-stock policy, they also discussed a policy that uses only local information. They presented exact and approximate methods for evaluation in finite horizon and explain how to extend the model when returns occur at different stages. DeCroix (2006) extended Simpson (1978) and Inderfurth (1997) by combining the multi-echelon structure of DeCroix et al (2005) to a series system without disposal. DeCroix and Zipkin (2005) and DeCroix et al (2009) considered assemble-to-order systems with returns of components or finished product for single-item and multi-item respectively by using a base stock policy and carry out numerical analyzes. An extensive and detailed comparison of production-inventory control models for production systems in CLSC can be found in the review papers of Akçalı and Çetinkaya (2011) and Ilgın and Gupta (2010).

All studies in the literature consider modifications of well-known production-inventory control mechanisms and optimization of related control parameters. Yet none of them investigate how to optimally control a hybrid production system. Furthermore, the majority of studies do not consider the link between satisfied demands and return flows. In their review paper, Akçalı and Çetinkaya (2011) emphasize the importance of studying the characteristics of optimal control for systems in CLSC. To the best of our knowledge there are no other studies than Zerhouni et al (2013) that consider operational level optimal control models for production systems with return flows and Flapper et al (2012) that consider product returns that are announced in advance by the customers. In Flapper et al (2012), a two-dimensional state space is considered to keep information of both serviceable inventory and announced returns with continuous review and random lead times. They focus on the potential value of advance return information. Zerhouni et al (2013) relax the instantaneous procurement lead-time assumption of Cheung and Yuan (2003) by considering capacitated production and analyze the impact of ignoring dependency between demands and returns. Yet for the sake of tractability they assume instantaneous lead times of product returns. In our study, we will explore the impact of the correlation among demand and return processes on the production decision of new products by considering the information of sold products. To this end, we will model the supply chain structure as a queueing network and we will seek for optimal stationary decision policies for production control by using Markov decision process models.

The correlation between products in use and return rate of cores is an important issue in controlling hybrid production systems. The literature on the analysis and control of return flows does not consider this correlation except for a few studies. Those studies usually make generalizing assumptions of zero usage time for products. Therefore, production control policies proposed so far usually operate with an estimate of constant return rate. However, the return rate is a function of the number of sold products, the time each product is in use (usage time) and the probability of a product being returned to the manufacturer at the end of its use. Thus, satisfying a demand has both a primary and a secondary effect in closed loop supply chains (CLSC). An analysis for the optimal control mechanisms of hybrid systems cannot disregard this correlation. In this study, we aim to fill this gap by generating and studying an average reward criterion based stochastic dynamic programming model.

MODEL DESCRIPTION

In this study, we consider a hybrid make-to-stock manufacturing/remanufacturing system that satisfies a single type of product demand either by manufacturing new products or by processing cores. The system produces new products with an exponentially distributed rate θ and places them in the finished goods inventory to meet the demand. Demands arrive one by one following a Poisson process with rate λ. After a product is sold, it is used for an exponential lead-time with rate μ before it is returned to the hybrid system. We consider two different control mechanisms one of which has admission control for returns. For both models, if a returned product is accepted it is assumed that it is added to the finished goods inventory as soon as it is returned similar to Heyman (1977). The considered products do not require reprocessing or require only minor reprocessing to be considered as good as new. Also, a product may be disposed of without being returned to the system after an independent exponential time with rate γ. The considered initial queueing network is given in Figure 1.

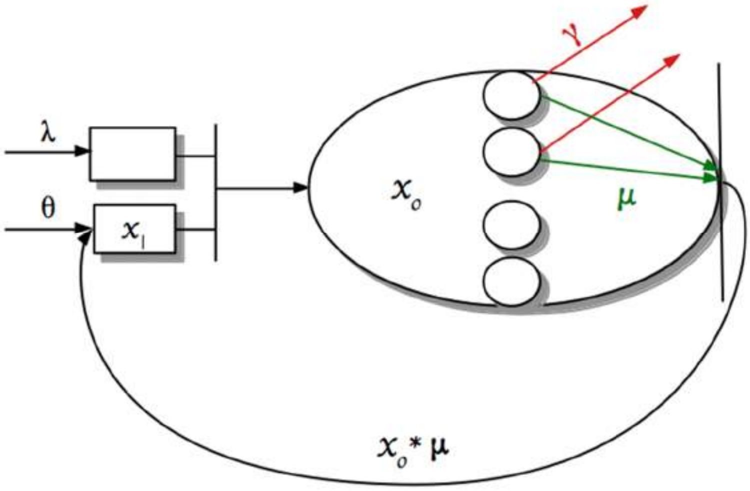

Figure 1. The Production System with Return Flows.

When nonzero lead times are introduced the number of products in use, *viz.* orbit, are to be considered along with the finished goods inventory level. Zerhouni et al (2013) considered that the number of products in orbit is unobservable. However, this quantity is partially observable in reality. In order to understand the value of capturing orbit information, we first assume that the orbit is fully observable. Therefore, the system state is denoted as where $x_0(t)$ represents the number of products in orbit while $x_I(t)$ represents the number of products in the finished goods inventory at time t. Using this state definition, two models are considered where in the first one only the production control is considered, while in the second one also the admission control of product returns is introduced.

The Model with Production Control

In this model, we consider the production decision dependent on the system state. To find the optimal production policy for the first model we construct a Markov decision process model with the value function given as:

$$v_{n+1}(x) = \Lambda^{-1}\big[\, hx_I^{+} + \mu x_0\big(v_n(x_0-1,x_I+1)+c_R\big) + \gamma x_0 v_n(x_0-1,x_I) + \lambda\left(v_n(x_0+1,x_I-1)+c_L\alpha(x_I)\right) + \theta\, min\{v_n(x_0,x_I+1)+c_M, v_n(x_0,x_I)\} + (\Lambda-\mu x_0-\gamma x_0-\lambda-\theta)\big(v_n(x_0,x_I)\big)\,\big] \quad (1)$$

where, $\Lambda = \lambda+\theta+M(\mu+\gamma)$

and $\alpha(x_I) = \begin{cases} 1 & if\ x_I = 0 \\ 0 & if\ x_I > 0 \end{cases}$

Here, h is the holding cost per period per product, c_L is the cost of lost sales per product, c_M is cost of manufacturing per product, c_R is cost of remanufacturing per product and M is the maximum number of products in orbit. Note that, although the remanufacturing is assumed to be instantaneous, considering the cost associated for a product to be redirected to the value stream gives an added flexibility for the cost analysis. This model can be referred as Production Control model (P-control) in the rest of the paper.

The value iteration method calculates the optimal decision matrix and the cost per unit time only. However for a meaningful analysis determining the stationary probability distribution, $P(x_0,x_I,\beta)$, of the MC under the control policy is required. To this end, we formulate the LP solution method for the MDP model with $y_{x,\beta}=P(x_0,x_I,\beta)$ where x is the current state and β is the decision given in that state.

$$min\ Z = \sum(c_{x,0}\, y_{x,0} + c_{x,1}y_{x,1}) \qquad \forall\, x \in S$$

$$s.t.\ \sum\big(y_{x,0}+y_{x,1}\big) = 1 \qquad \forall\, x \in S$$

$$y_{x,0}+y_{x,1} - \Lambda^{-1}\{\theta\big(y_{x,0}+y_{x-e_I,1}\big) + \lambda\big(y_{x-e_0+e_I,0}+y_{x-e_0+e_I,1}\big) + x_0\mu\big(y_{x+e_0-e_I,0}+y_{x+e_0-e_I,1}\big) + x_0\gamma\big(y_{x+e_0,0}+y_{x+e_0,1}\big) + (M-x_0)(\gamma+\mu)\big(y_{x,0}+y_{x,1}\big)\} = 0$$

$$y_{x,0} \geq 0, y_{x,1} \geq 0 \quad \forall\, x \in S$$
$$x = (x_0, x_I), e_0 = (1,0), e_I = (0,1)$$
$$c_{x,\beta} = hx_I + (1 - x_I)^+ \lambda c_L + \theta d_M c_M + x_0 \mu c_R$$
$$\beta = \{0,1\}$$

$$\text{and } \beta(d_M) = \begin{cases} 0 & if\ d_M = 0 \\ 1 & if\ d_M = 1 \end{cases} \tag{2}$$

where $c_{x,\beta}$ is the cost of making decision β in state x. A new binary variable, d_M, is introduced where $d_M = 0$ and $d_M = 1$ represent do not produce and produce decisions, respectively and β depends on d_M.

The Model with Production and Admission Controls

We extend the previous model to also consider the decision for admitting returns. To this end we define a second control parameter and revise the previous model as given below:

$$v_{n+1}(x) = \Lambda^{-1}\big[\, hx_I^+ + \mu x_0 \min\{v_n(x_0 - 1, x_I + 1) + c_R, v_n(x_0 - 1, x_I)\} + \gamma x_0 v_n(x_0 - 1, x_I) + \lambda\,\big(v_n(x_0 + 1, x_I - 1) + c_L \alpha(x_I)\big) + \theta\, min\{v_n(x_0, x_I + 1) + c_M, v_n(x_0, x_I)\} + (\Lambda - \mu x_0 - \gamma x_0 - \lambda - \theta)\big(v_n(x_0, x_I)\big)\big] \tag{3}$$

where, $\Lambda = \lambda + \theta + M(\mu + \gamma)$

$$\text{and } \alpha(x_I) = \begin{cases} 1 & if\ x_I = 0 \\ 0 & if\ x_I > 0 \end{cases}$$

The LP equivalent of this value iteration approach which calculates the stationary distribution of being in state x and giving decision β, $y_{x,\beta} = P(x_0, x_I, \beta)$ is given as:

$$min\ Z = \sum(c_{x,0}\, y_{x,0} + c_{x,1} y_{x,1} + c_{x,2} y_{x,2} + c_{x,3} y_{x,3}) \quad \forall\, x \in S$$
$$s.t.\ \sum\big(y_{x,0} + y_{x,1} + y_{x,2} + y_{x,3}\big) = 1 \quad \forall\, x \in S$$
$$\begin{aligned} y_{x,0} + y_{x,1} + y_{x,2} + y_{x,3} & \\ & - \Lambda^{-1}\{\theta\big(y_{x,0} + y_{x,1} + y_{x-e_I,2} + y_{x-e_I,3}\big) \\ & + \lambda\big(y_{x-e_0+e_I,0} + y_{x-e_0+e_I,1} + y_{x-e_0+e_I,2} + y_{x-e_0+e_I,3}\big) \\ & + x_0\mu\big(y_{x+e_0-e_I,0} + y_{x+e_0-e_I,1} + y_{x+e_0,2} + y_{x+e_0-e_I,3}\big) \\ & + x_0\gamma\big(y_{x+e_0,0} + y_{x+e_0,1} + y_{x+e_0,2} + y_{x+e_0,3}\big) + (M - x_0)(\gamma + \mu)\big(y_{x,0} + y_{x,1} + y_{x,2} + y_{x,3}\big)\} \\ & = 0 \end{aligned}$$

$$y_{x,0} \geq 0, y_{x,1} \geq 0, y_{x,2} \geq 0, y_{x,3} \geq 0 \quad \forall\, x \in S$$
$$x = (x_0, x_I), e_0 = (1,0), e_I = (0,1)$$
$$c_{x,\beta} = hx_I + (1 - x_I)^+ \lambda c_L + \theta d_M c_M + x_0 \mu d_R c_R$$
$$\beta = \{0,1,2,3\}$$

$$\text{and } \beta(d_M) = \begin{cases} 0 & if\ d_M = 0,\ d_R = 0 \\ 1 & if\ d_M = 0,\ d_R = 1 \\ 2 & if\ d_M = 1,\ d_R = 0 \\ 3 & if\ d_M = 1,\ d_R = 1 \end{cases} \tag{4}$$

In addition to d_M, another binary variable, d_R, is introduced where $d_R = 0$ and $d_R = 1$ are do not accept and, accept and remanufacture the returned product decisions, respectively. $c_{x,\beta}$ is the cost of making decision β in state x while $\beta = 0$ represents do not produce and do not accept a returned product decision, $\beta = 1$ represents do not produce but accept and remanufacture the returned product decision, $\beta = 2$ represents produce but do not accept a returned product decision and $\beta = 3$ represents produce and, accept and remanufacture the returned product decision. Also, this model can be referred as Production and Return Admission Control model (PR-control) in the rest of the paper.

NUMERICAL ANALYSIS

In this section we analyze the optimal control of a hybrid production system under the effect of information on the number of products in use. We first look at the optimal production decision when all returns are accepted and processed. Then we add the admission control of returns. Finally, since in most cases it is impossible to have an exact knowledge of the orbit size we measure the difference between estimates and exact knowledge. To this end, we first measure the difference between having no information and full information about the orbit while determining the optimal control values. Then we look at the improvement of using possible estimates for return flows.

The model in consideration has an infinite state space. In order to emulate this effect for the MDP analysis we first determine the finite state space size that would minimize the upper boundary effects of the inventory level and orbit size on the expected reward and tail probabilities. For the experiments to determine the state space, we fix the production rate, θ, and arrival rate, λ, to 1 and study the sizes of orbit and inventory by changing return rate, μ, and loss rate, γ, as 0.0005, 0.0015, 0.0025, 0.005, 0.001, 0.003, 0.01. Our objective in setting $\theta=\lambda$ is to observe the cases with maximum variance. Since the system operates as a semi- closed queueing network with an M/M/1 server that shuts off when the queue is $\geq$ S and a . / M / ∞ server with each server having the rate $\gamma + \mu$, it is trivial to see that the system will always converge. Therefore, any stationary policy that minimizes the long run average cost will generate a stationary distribution.

The results of experiments showed that the effect of setting orbit size to more than 100 and the inventory size to more than 50 on the expected cost per unit time is insignificant for all experiments. As can be observed from the probability distributions in the next sections, probabilities of having much larger or smaller values from the mean are very low. Thus, by setting the maximum orbit size M to 100 and the maximum inventory size N to 50 we emulate infinite state space. After determining the state space size, we constructed an experiment set to study the behavior of this system in detail. The sum of μ and γ is set to 0.02. To observe the effect of return probability p, μ and γ are set to the values given in Table 1 since $p = \mu / \gamma + \mu$.

Table 1. Parameters μ, γ and p

Parameters	1	2	3	4	5
μ	0.002	0.006	0.01	0.014	0.018
γ	0.018	0.014	0.01	0.006	0.002
p	0.1	0.3	0.5	0.7	0.9

While specifying the cost parameters, the holding cost h is used as a reference point by setting its value to 1. To examine its relationship with cost of lost sales, c_L, two different h/c_L ratios, 0.1 and 0.02, are determined. Furthermore, it is assumed that for the cost of manufacturing a new product, c_M, $c_M \leq c_L$ and three different c_M/c_L ratios are determined as 0.1, 0.5 and 1 to analyze the relationship between costs of manufacturing and lost sales. Finally, the cost of remanufacturing, c_R, is determined as given in Table 2 to satisfy five different ratios for c_R/c_M to study different profitability levels for recovery activities. Finally, the demand rate λ is given two more values as 0.8 and 1.2 to examine the system behavior when $\lambda < \theta$, $\lambda = \theta$ and $\lambda > \theta$. In this way, an experiment set with 360 different experiments is obtained.

Table 2. Parameters c_M and c_R.

c_M	c_R			
1	0.1	0.3	0.6	0.9
5	0.5	1.5	3	4.5
10	1	3	6	9
25	2.5	7.5	15	22.5
50	5	15	30	45
c_R / c_M	0.1	0.3	0.6	0.9

The Effect of Orbit Size Dependent Return Flows on Production Decision

It was shown in Zerhouni et al (2013) that the optimal production policy is a base stock policy when the return flow is independent of the orbit size. However, the return rate is a function of the number of products in use, the usage time and the probability of a product to be returned to the manufacturer. Thus, orbit dependent return rate affects the optimal production policy. To analyze this effect, we study the decision spaces of the

MDP model with production decision. Figure 2 shows the optimal orbit state dependent decision space for products with a return probability of 0.9 and an average usage length of 50 time units. Here, x-axis represents the size of orbit and y-axis represents the size of inventory. Also, 1 represents the decision to produce a new unit for the stock and 0 represents otherwise. In Figure 3 marginal probability distributions obtained from the LP solution of the MDP model are given for the same experiment.

We observe that when there are 0 to 6 products in the orbit, the system prefers to produce until the number of products in the inventory reaches to 7 as base stock level. However, there is a decline in the base stock level as the number of products in use increases. It is because of the increase in return rate which is calculated as μ times x_0. When the return rate increases, a higher percentage of the demands is satisfied from the returned products and the need for production decreases and it allows the base stock level to decrease. This behavior of the switching curve is also observed by Flapper *et al* (2012) where they have modeled a system with partial knowledge for products to be returned.

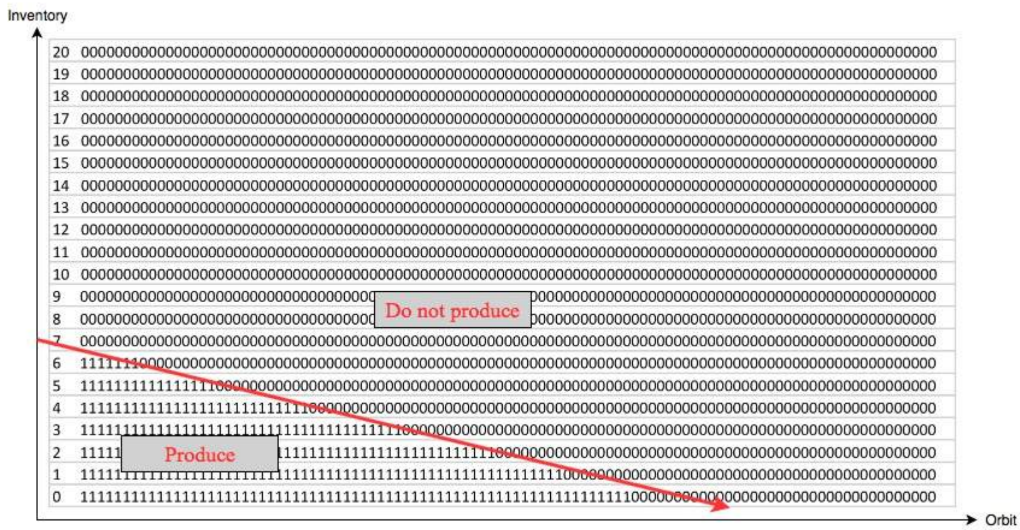

Figure 2. Decision Space of P-control Model where Return Probability p= 0.9, μ =0.018, θ =1, λ =1, h/c_L=0.02, c_M/c_L =0.1, c_M=5, c_R =3 and h=1

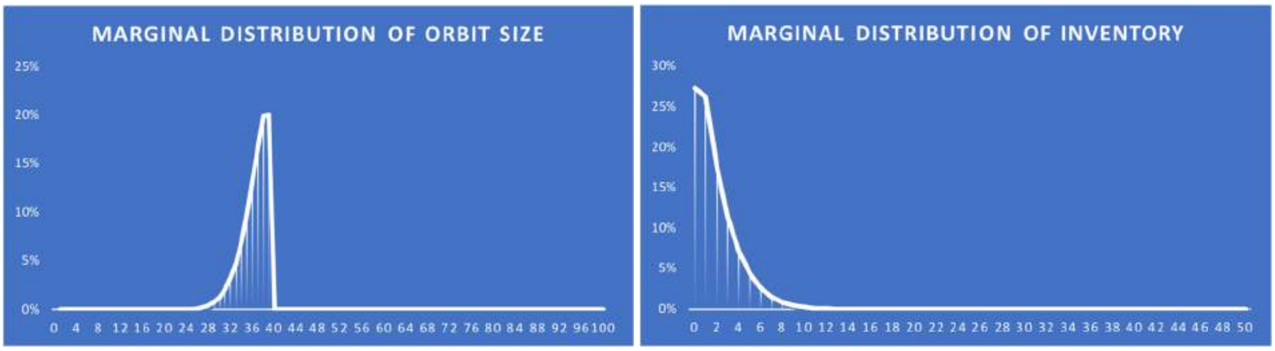

Figure 3. Marginal Probability Distributions of Orbit Size and Inventory for P-control Model p = 0.9, μ =0.018, θ =1, λ =1, h/c_L=0.02, c_M/c_L =0.1, c_M=5, c_R =3 and h=1

Sensitivity Analysis on the Switching Curve Behavior for Production Decision

In this section, the changes in the behavior of switching curve with different return probabilities, h/c_L, c_M/c_L and c_R/c_M ratios and different demand rates are examined, respectively. In Figure 4, the decision spaces of three different experiments with increasing return probabilities are given. We observe that when the return probability is low, 0.1, the control policy is very similar to the base stock type policy for a fixed return rate. On the other hand, as the return probability increases, the impact of orbit information becomes more noticeable. The increase in the impact of orbit can be observed in the change of the base stock level. Number of states with production decision decreases and base stock level is updated more frequently by decreasing it one by one as the orbit size increases. Depending on the magnitude of the return probability, a critical orbit size exists where the control policy chooses not to produce since the return rate is high enough to satisfy the demand by itself. These results can be interpreted as the increase in probability of return increases the value of orbit information.

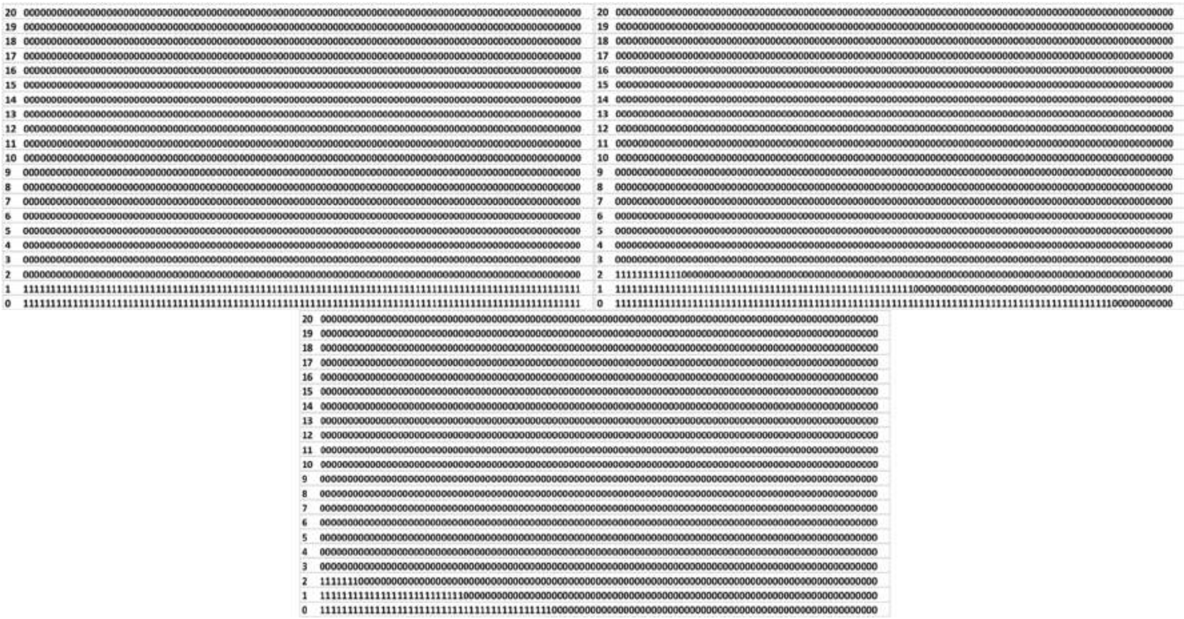

Figure 4. Decision Spaces where p = (0.1,0.5,0.9), (top left clockwise) μ = (0.002, 0.01, 0.018), θ =1, λ =1, h/c_L=0.1, c_M / c_L =0.5, c_R / c_M= 0.3 and h=1

Figure 5 depicts the decision matrices of experiments with significantly higher lost sales costs with respect to holding costs. As an expected result, the control policy holds more finished goods in the inventory and the number of states with production decision is increased. When we compare these results with the results in Figure 4 we observe that the base stock levels are updated more frequently as the orbit size increases. This effect can be observed even for p=0.1, the effect of orbit on the control policy becomes more visible also in low probabilities.

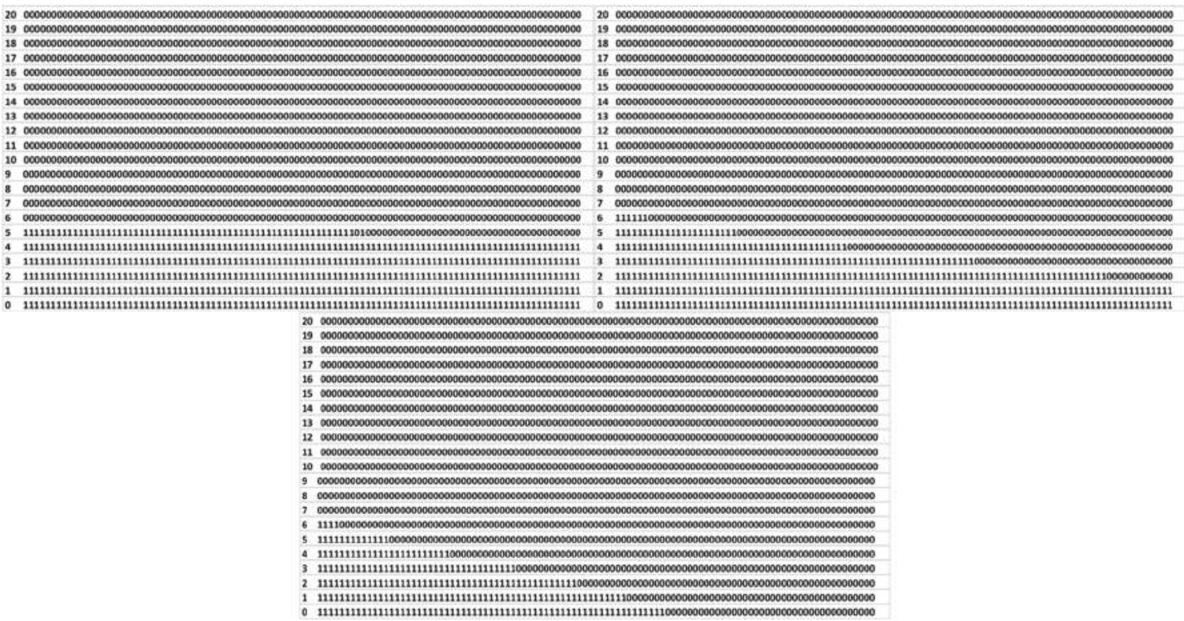

Figure 5. Decision Spaces where p = (0.1,0.5,0.9), (top left clockwise) μ = (0.002, 0.01, 0.018), θ =1, λ =1, h/c_L=0.02, c_M / c_L =0.5, c_R / c_M= 0.3 and h=1

When the cost of manufacturing gets closer to the cost of lost sales, the benefit of production decreases. In Figure 6 and 7 we observe that the increase in c_M / c_L ratio results in a decrease in the number of states with production decision. Base stock levels are pulled down and updated less frequently. Furthermore, by comparing Figure 6 and 7 with each other, we see that a higher c_R / c_M ratio makes the effect of c_M / c_L ratio more powerful since the profitability of remanufacturing also decreases. As expected the probability of incurring a cost of lost sale increases with an increase in both c_M / c_L and c_R / c_M ratios.

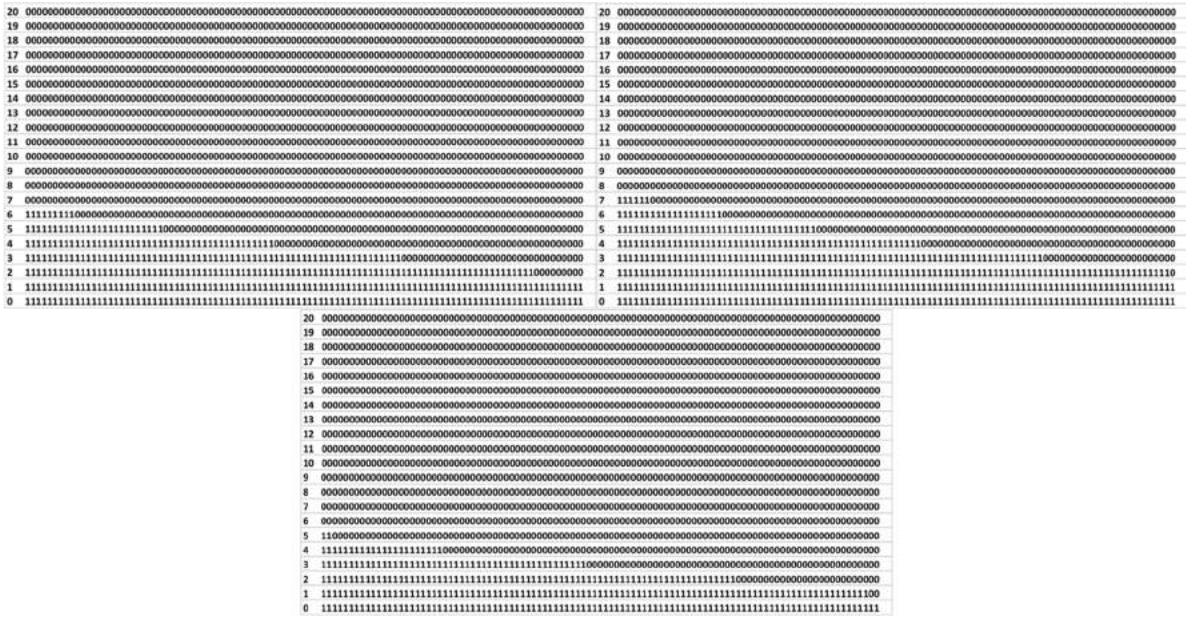

Figure 6. Decision Spaces where $p = 0.5$, $\mu = 0.1$, $\theta = 1$, $\lambda = 1$, $h/c_L = 0.02$, $c_M / c_L = (0.1, 0.5, 1)$ (top left clockwise), $c_R / c_M = 0.1$ and $h = 1$

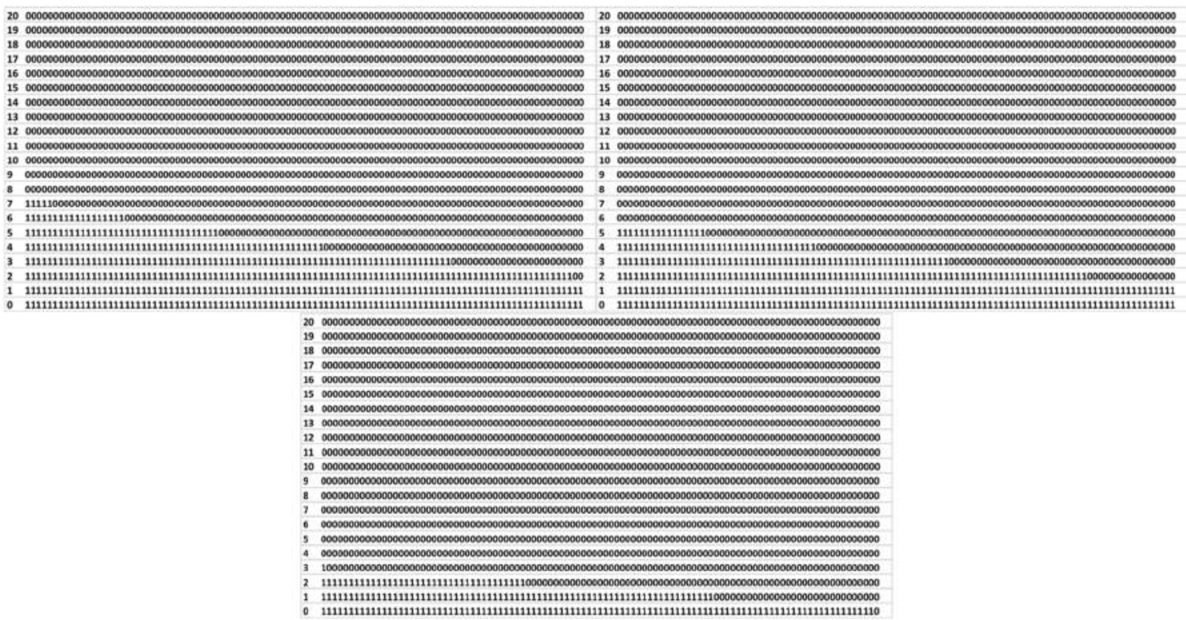

Figure 7. Decision Spaces where $p = 0.5$, $\mu = 0.1$, $\theta = 1$, $\lambda = 1$, $h/c_L = 0.02$, $c_M / c_L = (0.1, 0.5, 1)$ (top left clockwise), $c_R / c_M = 0.6$ and $h = 1$

Figure 8 shows the response of the system to increase in demand rate. Here, the produce up to level as well as orbit based update frequency increase. Thus we can conjecture that the value of orbit information increases as the demand rate increases.

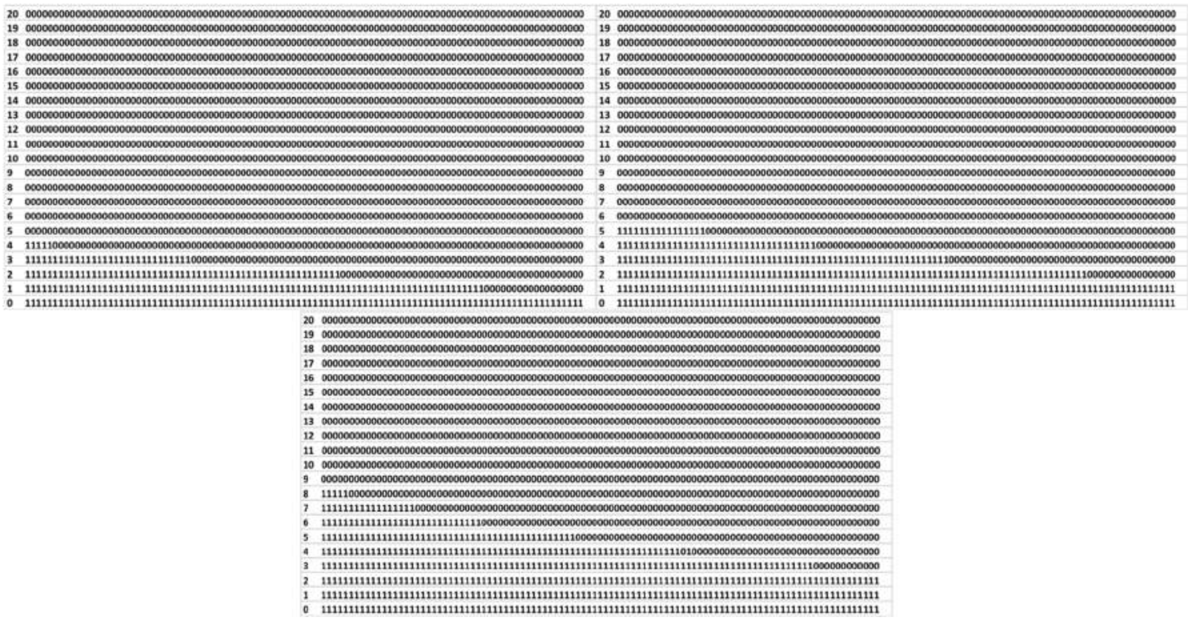

Figure 8. Decision Spaces where p = 0.5, μ = 0.1, θ =1, λ = (0.8, 1, 1.2) (top left clockwise), h/c_L=0.02, c_M / c_L= 0.5, c_R / c_M= 0.6 and h=1

The Effect of Orbit Size Dependent Return Flows on Production and Admission Controls

In Figure 9, an optimal orbit state dependent decision space for both production and admission controls is given. Here, x-axis represents the size of orbit and y-axis represents the size of inventory. Also, 0 represents no production or admission of returned products, 1 represents only admission of returned products without producing new products, 2 represents only producing new products without admission of returned products and 3 represents both producing and admission of returned products decisions.

Figure 9. Decision Space of PR-control Model where p = 0.5, μ = 0.1, θ =1, λ = 1, h / c_L = 0.1, c_M / c_L= 0.5, c_M = 5, c_R = 0.5 and h=1

We observe that the system produces new products and admits returns until the number of products in the inventory reaches 3. Then, only returned products are remanufactured until the number of products in the inventory reaches 7. Since returns are remanufactured instantaneously the control levels can be named as, produce-up-to level and remanufacture-up-to level, respectively. As we can observe in Figure 9, the remanufacture-up-to level decreases in a stepwise fashion with the increase in the number of products in use similar to the produce-up-to level.

It can also be noticed that the decision of only production, β = 2, is only seen when there are no products in the orbit. Similarly, the decision of only admission of returned products, β = 1, can be seen after having some products in the orbit and in the upper part of the up-to-produce level.

Sensitivity Analysis on the Switching Curve Behavior for Production and Admission Decisions

In this section, the changes in the behavior of switching curves with different return probabilities, h / c_L, c_M/c_L and c_R/c_M ratios and different demand rates are examined, respectively. In Figure 10, the decision spaces of three different experiments with increasing return probabilities are given. We observe that when the return probability is low, 0.1, the control policy is very similar to the base stock type policy for a fixed return rate. Both produce and remanufacture-up-to levels are almost fixed; however, we can observe the effect of the orbit information in the remanufacture-up-to level. On the other hand, as the return probability increases, the impact of orbit information becomes more noticeable. Number of states where the system decides to produce or to accept returned products decreases and produce and remanufacture-up-to levels are updated more frequently by decreasing it one by one as the orbit size increases. These results can be interpreted as the increase in probability of return increases the value of orbit information. Comparing to Figure 4, the states with decision "1" in the P-control model and the states with decision "3" in the PR-control model are almost the same.

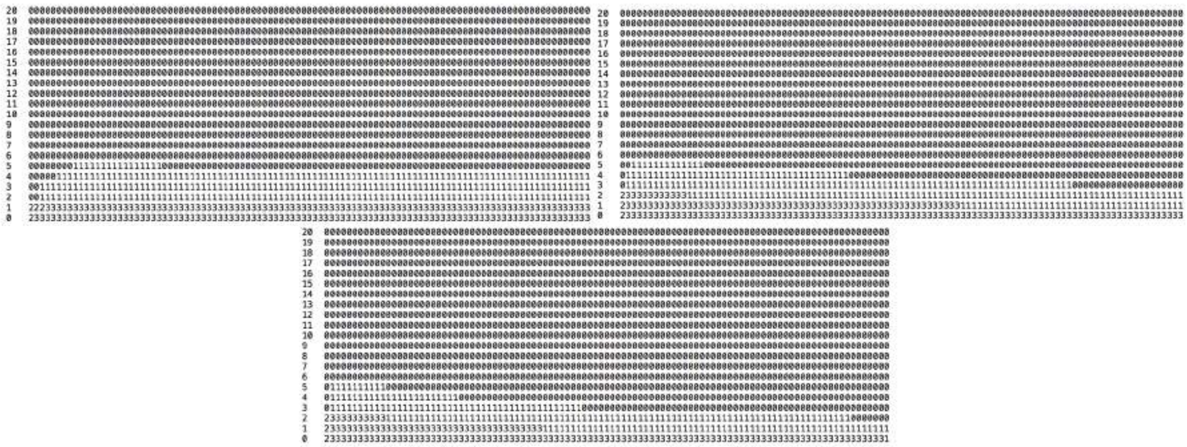

Figure 10. Decision Spaces where p = (0.1, 0.5, 0.9) (top left clockwise), μ = (0.002, 0.01, 0.018), θ =1, λ = 1, h / c_L = 0.1, c_M / c_L = 0.5, c_R / c_M = 0.3 and h=1

Figure 11 depicts the decision matrices of experiments with significantly higher lost sales costs with respect to holding costs. As an expected result, the control policy holds a higher finished goods inventory. Both produce and remanufacture-up-to levels are increased significantly. When we compare these results with the results in Figure 10 we observe that the produce and remanufacture-up-to levels are updated more frequently as the orbit size increases. This effect can be observed even for p = 0.1. However, the updates of the remanufacture-up-to level is more frequent than the updates of produce-up-to level.

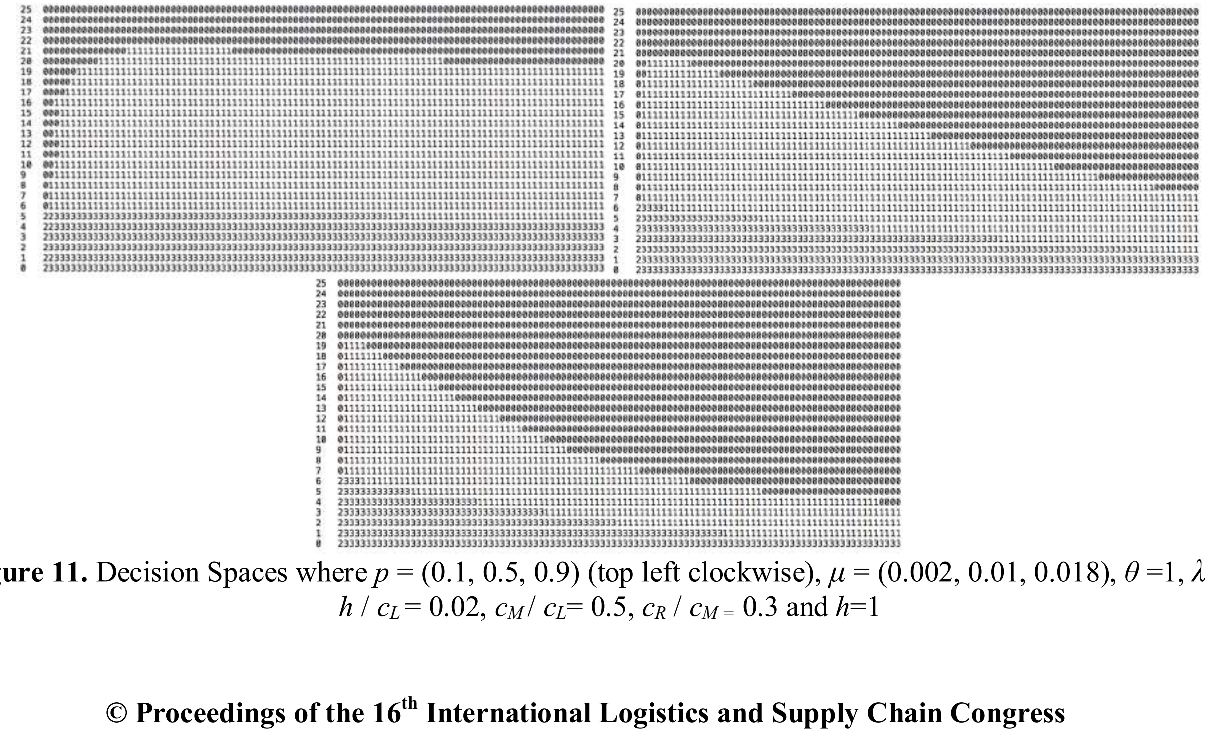

Figure 11. Decision Spaces where p = (0.1, 0.5, 0.9) (top left clockwise), μ = (0.002, 0.01, 0.018), θ =1, λ = 1, h / c_L = 0.02, c_M / c_L = 0.5, c_R / c_M = 0.3 and h=1

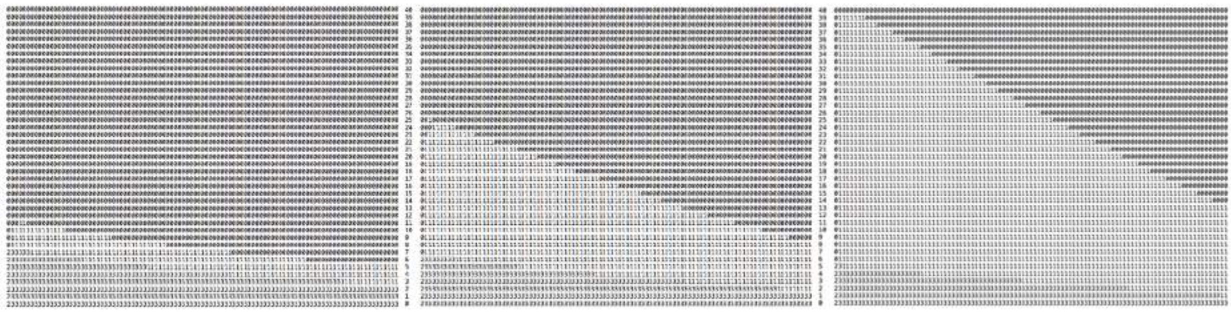

Figure 12. Decision Spaces where p = 0.5, μ = 0.01, θ =1, λ = 1, h / c_L = 0.02, c_M / c_L = (0.1, 0.5, 1), c_R / c_M = 0.1 and h=1

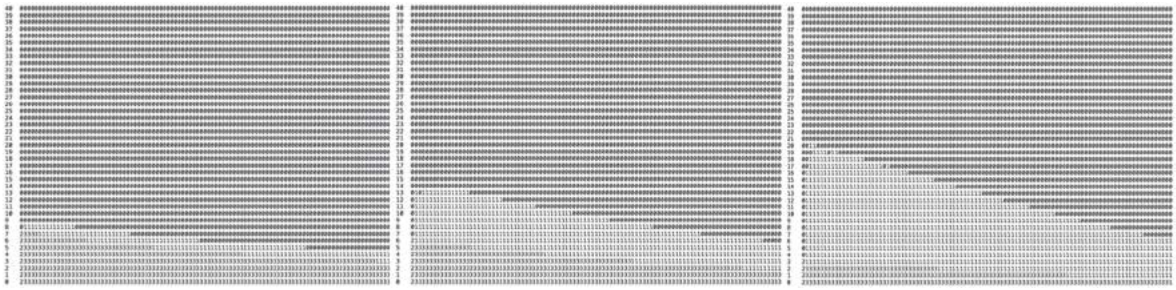

Figure 13. Decision Spaces where p = 0.5, μ = 0.01, θ =1, λ = 1, h / c_L = 0.02, c_M / c_L = (0.1, 0.5, 1), c_R / c_M = 0.6 and h=1

When the cost of manufacturing gets closer to the cost of lost sales, the benefit of production decreases. In Figure 12 and 13 we observe that the increase in c_M / c_L ratio results in a decrease in the area of production decisions are depicted as "3". Produce-up-to levels are pulled down and updated less frequently. On the other hand, remanufacturing has become a more valuable source to satisfy demands and therefore the area of remanufacturing decisions is increased as can be seen by looking at the states with decision "1". Remanufacture-up-to level is increased and updated more frequently with increase in the number of products in use.

Furthermore, by comparing Figure 12 and 13, we observe that a higher c_R / c_M ratio makes the effect of c_M / c_L ratio on produce-up-to level more powerful. Since the profitability of remanufacturing also decreases because of its increasing cost, the remanufacture-up-to level also decreases. There are some cases with a high c_R / c_M of 0.9 in which there is almost no decision "1", only admission of returned products to remanufacture decision, as can be seen in Figure 14.

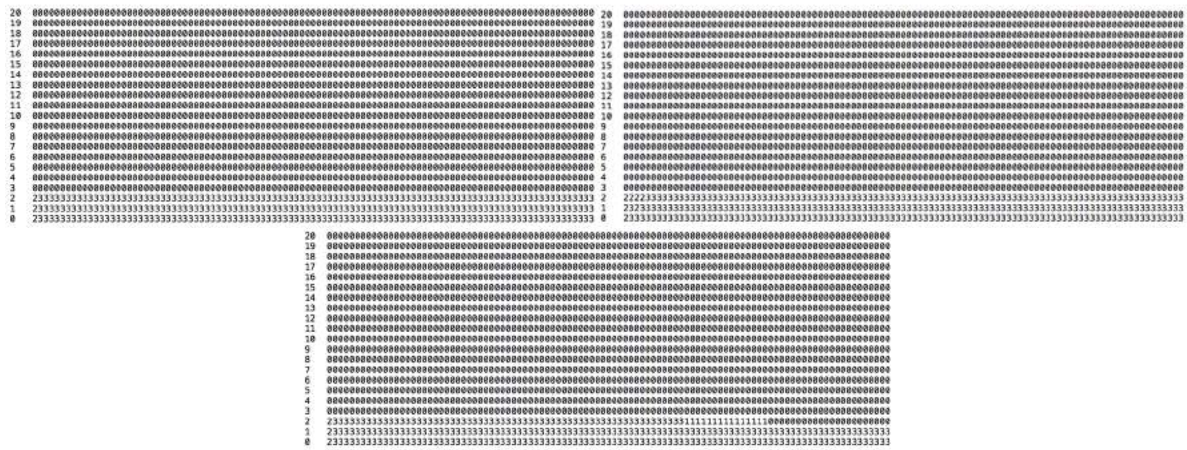

Figure 14. Decision Spaces where p = (0.1, 0.3, 0.5) (top left clockwise), μ = (0.002, 0.006, 0.01) θ =1, λ = 1, h / c_L = 0.1, c_M / c_L = 0.1, c_R / c_M = 0.9 and h=1

In Figure 15 the increase in the demand rate increases both the area of production and remanufacturing decisions as the control policy minimizes lost sales probability. The behavior of produce-up-to curves changes similar to Figure 11 but the change of the remanufacture-up-to curve is closer to being parallel to the produce-up-to curve in the case of increasing demand.

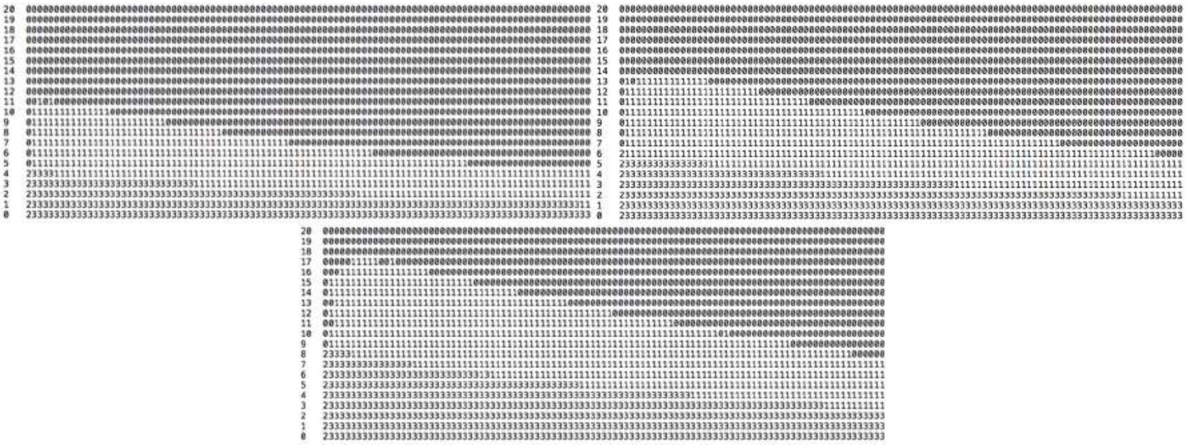

Figure 15. Decision Spaces where p = 0.5, μ = 0.01, θ =1, λ = (0.8, 1, 1.2), (top left clockwise), h / c_L = 0.02, c_M / c_L = 0.5, c_R / c_M = 0.6 and h=1

Sensitivity Analysis on the Cost of Model with Production Decision

After analyzing the effect of return flow on the production decision space, we look at the changes in the optimal long run expected cost values and the stationary probability distributions. Costs and probability distributions are obtained from the LP model. In Figure 16, optimal cost values of six graphs are plotted according to their c_R / c_M ratio as a function of return probability values. The graphs in the first row belong to the experiments with c_M / c_L = 0.1 and the ones in the second row belong to the experiments with c_M / c_L = 0.5. Each column includes the experiments with same λ parameters.

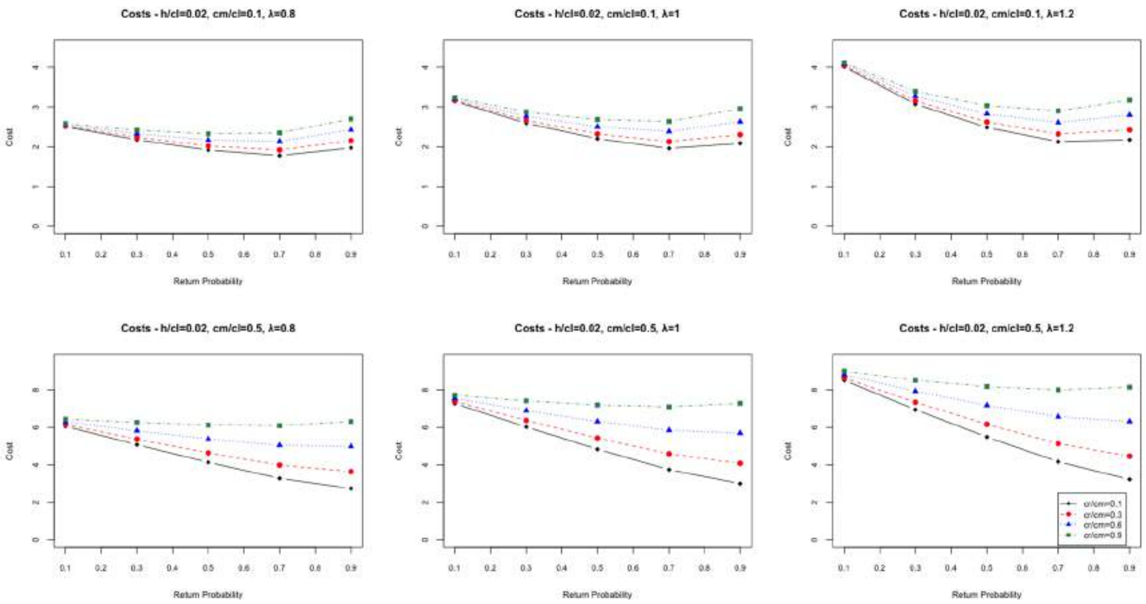

Figure 16. Cost Graphs of P-control Model, h / c_L = 0.02, p = (0.1, 0.3, 0.5, 0.7, 0.9), μ = (0.002...0.018), λ = (0.8, 1, 1.2), (top left clockwise), θ =1 and h=1

From Figure 16, we observe that the average costs increase with increasing demand rate, λ, as expected since the increase in demand causes an increase in the number of finished products in the inventory. This effect can be observed in the marginal probability mass functions depicted in Figure 17. Also, since more demand is satisfied there are more products in use with increasing λ as we see in the marginal probability distributions of orbit in Figure 18. The increase in the expected number of products in orbit also increases the expected number of returned products. Therefore, the control policy updates the produce-up-to level more frequently with increasing λ (Figure 8). However, having more products in the inventory causes a higher expected total cost as inventory holding, manufacturing and remanufacturing costs increase.

Figure 17. Marginal Probability Distributions of Inventory of P-control Model, h / c_L = 0.02, c_M / c_L = 0.5, c_R / c_M = 0.6, p = 0.5, μ = 0.01, λ = (0.8, 1, 1.2), θ =1 and h=1

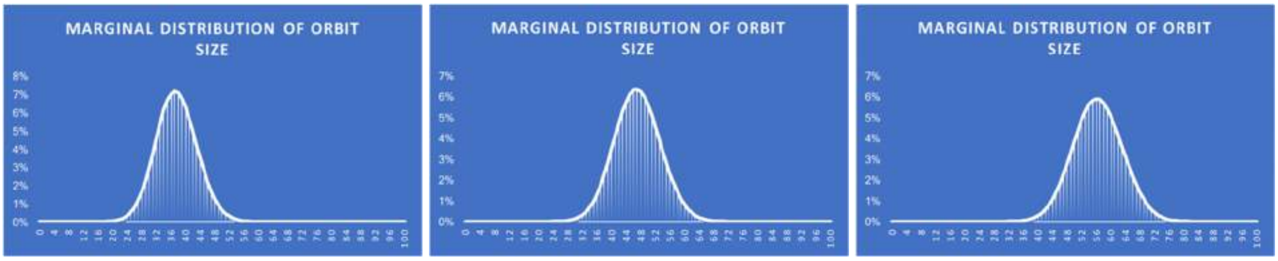

Figure 18. Marginal Probability Distributions of Orbit Size of P-control Model, h / c_L = 0.02, c_M / c_L = 0.5, c_R / c_M = 0.6, p = 0.5, μ = 0.01, λ = (0.8, 1, 1.2), θ =1 and h=1

In all graphs within Figure 16, we observe that there is not much cost difference in experiments with different c_R / c_M ratios when return probability is as low as 0.1. When return probability increases, cost differences become more noticeable between experiments with different c_R / c_M ratios. The experiments with higher c_R / c_M ratio have higher costs because of both of an increase in c_R and in probability of lost sale as it can be seen in Table 3 by comparing the experiments with same c_L value and c_M / c_L ratio. The probability of lost sales is calculated as probability of having zero finished goods in inventory, P(x_I=0). The change in behavior of switching curve is more noticeable when both c_M / c_L and c_R / c_M increases as depicted in Figure 6 and 7. We expect that the probability of incurring a lost sales cost increases with an increase in both c_M / c_L and c_R / c_M ratios. This increase in probability of lost sale with increasing c_R / c_M ratio is small where c_M / c_L is low but when c_M / c_L ratio is higher, the probability of lost sale increases more with increasing c_R / c_M ratio because of both decrease in the value of manufacturing and remanufacturing.

Table 3. Probability of Lost Sales where λ=1, p = 0.5, c_R / c_M = (0.1, 0.6), c_M / c_L = (0.1, 0.5), c_L = (10, 50), θ = 1 and h=1

c_M	c_L	c_M/c_L	c_R/c_M	Probability
1	10	0.1	0.1	0.165
5	10	0.5	0.1	0.171
1	10	0.1	0.6	0.167
5	10	0.5	0.6	0.185
5	50	0.1	0.1	0.038
25	50	0.5	0.1	0.051
5	50	0.1	0.6	0.039
25	50	0.5	0.6	0.058

Figure 16 depicts that in all cases where the lost sales cost is high relative to manufacturing cost expected cost functions are convex in return probability. The costs start to increase for p>0.7. We observe the same behavior in experiments with c_M / c_L = 0.5 only when remanufacturing profitability is low. The cost of a system with return probability, 0.9, may be even higher than a system with return probability, 0.1, as seen in the graph located in the first row and first column of Figure 16. Here the increase in the costs is due to the uncontrolled admission of returns. Control of new production can limit the average inventory only to a certain extent. As the average orbit size increases the return rate increases as well, resulting in a higher inventory than necessary. The increase in the inventory can be observed from Figure 19. However, when c_M / c_L ratio increases while keeping λ same, cost curves start to turn into monotonically decreasing lines even though average costs increases because of the increase in manufacturing and remanufacturing costs and the increase in probability of lost sale as we see in Table 3. In other words, increasing number of returned products increases the total cost where manufacturing cost is low compared to cost of lost sale but decreases the total cost when manufacturing cost increases as long as remanufacturing cost, c_R, is not very close to c_M. Therefore, it can be interpreted that the importance of remanufactured products increases as c_M/ c_L increases. We also observe in graphs in the second row of Figure 16 that as λ increases where c_M/ c_L is higher, even higher c_R/ c_M ratio does not cause an increase in the cost at higher return probabilities. The reason is that when demand is increased, the higher amount of returned products are more beneficial and used to satisfy increased demand. In the discussion of switching curves we stated that the production area decreases as c_M/ c_L increases due to the increasing cost of production. As production decreases, the average orbit and inventory sizes decrease as we observe in marginal distribution of the orbit size and the finished goods inventory in Figure 20 and Figure 21. This also confirms the increase in probability of lost sales with increasing c_M/ c_L ratio.

Figure 19. Marginal Probability Distributions of Inventory of the P-control Model, h / c_L = 0.02, c_M / c_L = 0.5, c_R / c_M = 0.6, p = (0.3, 0.5, 0.7), λ = 1, θ =1 and h=1

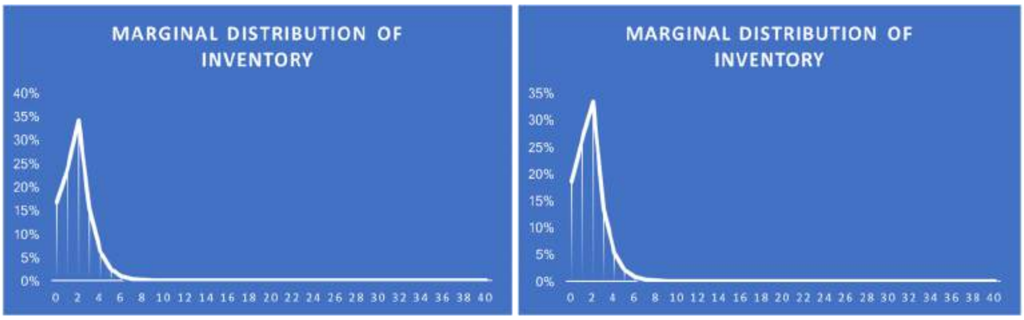

Figure 20. Marginal Probability Distributions of Inventory of the P-control Model, h / c_L =0.1, c_M / c_L = (0.1,0.5), c_R / c_M = 0.6, p = 0.5, μ = 0.01, λ = 1, θ =1 and h=1

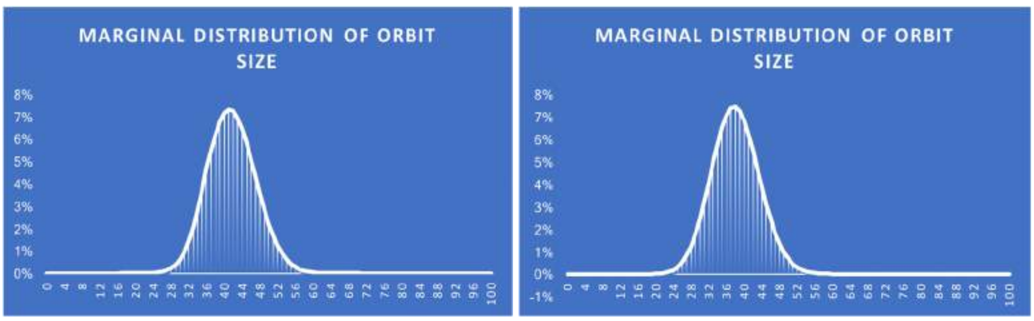

Figure 21. Marginal Probability Distributions of Orbit Size of the P-control Model, h / c_L =0.1, c_M / c_L = (0.1,0.5), c_R / c_M = 0.6, p = 0.5, μ = 0.01, λ = 1, θ =1 and h=1

In Figure 22 we observe that when c_L increases control policy holds more finished goods in the inventory as we discussed in Figure 8. Also, when the cost of a lost sale is high relative to its holding cost, probability of a lost sale decreases as can be seen in Table 3. Therefore, higher percentage of demand is satisfied, and this causes orbit size to expand as shown in Figure 23 where marginal orbit size distribution moves to the right.

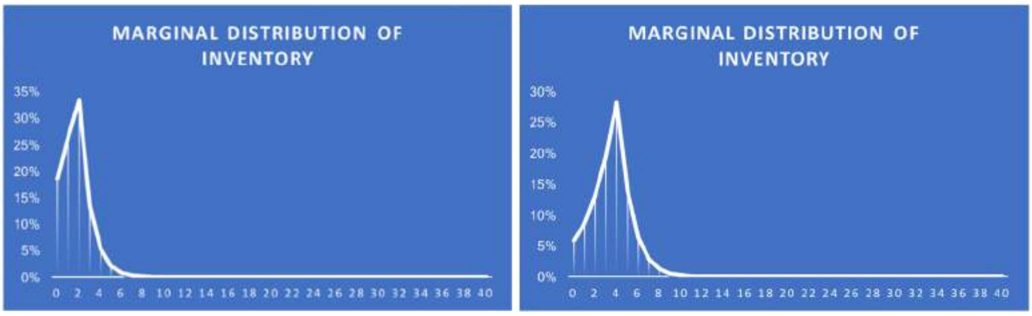

Figure 22. Marginal Probability Distributions of Inventory of the P-control Model, h / c_L = (0.1, 0.02), c_M / c_L = 0.5, c_R / c_M = 0.6, p = 0.5, μ = 0.01, λ = 1, θ =1 and h=1

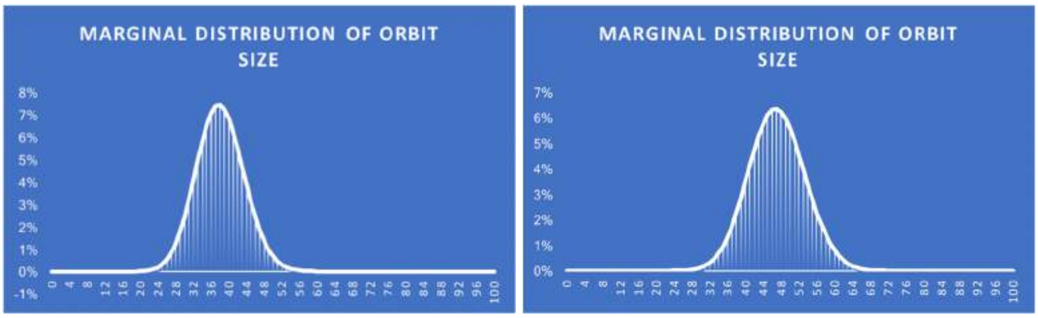

Figure 23. Marginal Probability Distributions of Orbit Size of the P-control Model, h / c_L = (0.1, 0.02), c_M / c_L = 0.5, c_R / c_M = 0.6, p = 0.5, μ = 0.01, λ = 1, θ =1 and h=1

Value of Admission Control

The benefits of utilizing return flows are already shown in the literature. Even though it is mostly beneficial, its benefits diminish when the return probability increases excessively as a result of uncontrolled admission of cores. Therefore, an admission control becomes necessary.

In the graph at the left of Figure 24, the optimal costs for the P-control model are given. The costs are convex in return probabilities when only production decision is controlled. The improvement in cost decreases with increasing return probability and after a certain probability costs start to increase. On the other hand, the effect of being able to reject the unnecessary returns generates a monotonically decreasing cost structure as can be observed in the graph at the right of Figure 24. Admission control helps to control inventory level which prevents system to incur unnecessary holding and remanufacturing costs. In a model that disregards the orbit effect Van der Laan and Salomon (1997) also discussed that the increase in return rate decreases the total cost at first but then cost increases due to the higher variability of output of remanufacturing process since it increases the sum of inventory holding costs as we show here.

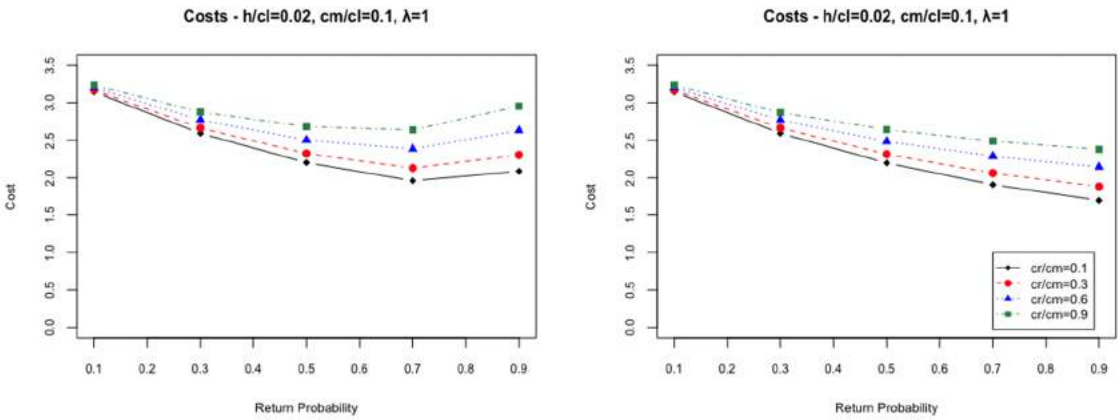

Figure 24. Optimal Cost Graphs of P-control Model (left) and PR-control Model (right), h / c_L = 0.02, p = (0.1, ...0.9), μ = (0.002, ...0.018), λ = 1, θ =1 and h=1

The marginal inventory distribution graphs in Figure 25 show that the control policy keeps the same inventory level in both P-control model and PR-control model. However, we see that the probability of having 10 or more products in the inventory is equal to zero for the model with admission control. For the experiments used in Figure 25 probability of lost sales, P(x_I=0), are 0.04725 and 0.04766 in P-control and PR-control models, respectively. We observe that there is no significant change in lost sales probability since admission control both ensures to keep enough inventory and costs of holding and remanufacturing as low as possible by rejecting unnecessary returned products.

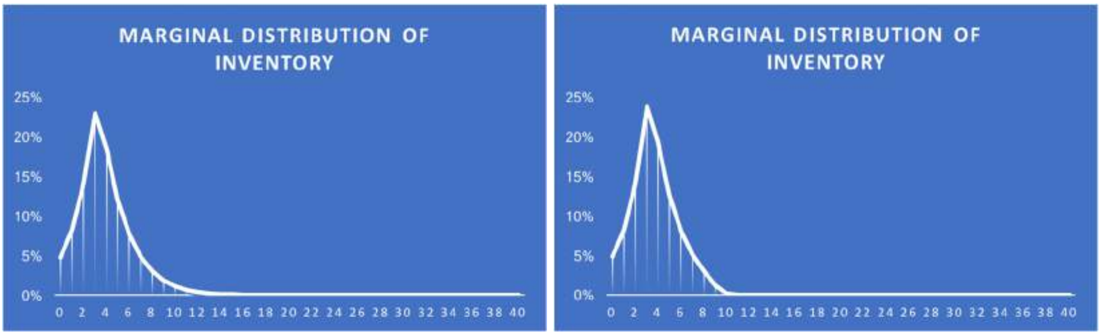

Figure 25. Marginal Inventory Distributions of P-control and PR-control Models, h / c_L = 0.02, c_M / c_L = 0.5, c_R / c_M = 0.6, p = 0.7, μ = 0.014, λ = 1, θ =1 and h=1

It is also important to examine how the magnitude of the effect of admission control changes with different parameter sets. In Figure 26, 6 graphs in which the percentage cost differences of P-control model from PR-control model are plotted according to their c_R / c_M ratio with the increasing return probability in the x-axis. The graphs in the first row belong to the experiments with c_M / c_L = 0.1 and the ones in the second row belong to the experiments with c_M / c_L = 0.5. Arrival rate takes the values 0.8, 1, and 1.2 in columns one, two and three of the depicted graphs, respectively. We observe that when c_M / c_L is low where both manufacturing and remanufacturing costs are also low with respect to cost of lost sales, the cost difference between two models are not sensitive to c_R / c_M ratios. On the other hand, when c_M / c_L is higher, the effect of c_R / c_M ratio becomes more noticeable. Especially the experiments with c_R / c_M = 0.9 have noticeably higher cost difference and slope of the cost difference curve increases at a smaller return probability since unnecessary returned products cause a higher cost of remanufacturing with higher c_R in the P-control model. Furthermore, the average cost difference of two models decreases significantly with a higher c_M / c_L ratio and a higher λ. As it is mentioned earlier, the increase in c_M / c_L ratio makes remanufacturing more valuable and increase in returned products helps in satisfying demand more economically in that case. Since the main reason of cost difference between these two models is the costs of unnecessary returns, this cost difference decreases when the amount of returned products which are considered unnecessary decreases as c_M / c_L and λ increases.

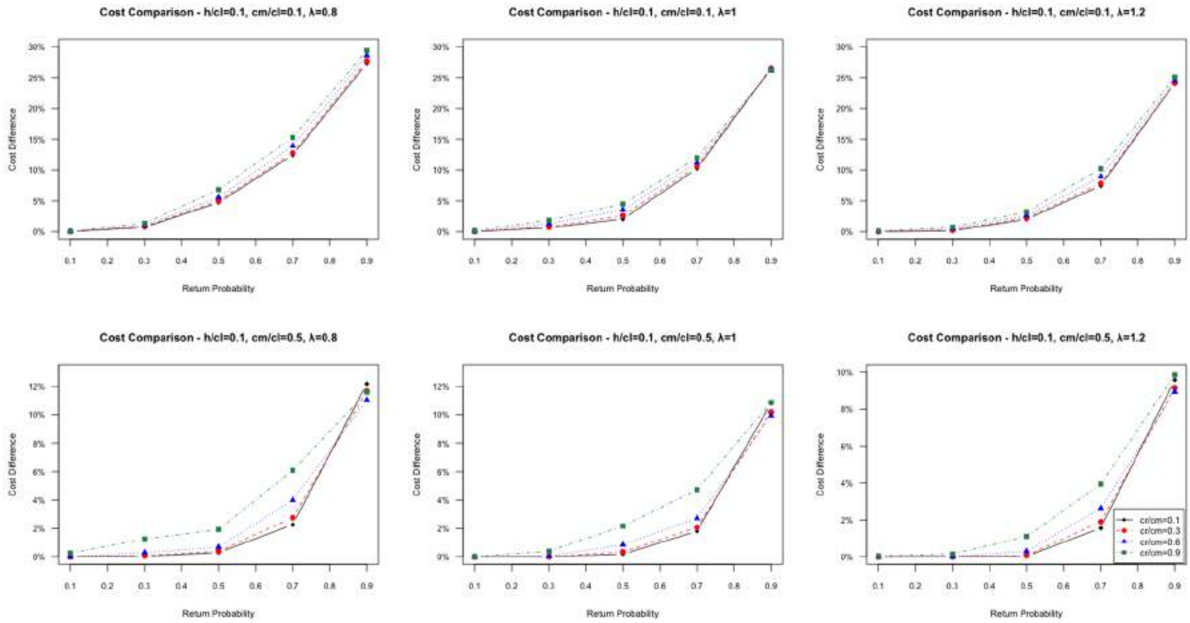

Figure 26. Cost Difference of P-control Model from PR-control Model, h / c_L = 0.1, c_M / c_L = (0.1, 0.5), c_R / c_M = (0.1, 0.3, 0.6, 0.9), p = (0.1, ...0.9), μ = (0.002, ...0.018), λ = (0.8, 1, 1.2), θ =1 and h=1

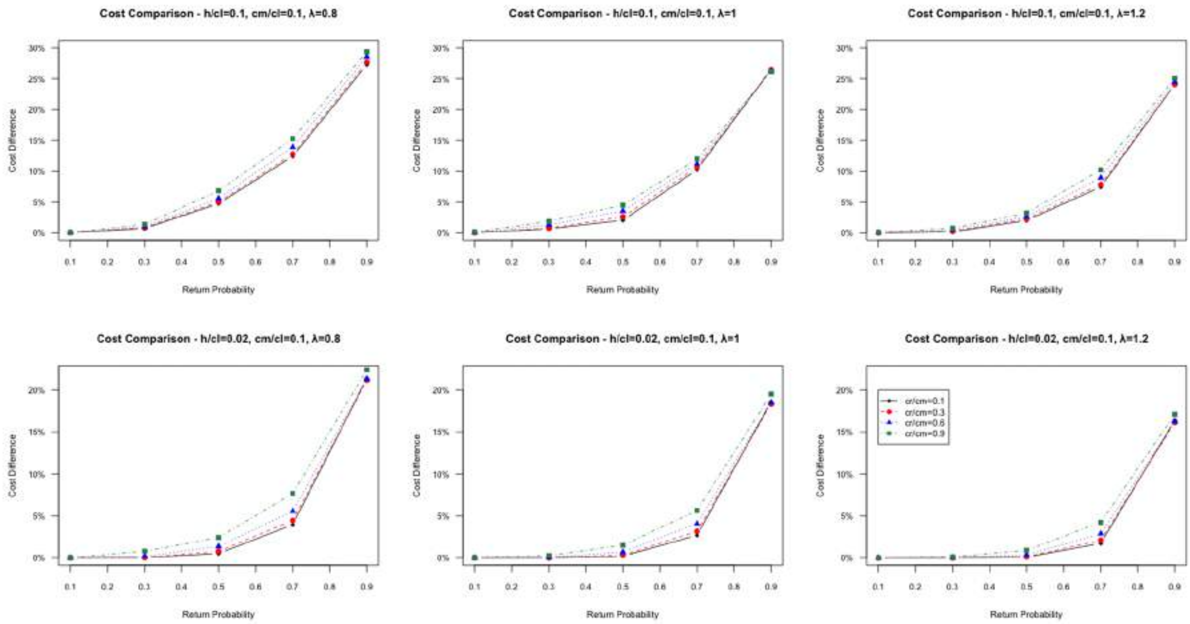

Figure 27. Cost Difference of P-control Model from PR-control Model, h / c_L = (0.1, 0.02), c_M / c_L = 0.1, c_R / c_M = (0.1, 0.3, 0.6, 0.9), p = (0.1, ...0.9), μ = (0.002, ...0.018), λ = (0.8, 1, 1.2), θ =1 and h=1

In Figure 27, the effect of c_L on cost differences can be observed by comparing graphs within different rows and the effect of λ can be observed by comparing graphs in different columns. We observe that the cost difference of two models decreases when c_L increases. As we mentioned earlier, when c_L increases, control policy holds more finished goods in the inventory and meets a higher percentage of demand because of the high cost of lost sale. Therefore, the value of remanufacturing increases as in the previous case and cost difference of two models decreases.

In both of Figure 26 and Figure 27, the cost difference increases significantly with the increase of return probability, as mentioned before. As a summary, where the c_L, c_M / c_L and λ are low, and the return probability and c_R / c_M are high, the benefit of using admission control is higher. Especially when the return probability gets higher, the importance of admission control increases. On the other hand, in the previous section we observed that with the increase in return probability, the higher number of returned products allows higher amount of cost improvement when c_L, c_M / c_L and λ are high and c_R / c_M is low. Therefore, it can be concluded that value of admission control decreases with the increasing importance of returned products and increases otherwise.

Cost of Misjudging the Return Rate

As presented in the previous sections, using return flows helps to decrease the cost of the system significantly. However, the return flow is usually considered by taking a fixed return rate estimate since the orbit is at best partially observable in reality. In this case, the optimal control policy would be a base stock control policy for the system where the actual return flow depends on the orbit size. Therefore, applying a base stock control policy will generate an optimality gap and it is important to evaluate this cost difference especially for incorrect estimates. In our model we represent the correct return rate estimate with the help of the marginal pmf P(x_0=i) obtained from the optimal LP model and calculate it as E[μ]= $\bar{\mu}$ = E[x_0] μ. Then in order to measure the impact of incorrect estimates we numerically analyzed three different cases for overestimating and underestimating the return rate by multiplying best return rate estimate, $\bar{\mu}$, with 0.5, 0.8, 1 and 1.2. The produce up-to levels, that are obtained by using these four return rate estimates in a fixed return rate estimate model are then used as a base stock control policy in the model with orbit dependent return flow to compare the results with P-control model as can be seen in Figure 28 which leads to a suboptimal solution.

Figure 28. Optimal Base Stock Level

Figure 29 includes 6 graphs representing the percentage cost differences of model which assumes fixed return rate where returns are actually orbit dependent from the P-control model with the increasing return probability in the x-axis. Return rate estimates are taken as 0.5$\bar{\mu}$, 0.8$\bar{\mu}$, $\bar{\mu}$ and 1.2$\bar{\mu}$. The graphs in the first row belong to the experiments with c_R / c_M = 0.1 and the ones in the second row belong to the experiments with c_R/c_M= 0.6. Each column includes the experiments with same λ parameters.

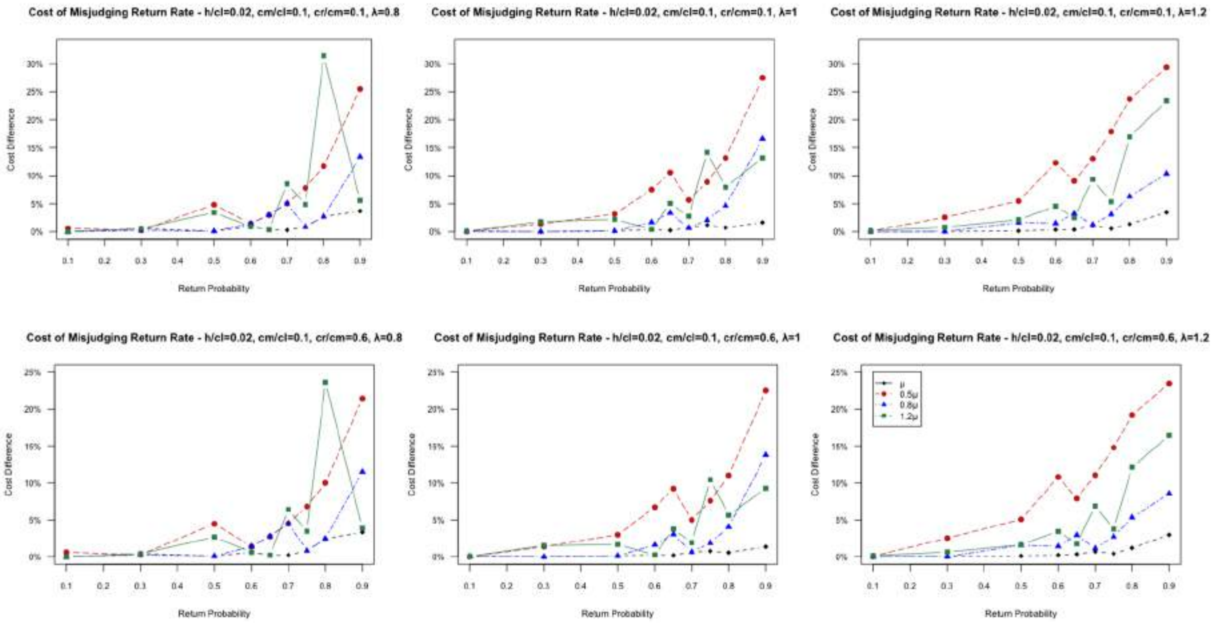

Figure 29. Cost Difference of Misjudging the Return Rate, $h / c_L = 0.02$, $c_M / c_L = 0.1$, $c_R / c_M = (0.1, 0.6)$, $p = (0.1, ...0.9)$, $\hat{\mu} = \bar{\mu}\ (0.5, 0.8, 1, 1.2)$, $\lambda = (0.8, 1, 1.2)$, $\theta = 1$ and h=1

We observe from Figure 29 that using a fixed return rate estimate as $\bar{\mu}$ for a base stock policy causes at most 5\% cost difference with P-control model. However, overestimating and underestimating the return rate increases the cost significantly with increasing return probability. By comparing the cost differences in case of taking return rate estimate as $0.5\bar{\mu}$ and $0.8\bar{\mu}$ we observe that the cost difference increases with the increasing absolute difference from average return rate which is obtained from the LP model by considering the orbit size and return rate relationship, and the estimated return rate. In Table 4, the base stock levels which are obtained for return rate estimates $0.5\bar{\mu}$, $0.8\bar{\mu}$, $\bar{\mu}$ and $1.2\bar{\mu}$ in a fixed return rate estimate model are given with increasing p and c_R / c_M values. Here, we see that base stock levels of the model with $0.5\bar{\mu}$ are always higher than the base stock levels of $\bar{\mu}$ unlike base stock levels of models with $0.8\bar{\mu}$ and 1.2.

Table 4. Base Stock Levels Obtained from Fixed Return Rate Estimate Model, λ=1, $c_M / c_L = 0.1$, $h / c_L = 0.02$, $\theta = 1$ and h=1

c_R / c_M	p	$\bar{\mu}$	$0.5\bar{\mu}$	$0.8\bar{\mu}$	$1.2\bar{\mu}$
0.1	0.1	6	7	7	6
0.3	0.1	6	7	7	6
0.6	0.1	6	7	7	6
0.9	0.1	6	7	7	6
0.1	0.3	5	6	5	4
0.3	0.3	5	6	5	4
0.6	0.3	5	6	5	4
0.9	0.3	5	6	5	4
0.1	0.5	4	5	4	3
0.3	0.5	4	5	4	3
0.6	0.5	4	5	4	3
0.9	0.5	4	5	4	3
0.1	0.7	3	4	3	2
0.3	0.7	3	5	3	2
0.6	0.7	3	4	3	2
0.9	0.7	3	5	3	2
0.1	0.9	1	4	3	0
0.3	0.9	1	4	3	0
0.6	0.9	1	4	3	0
0.9	0.9	1	4	3	0

Figure 29 also depicts that the cost difference is negligible when return probability is as low as 0.1 but increases with increasing return probability since the return flow is actually orbit dependent and the orbit information becomes more valuable as return probability increases. Cost difference of model which assumes fixed return rate as $\bar{\mu}$ from P-control model increases up to 78% as return probability increases. The biggest cost difference is obtained where return probability, p, is 0.9, c_L=10, c_M / c_L =1 and $\lambda \geq \theta$. Also, the increase of λ, demand rate, increases the average cost difference of overestimating and especially the cost difference of underestimating.

In Figure 29 we also observe that when return probability is higher, especially after 0.5, the cost differences decrease as c_R / c_M ratio increases. Even though the decrease in the model with return rate estimate as $\bar{\mu}$ is not significant, the cost of overestimating and underestimating decreases more noticeably. This is an expected result since the profitability of remanufacturing is diminished with the increasing c_R / c_M ratio. Therefore, the produce-up-to level of the P-control model converges to a base stock control policy as c_R / c_M increases.

Figure 30 includes 2 graphs representing the cost difference of model with fixed return rate where returns are actually orbit dependent from the P-control model with the increasing return probability in the x-axis. Return rate estimates are taken as 0.5$\bar{\mu}$, 0.8$\bar{\mu}$, $\bar{\mu}$ and 1.2$\bar{\mu}$. The graph on the left belongs to experiments with c_M / c_L = 0.1 and graph on the right belongs to experiments with c_M / c_L =0.5. We observe that when c_M / c_L ratio increases the cost difference of overestimating becomes significantly more than cost difference of underestimating while cost differences of underestimating decrease. When c_M / c_L increases the value of return flow increases and having less return than the expected return increases total cost significantly in case of overestimating.

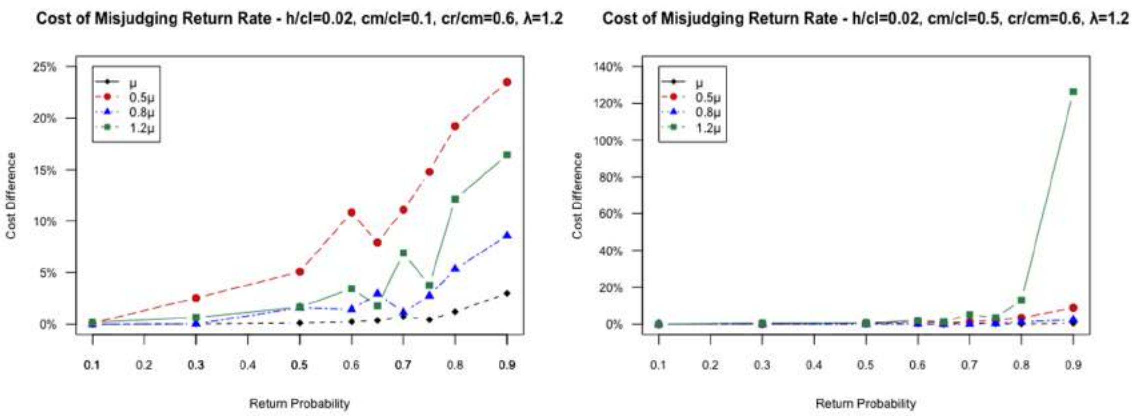

Figure 30. Cost Difference of Misjudging the Return Rate, h / c_L = 0.02, c_M / c_L = (0.1, 0.5), c_R / c_M = 0.1, p = (0.1, ...0.9), $\hat{\mu}$ = $\bar{\mu}$ (0.5, 0.8, 1, 1.2), λ = 1.2, θ =1 and h=1

To evaluate the results of misjudging the return rate in case of having both production and admission control, the produce up-to and remanufacture-up-to levels are obtained by using four return rate estimates, $\bar{\mu}$ x {0.5, 0.8, 1, 1.2}, in a fixed return rate estimate model. Then those levels are used as in a base stock control policy for both manufacturing and remanufacturing in the model with orbit dependent return flow as can be seen in Figure 31.

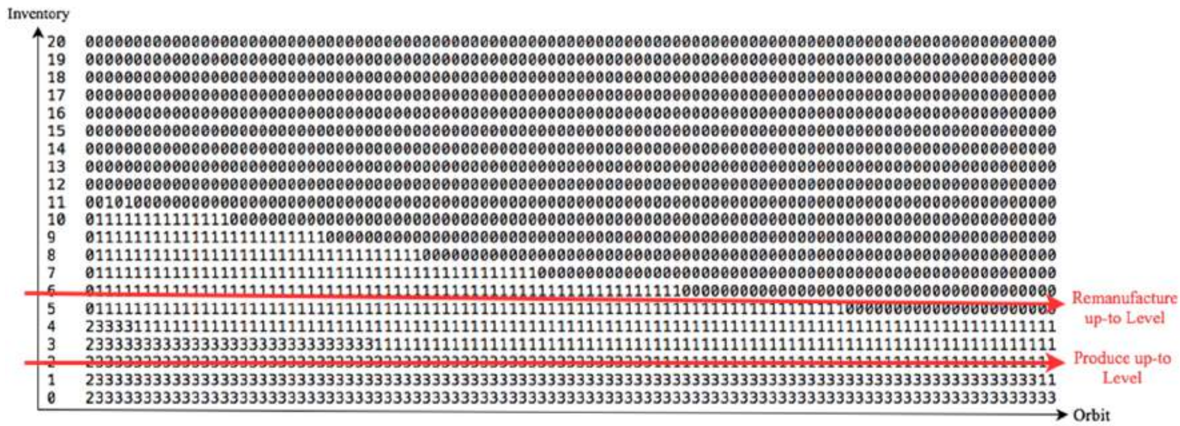

Figure 31. Optimal Produce-up-to and Remanufacture-up-to Levels

In Figure 32, 6 graphs in which the percentage cost differences of the fixed return rate model from the optimal PR-control model are plotted with the increasing return probability in the x-axis. Return rate estimates are taken as $0.5\bar{\mu}$, $0.8\bar{\mu}$, $\bar{\mu}$ and $1.2\bar{\mu}$. The graphs in the first row belong to the experiments with c_R / c_M = 0.1 and the ones in the second row belong to the experiments with c_R / c_M = 0.6. Each column includes the experiments with same λ parameters.

Figure 32 depicts that the behavior of cost difference of model which assumes fixed return rate where returns are actually orbit dependent from PR-control model is similar to previous results. We observe that overestimating and underestimating the return rate increases the cost difference with increasing return probability and also average cost difference decreases when c_R / c_M ratio increases. However, the average cost of misjudging return rate is significantly lower than the previous case in which there is only one base stock level that controls the production and applied to model where returns are actually orbit dependent. Having both produce-up-to and remanufacture-up-to levels decreases the average cost difference from PR-control model as can be seen by comparing Figure 29 and Figure 32.

We also observe that the cost difference caused by underestimating is significantly higher than the cost difference of true estimate or overestimating as can be seen in Figure 32. The reason behind that is the underestimation causes both produce-up-to and remanufacture-up-to levels to increase and therefore the number of products in inventory increases which increases the holding costs more than the cost of lost sales in case of underestimating.

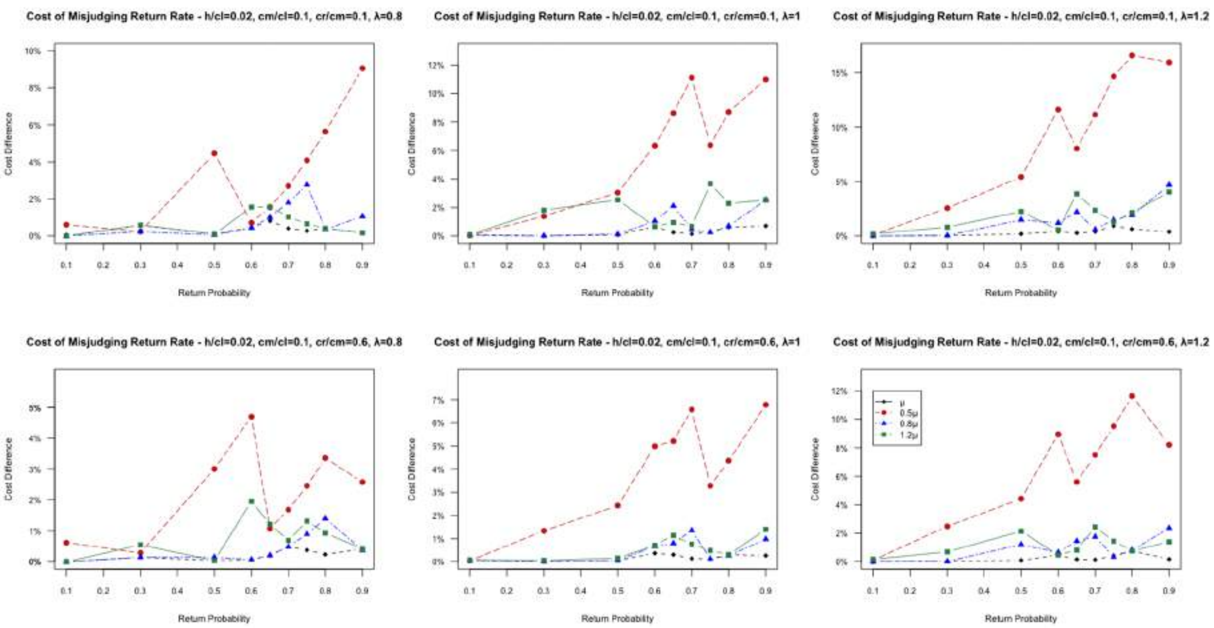

Figure 32. Cost Difference of Misjudging the Return Rate, h / c_L = 0.02, p = (0.1, ...0.9), $\hat{\mu}$ = $\bar{\mu}$ (0.5, 0.8, 1, 1.2), λ = (0.8, 1, 1.2), c_M / c_L = 0.1, c_R / c_M = (0.1, 0.6), θ =1 and h=1

Another difference in behavior of cost of misjudging return rate is observed in the case of c_M / c_L ratio change. In Figure 33, 2 graphs in which the cost difference of model which assumes fixed return rate where returns are actually orbit dependent from the PR-control model are plotted with the increasing return probability in the x-axis. Return rate estimates are taken as $0.5\bar{\mu}$, $0.8\bar{\mu}$, $\bar{\mu}$ and $1.2\bar{\mu}$. The graph on the left belongs to experiments with c_M / c_L = 0.1 and the graph on the right belongs to experiments with c_M / c_L = 0.5. We observe that the increase of c_M / c_L ratio does not cause the cost difference in case of overestimating to increase significantly at higher return probabilities as we observe in Figure 30. It is important to see that the average cost differences are low in this case even return flow is misjudged.

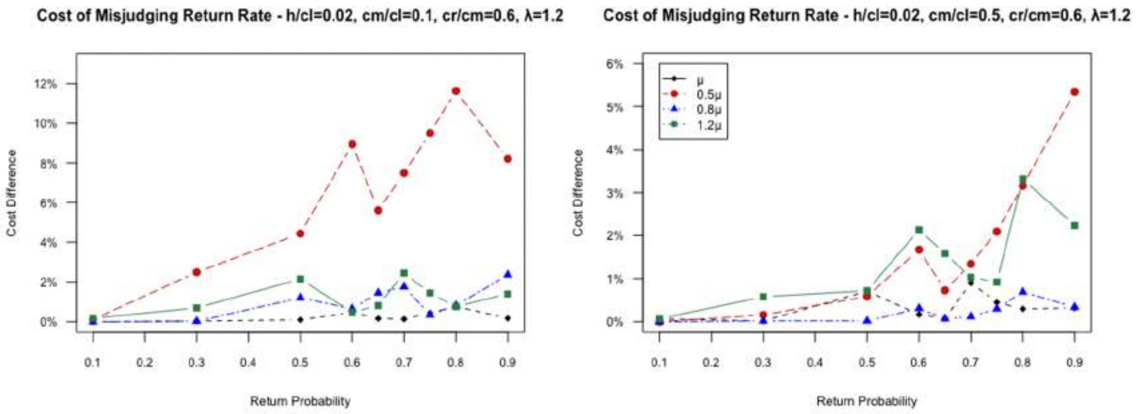

Figure 33. Cost Difference of Misjudging the Return Rate, h / c_L = 0.02, p = (0.1, ...0.9), $\hat{\mu} = \bar{\mu}$ (0.5, 0.8, 1, 1.2), λ = 1.2, c_M / c_L = (0.1, 0.5), c_R / c_M = 0.1, θ =1 and h=1

CONCLUSION

In this study, a testbed for measuring the impact of the number of products in use on the production control of hybrid production systems is introduced. It is shown that base stock levels change with the number of products in use and there is a step-wise production policy. Results indicate that the control policy is dependent on the orbit size and return probabilities. When the expected return rate increases because of increase in the expected number of products in use or in return probability, control policy updates base stock levels more frequently. The increase in λ, c_L and p results in an increase in the expected return rate and a step-wise production policy is observed where base stock levels are updated frequently. On the other hand, the increase in c_M / c_L and c_R / c_M causes return rates to decrease since the profitability of new product manufacturing and remanufacturing decrease simultaneously.

When an admission control is introduced to the system in addition to the production control, two distinct switching curves determining the produce-up-to level and the remanufacture-up-to level observed. The control policy with two decisions shows similar results to the control policy with only production decision. There is a step-wise production and remanufacturing policy. However, the remanufacture-up-to level is updated more frequently with increasing number of products in use. On the other hand, when the cost of manufacturing gets closer to the cost of lost sale, the value of manufacturing decreases and remanufacturing becomes more important to satisfy demand. Therefore, the number of states with production decision decreases while the number of states with remanufacturing decision increases. It is also possible to observe that having admission control does not make a significant difference when the value of remanufacturing is low, perticularly when the cost of remanufacturing is high.

The numerical study also indicates that introducing an additional control for admissions of returned products generates an additional 30% cost reduction. However, the value of using admission control decreases as c_L, c_M/c_L and λ get higher, and as c_R / c_M gets lower because of the increase in benefits of additional returned products. Yet it is usually necessary to lower the cost of the system especially when return probability, p, is high.

Finally, it is shown that both overestimating and underestimating the return rate increase the cost significantly where orbit information has a higher importance as in cases with higher return probability. Similarly, the cost of misjudging the return rate decreases when the switching curve behavior gets similar to fixed return rate model as in cases with higher c_M / c_L and c_R / c_M ratios. However, the cost of overestimating the return rate also decreases in higher c_M / c_L ratios when an admission control is introduced to the system. Having an additional admission control causes a significant decrease on the cost of misjudging the return rate on average.

In this study, we numerically analyzed the behavior of the optimal decision for hybrid production systems. The proposed model can be extended to include the remanufacturing lead-time, and to develop new control mechanisms customized for hybrid systems. Also, we have generated a testbed based on the LP solution of a stochastic dynamic model. Using the new computational capabilities developed for LP based optimization higher dimension models can be generated to test previously proposed control mechanisms.

ACKNOWLEDGMENT

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PRODUCTION PLANNING PROBLEM WITH UNDER UNCERTAINTY IN ELECTRONIC INDUSTRY: CVAR METHOD

Elif Sedef Kılınç[1],Bilge Bilgen[2]

Abstract*-Today, product variety is extending with ever-changing competition environment. Electronics industry has short product life cycles of demands, the risk should be considered. We studied the planning processes of the company which is among the largest OEMs (original equipment manufacturer) and ODMs (original design manufacturer) in the world. The company produces LCD (Liquid-crystal display) TVs and digital consumer products in the electronics industry. The production planning and scheduling problem with independent sequence and eligibility constraints are addressed in the electronics industry. A mixed integer linear programming model (MILP) for the independent production scheduling problem is developed. This model aims to minimize penalty costs which arise due to earliness and tardiness of the orders. To conduct a risk management study on the model, the conditional value at risk method, which is a downside risk method, is used. Due to the mathematical structure, this method is chosen to evaluate the risk scenarios. The mathematical model has been reformulated and scenario trees have been created. In the model, Conditional Value at Risk (CVaR) method has been applied for examining model's output with related to the risk scenarios. The possibilities of each scenario tree according to the determined risk factors have been calculated and analyzed.*

Keywords-CVaR, production scheduling, risk management

INTRODUCTION

Rapid changes in the environmental conditions cause frequent changes in the plan and target of the companies. In an increasingly competitive environment, companies must be proactive and active in order to continue their processes. This necessity requires fast action and requires planning to take into account uncertainties.

Production planning and scheduling is crucial to meet demands of customers at the right time production plus on the right conditions in electronic sectors. Production planning is one of the fields most affected to dynamic and uncertain conditions in the company. Taking into account the uncertainties that may arise in terms of economic, social and political environmental factors in the process of recruitment, will provide the company with a competitive advantage.

This studies focuses on production planning problem of an electronic company. The planning processes of the company which produces LCD TVs and digital consumer products are studied in the electronics industry. This study is based on a real-world production planning and scheduling problem with independent sequence and eligibility constraints in the electronics industry. The company faces many risks all the year round. Three risk measures, e.g. "demand at risk", "arrival time of material at risk." and "efficiency of product line at risk," are addressed.

THE INDUSTRIAL APPLICATION

Information About The Company

The company is among the largest OEMs (original equipment manufacturer) and ODMs (original design manufacturer) in the world. The company produces LCD TVs and digital consumer products in the electronics industry. The company's major product is LCD TV. The company produces ranging from 19" to 84".

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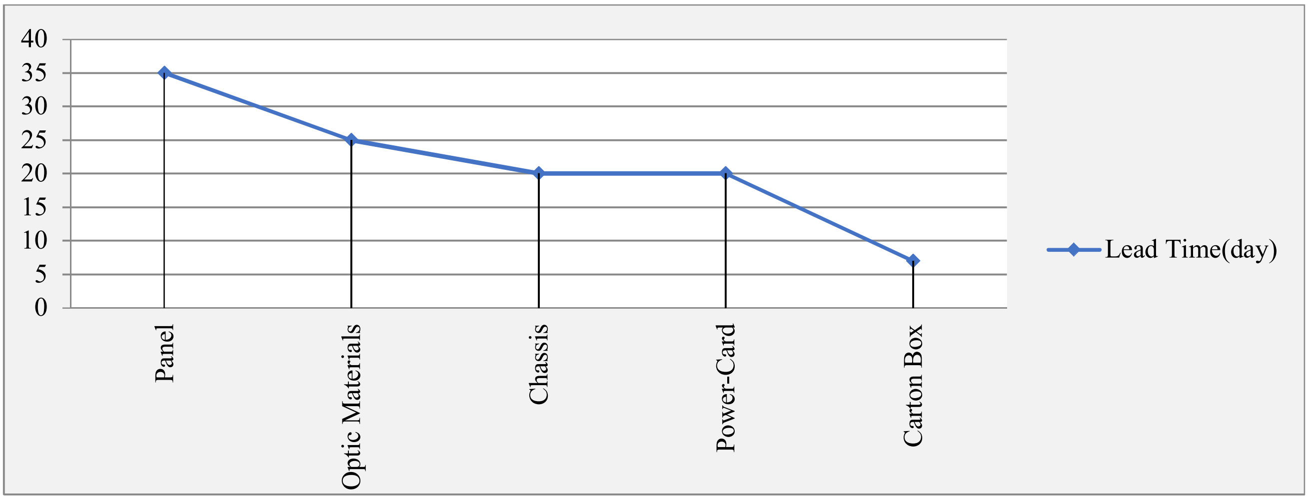
Overview Of The Production System

The production system of the company is make to order. There are 550 components in average in LCD TV. Components are procured from Europe, Turkey and The Far East. The panel, which is an optic component in LCD TV, is the most crucial component. There are also 187 other optic components in LCD TV varying with the panel assigned. Nevertheless, by using different combinations of panel and optic components, technically similar TVs can be produced.

There is no company with panel production in Turkey. 90% of the panels are supplied from the Far East and the rest is supplied from Europe. As a result, the average supply time of this component is the longest one when compared to other components. Each customer's orders are specific in the company. Different panels are used for the same LCD TV according to the specification of customer orders.

Table 1. Lead time of materials



Problem Definition

In this study, the production planning and scheduling problem with independent sequence with eligibility constraints in electronic sector are examined. This study aims at minimizing penalty cost due to earliness and tardiness of the orders. In the production planning and scheduling process, first, the production capacity is determined by the orders given by the Marketing and Foreign Trade department. The demand planning department determines due date of customer orders according to the plastic and metal of the company's production capacity. The production planning department prepares production scheduling according to;

- Due date
- Production line capacity
- Quantity
- Materials from both the internal and external suppliers
- Evaluating feasibility constraints (line product group eligibility)

Preparing the production schedule, main consideration is not to deviate from due date of the orders. However, delay of the customer orders are occurred with different problem. Causes of delays are delay of panels, customer prioritization, delay of cartoon box, delay of external material, delay of production, and technical hold. We studied delay of panels. In this report, the production schedule for LCD TV and effects of the delays on production schedule is evaluated by presenting the mathematical model.

The proposed model has five production lines designed for LCD TV production. The schedule has been made according to the most important component and the most expensive component in TV. The objective function and the constraints in the model are linear. All the customer orders are required to be delivered on the asked due date according to the material control.

The following considerations further define and delimit the problem.

- The eligibility and productivity of these production lines are different from each other.
- It is assumed that the other materials for the TV production are controlled and prepared beforehand.
- The production stops between the orders are ignored.
- A production line manufactures a single order at any time.

- A customer order can begin after previous one is completed.
- Customers send their daily orders for the next 4 weeks to the demand planning department.
- Production planning department schedules customer orders whose (which of whom) due date between 7 days with the next 15 daily.
- The schedule is revised with new customer orders and changes in current customer orders during the day.

Key decision variables are:

- the starting and finishing time of each customer order on each line and sequence.
- number of storage days of each customer order.
- number of tardy days of each customer order.

Objective function aims to minimize the storage cost and warehouse cost. Several constraints are considered. Constraints are stated as follows: every customer order must be assigned to only one sequence in only one line, each lines must be occupied with at least one customer order, each customer order must be assigned to only one sequence in only one line, customer orders should be assigned in ascending sequence in the scheduling of each production line, customer orders assigned to a production line must not exceed production line capacity, a customer order can be assigned to a production line when panel of this customer order arrives, a customer order cannot be at the same time both the predecessor and the successor of another customer orders.

Conditional Value-At-Risk Model

After getting solutions, risk method is applied in order to evaluate the results under alternative scenarios. In order to conduct a risk management study on the model, the conditional value at risk method, which is a downside risk method, is used. Within the scope of this model, the mathematical model designed before has been reformulated. In this study, the scenario trees were formed by the combination of three stochastic parameters. These are efficiency of production line (e_{lt}), demand of customer order i (Q_{it}) and arrival dates of panels for customer order i (AR_{it}).

RESULTS

The model is solved with 27 scenarios. The possibilities of each scenario tree according to the determined risk factors is calculated and analyzed. The mathematical formulation is solved using IBM ILOG CPLEX Optimization Studio 12.6.1 8 GB memory under a Microsoft Windows 10 platform. The solutions of each scenario are take under one minute. The minimum value of total cost is $0. However, total cost is $6,752 in the 95% confidence interval for scenarios when there is a delay for the arrival of the panels. Probability of scenarios are given figure 1.

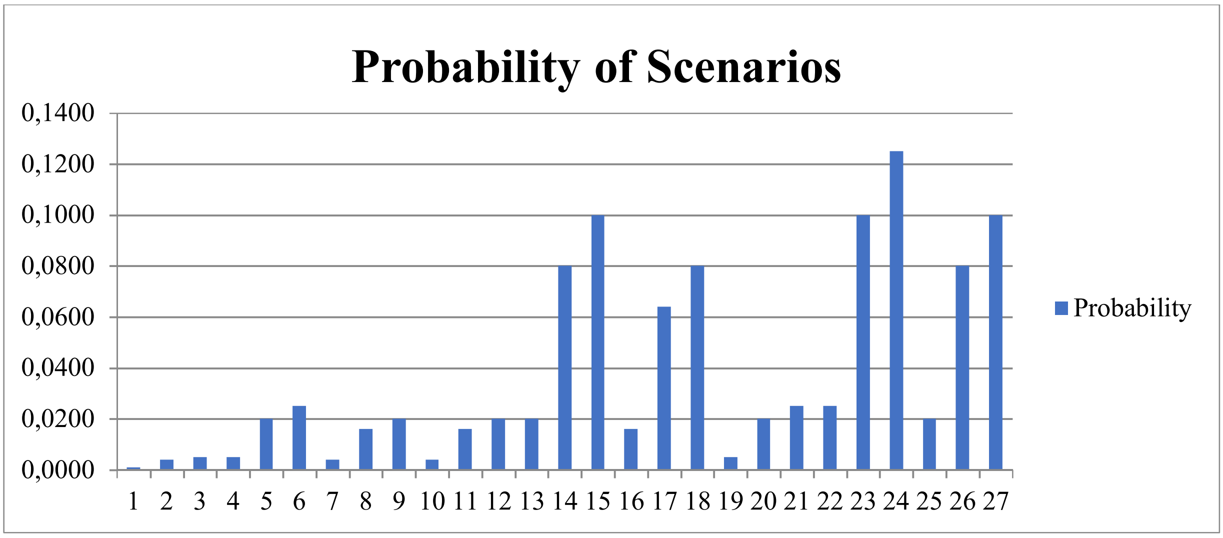


Figure 1. Probability of scenarios

CONCLUSION

In this study a MILP model is developed for the independent production scheduling. The production planning and scheduling problem with independent sequence and eligibility constraints is investigated in the electronics industry. The mathematical model is reformulated and scenario trees are created. According to these scenario trees, 27 models in total are solved. In the model, CVaR method is applied in order to analyze differences in quantity of customer orders, the dependence of panel deliveries on ship arrivals, differences in the productivity of production lines. As a result, arrival dates of panels for customer order i is more important than other parameters. The difference of customer demands and efficiency of line are tolerance. Different conditions arrival date of cells for each customer order i (AR_{it}) is not tolerated. So this condition caused loss of customers. With this study, an effective tool for the production planning and scheduling process under stochastic parameters is provided. In this problem, our goal was to know the risks and to maintain sustainability according to the risks. Also, we tried to optimize the expected value between outputs. The result showed that there were still some external factors and different aspects that could be developed of this planning problem. There was always a better solution, so we can come up with different questions for following studies. How can it be applied to the factory? How can it be used in different problems under different circumstances? Is it possible to establish a decision support system such as this method for the whole manufacturing system in the factory, and so on.

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SUPPLY CHAIN STRATEGY MANAGEMENT AND WOOD BASED PANEL INDUSTRY SECTOR CASE STUDY

Songul Aksoy[1]

Abstract *– Nowadays as known not only firms are competing but also their supply chain operations do. Supply chain strategy is connected with firm business strategy and also align with firm's rival strategy in the market. In this Study we examine the supply chain management, supply chain strategy management, wood based panel industry sector, and SWOT analysis of the sector. Finally an interview done with KEAS supply chain logistics manager about firm's targets and organizational structures and operations, to be able to define the right strategy tool in the conclusion.*

Keywords – Supply Chain, Supply Chain Strategy, Wood Based Panel Industry, KEAS

PROBLEM DEFINITION

Supply chain strategy is not being practiced by the most of the companies in Turkey. The firms ıf they want to achieve the total advantage both in service and production in the market, also to be able to provide profit both in cost and sales they have to determine own rival strategy and in accordance with supply chain strategy. This study is trying to determine a strategy in a company called KEAS in wood based panel industry sector. As known the sector is getting bigger day by day thanks to new conditions. So the firms in the sector should take their part as a role player if they want, to do this firms rival strategy must be align with all departments inside.

Every department should indicate their strategy in accordance with firm's rival strategy. With this study we search for supply chain strategy for the company KEAS, so that we did an interview with the department manager in supply chain and logistics at KEAS. We try to determine the right strategy in the end.

INTRODUCTION TO SUPPLY CHAIN MANAGEMENT

Supply chain encompass the companies and the business activities needed to design, make, deliver and use a product or service. Businesses depend on their supply chains to provide them with what they need to survive and thrive. Every business fits into one or more supply chains and has a role to play in each of them.

The pace of change and uncertainty about how markets will evolve has made it increasingly important for companies to be aware of the supply chains they participate in and to understand the roles that they play. Those companies that learn how to build and participate in strong supply chains will have substantial competitive advantage in their markets. (http://catalogimages.wiley.com/images/db/pdf/R0471235172.01.pdf 02.08.2018)

The practice of supply chain management is guided by some basic underlying concepts that have not changed much over the centuries. Several hundred years ago, Napoleon made the remark "An army marches on its stomach" Napoleon was a master strategist and a skillful general and this remark shows that he clearly understood the importance of what we would now call an efficient supply chain. Unless the soldiers are fed, the army cannot move.

Along these same lines, there is another saying that goes "Amateurs talk strategy and professionals talk logistics." People can discuss all sorts of grand strategies and dashing maneuvers but none of that will be possible without first figuring out how to meet the day to day demands of providing an army with fuel, spare parts, food, shelter, and ammunition. It is the seemingly mundane activities of the quartermaster and the supply sergeants that often determine an army's success. This has many analogies in business. The term supply chain management arose in the late 1980s and came into widespread use in the 1990s. Prior to that time, businesses used terms such as logistics and operations management instead. Some definitions of supply chain are offered below; (http://catalogimages.wiley.com/images/db/pdf/R0471235172.01.pdf 02.08.2018)

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According to Martin Christopher, A supply chain is to create and provide added value with lower cost between suppliers and customers. Lambert, Stock and Ellram has defined the supply chain as, the alignment between customers and suppliers which bring products and service to the market. (Görçün, 2016).

A supply chain is the collection of processes and resources required to make and deliver a product to the final customer. (Rajgopal, 2016)

A supply chain is an event chain which concludes a products lifecycle from the beginning till the end of consumption. (Tanyaş and Düzgün, 2017)

There is a difference between the concept of supply chain management and traditional concept of logistics. Logistics is used more broadly to refer the process of coordinating and moving resources- people, materials, inventory, and equipment – from one location to storage at the desired destination. The term of logistics originated in the military, referring to the movement of equipment and supplies to troops in the field. (Shopify, 2018)

Logistics and supply chain management are terms that are often used interchangeably, but they actually refer to two aspects of the process. Logistics refers to what happens within one company, including the purchase and delivery of raw materials, packaging, shipment, and transportation of goods to distributors, for example. While Supply chain management refers to a larger network of outside organizations that work together to deliver products to customers, including vendors, transportation providers, call centers, warehouse providers, and others. (Shopify, 2018)

The logistics components are ınbound transportation, outbound transportation, fleet management, warehousing, materials handling, order fulfillment, inventory management, demand planning. On the other hand, companies in supply chain must make decisions individually and collectively regarding their actions in five areas; production, inventory, location, transportation, information.

SUPPLY CHAIN STRATEGY MANAGEMENT

Supply chain strategies are used to show the companies competitiveness and the position in the market against their competitors. Companies that focus on a specific supply chain strategy are more likely to build shareholder value than those do not. This ideawill call for a company in a supply chain to exercise specific strategies. Not all products need the same supply chain strategy. These supply chain strategies for any product or service industries depends on supply and demand uncertainty, product life cycle and manufacturing strategies. Hence, setting the right SC strategy is compulsory for companies competing in the market. (Birhanu, Lanka and Rao, 2014)

So that set up a supply chain strategy in company is important to be able to compete in the market. There are some tools that are useful to bring the company in best among others. The strategies of supply chain management are, Efficient & Responsive, Lean & Agile, and Push & Pull.

Efficient & Responsive Supply Chains: One could argue that one sensible approach to increase responsiveness could be to raise the inventory levels of finished goods or components, which would allow more flexibility for reactions to changes in customer demand. Increased inventory levels do, however, reduce the efficiency of the SC. A responsive SC, in contrast, requires an information flow and policies from the market place to SC members in order to hedge inventory and available production capacity against uncertain demand. Improving responsiveness in a SC, however, incurs costs for two primary reasons: (1) excess buffer capacity and inventories need to be maintained, (2) investments to reduce lead times need to be made.

Providing the right degree of responsiveness and having an efficient SC at the same time is a goal that is hard to achieve and that typically involves trade-off decisions by management, since increased responsiveness can be perceived to come at the expense of reduced efficiency, and vice versa. Due to these difficulties, many authors see responsiveness and efficiency as distinct strategies that are strongly linked to different types of products.

Fisher revolutionized SCM by observing that companies were not choosing the SC that matched the nature of their products. He presented a rather stark difference between product and SC types. On one end of the spectrum are functional, commoditized products such as grocery food products. On the other end are innovative, quick lifecycle products such as computers and fashion. Functional products are ones that have long product life cycles and therefore stable demand, while innovative products are products that have short life cycles with high innovation and fashion contents-and which, as a result, have highly unpredictable demand. Therefore, the design strategy of the chain naturally varies depending on the product type, whether it is an innovative product or a functional product. As Fisher has pointed out it is important that the characteristics of demand are recognized in the design of SCs.

Fisher's model is tested by on 128 Swedish manufacturing companies whether product types and supply chain strategies match. They matched product type with supply chain strategies. They conclude that companies with functional products followed physically efficient supply chain strategy. They also found that there is a considerable match in between innovative products and market responsive supply chains. Similarly analyzed the factors influencing supply chain strategies (efficient and responsive) and the alignment of strategies to the product types and performance of manufacturers in Romania. Conducting on 418 manufacturing companies she concludes that larger companies and companies further upstream are more likely to use a responsive supply chain. (Birhanu, Lanka and Rao, 2014)

Table 1. Pysically Efficient Versus Market- Responsive Supply Chains

	Physically Efficent Process	**Market Responsive Process**
Primary Purpose	Supply predictable demand efficiently at the lowest possible cost	Respond quickly to unpredictable demand in order to minimise stock outs, forced mark downs and obsolete inventory
Manufacturing Focus	Maintain high avarage utilisation rate	Deploy excess buffer capacity
Invetory Strategy	Generate high turns and minimise inventory throughout the claim	Deploy significant buffer stocks of parts or finished goods
Lead Time Focus	Shorten lead time as long as it doesnot increase cost	Invest aggresively in ways to reduce lead time
Approach to Choosing Suppliers	Select primarily for cost and quality	Select primarily for speed, flexibility and quality
Product-design Strategy	Maximise performance and minimise cost	Use modular design in order to postpone product differentation for as long as possible

Lean & Agile Supply Chains: Lean supply chain management is about reducing costs and lowering waste as much as possible. This methodology is important for organizations with high volumes of purchase orders since waste and costs can accumulate quickly. Additionally, companies with high volumes of low variability purchase orders, such as food items, benefit their efficiency greatly by utilizing the lean supply chain methodology.

Agile Supply Chain is built to be highly flexible for the purpose of being able to quickly adapt to changing situations. This methodology is considered important for organizations that want to be able to adapt to unanticipated external economic changes, such as economic swings, changes in technology, or changes to customer demand. Implementing an agile supply chain allows organizations to quickly adjust their sourcing, logistics, and sales.(https://blog.procurify.com/2014/04/22/agile-lean-supply-chain-management/14.08.2018)

Push & Pull Supply Chains: The other classification of supply chain revealed by different authors is based on pull and push strategy. Identified push and pull supply chain strategies in fulfilling orders. In push based systems, production decisions are based on the long term forecasts, where as in pull-based systems production is driven by demand. Also strengthened the significance of the push-pull strategy depending up on the timing of their execution relative to its end-customer demand. With pull processes, execution is initiated in response to a customer order where as with push processes, execution is initiated in anticipation of customer orders. The idea behind pull and push strategies are further strengthened by stating that push-based system is driven by a forecast as production and distribution decisions are based on long-term estimates of demand, while the production and distribution processes in a pull based system are driven by actual downstream demand and not forecasted demand.

A supply chain is almost always a combination of both push and pull, where the interface between the push-based stages and the pull-based stages is sometimes known as the push–pull. In particular, this hybrid strategy is composed of a push element for the component procurement and a pull element for production as well as additional push/pull elements based on network equilibrium and other cooperative mechanisms. However, it is not using both or independent strategies that makes difference to the organizational competences; but, using the combined effect of strategies in order to fetch off the advantages of both strategies in serving customer better at relatively lower cost.

Despite its benefits and growing popularity, the push-pull strategy is not devoid of risk, particularly when it comes to order fulfilment and robustness against external variability. Inventories at different locations have differing levels of responsiveness to the customer delivery lead time requirements. If the remaining processing time and transportation time from boundary are too long, unstable order-fulfilment performance may occur and result in penalties for failing to meet the customer's negotiated delivery lead time, lost sales costs, and other immeasurable negative impacts on the credibility of the organization. (Birhanu, Lanka and Rao, 2014)

Table 2. Proposed SC Problems and Solutions for Supply Chain Types

		Demand Uncertainty	
		Certain	Uncertain
Supply Uncertainty	Certain	***Efficient SC's*** **Problem:** Bullwhip Effect **Solution:** -Alignment of incentives and information among SC partners -Collaborative planning, forecasting and replenishment -Vendor management inventories	***Responsive SC's*** **Problem:** -Long and uncertain development and leadtimes -Highly uncertain demand patterns - Short selling season **Solution:** -Mass Customization -Postponement of final customization -Early orders from csutomers
	Uncertain	***Risk-Hedging SC's*** **Problem:** -Higly uncertain Supply -Distribution risk in supply **Solution:** -Pooled inventory and resources -Extends to reach suppliers and inventory -Contracts taht manage risk by locking in factors such as price and delivery	***Agile Sc's*** **Problem:** All problems in three SC listed **Solution:** -Postponement of final customization -Pooling of Suppliers to hedge uncertainties -Platforms and modular design that allow postponement of final customization

TEN FUNDAMENTAL SUPPLY CHAIN STRATEGIES

The ten initiatives described below represents a framework of strategies and best practices that best of class supply chain organizations should strive to achieve. (Engel, 2017)

Establish A Governing Council: Who should be on this council? Certainly the supply chain organization leadership but more importantly it should consist of members of the executive group, key internal business unit leaders, and other influential company leaders.

Align the Supply Chain Organization: All departments must be align both in startegy and common rival strategy aim.

Recruit Supply Chain Professionals: To expand the capabitly, of supply chain team, many supply chain leader are recruiting, internally as well externally, for two kind of skills: Technical skills,Project management skills.

Set The Strategic Sourcing Strategy: Strategic sourcing is a cornerstone of supply chain management. A successful collaborative strategic sourcing initiative not only ensures availability of supplies, but will result in the obtainment of overall lower total cost, streamlined processes, and increased responsiveness to customers' changing needs. Strategic sourcing is not just a purchasing department initiative. It requires input from all functional areas such as finance and accounting, engineering, operations, maintenance, safety/health/ & environmental, quality assurance, and internal business unit team membersthat will contribute to the initiative's success.

Establish Key Suppliers Alliences: An effective Alliance Management program with key suppliers are:

1. Provide a mechanism to ensure that the relationship stays healthy and vibrant,
2. Create a platform for problem resolution, and
3. Develop continuous improvement goals and objectives with the objective of achieving value for both parties.

Manage Total Cost Ownership: Strategic sourcing shifts the company's and team's focus from just looking at the purchase price, to understanding the dynamics of the total cost of owning or consuming a product or service. Establishing a Total Cost of Ownership mindset is a goal that the supply chain organization needs to embrace and perpetuate throughout the entire enterprise.

Manage Compliance And Risk: A driving force of comtract management movement to the supply chain organization is the need to ensure the contracts are collected and maintained in a central repository. Furthermore, the migration of the contract management function to the supply chain organization allows the supply chain leader to more effectively leverage spend particularly in the areas of services, where there is a greater opportunity for cost reduction and risk mitigation.

Reduce Company-owned Inventory: With key suppliers in place and delivering against their contracts, supply chain organizations should strive to constantly review their inventory levels and to keep them at an optimized level. To achieve this objective, Vendor Managed Inventories (VMI) is a logical scenario and alternative. But with the current sellers market, VMI's can prove to be challenging in regards to lead times, deliverability, logistics, etc. And this puts more emphasis on demand planning and forecasting to assist in achieving the goals.

Gather Information on A Timely Basis: In all of the above initiatives, supply chain strategy is set and executed. One traditional "gap" or stumbling block has been the ability of supply chain organizations to retrieve critical and detailed data from the ERP or accounting system. The need for timely, complete and accurate information is the foundation for understanding how, when, where, and for what are we spending our money. Yet, most organizations do not have the mechanism to retrieve the necessary data and information from their various information systems. And the difficulty expands exponentially where disparate ERP or other information systems are in play and do not have the means to "speak" to each other. For organizations in this situation, the decision must be made whether to combine the systems into one, or to keep separate.

Establish Processes and Controls: In our high tech world, we see an inherent fallacy Of companies who first select technologies to make them more efficient and then structuring the processes around the chosen technology. Technology should be considered as the tool to help increase efficiency, not the focal point of what is to done.

RESEARCH METHODS

The Research methods contains a deep search of internet articles from Science Direct, academia.edu, some university published documents, books and websites. The articles are about supply chain management, supply chain strategy management, articles of wood based panel sector analysis, logistics, and finally an interview with Mr. Nail Tuzuner who is supply chain logistics manager of KEAS.

Information About Wood Based Panel Industry Sector

The greatest panel producer with 83 billion m3 volume is China in the world, Turkey has saved his importance as being the fifth panel producer all around the world. The world panel production volume is 222 billion m3 in the world. In 2017, the sector has growed 3%. (KEAS Business Service Report, 2017)

Table 3. Global Panel Production Indicators

Panel Type	2010	2011	2012	2013	2014	2015	2016
MDF							
Production(m3)	61.115.888	67.620.398	75.364.133	80.103.786	86.239.736	87.481.778	90.030.278
Consumption(m3)	60.854.980	66.326.738	73.413.282	78.915.256	84.960.164	86.947.570	89.568.449
Laminate Parquet							
Production(m3)	935.000.000	915.000.000	890.000.000	925.000.000	940.000.000	960.000.000	1.010.000.000
Consumption(m3)	5.737.559	6.143.234	5.312.688	6.227.154	6.704.253	6.838.338	7.180.255
Door Panel							
Production(m3)	767.550	740.138	718.208	745.620	760.532	760.000	730.000
Consumption(m3)	701.616	646.731	624.801	668.147	681.510	690.000	685.000
Oriented Strand Board							
Production(m3)	18.234.000	18.000.000	19.415.000	20.825.000	21.241.500	22.640.092	29.663.842
Consumption(m3)	17.985.571	17.233.856	19.426.641	21.656.549	22.089.680	26.600.092	29.231.332
Particleboard							
Production(m3)	77.536.761	80.034.856	78.059.699	85.777.978	85.828.449	86.070.134	93.203.723
Consumption(m3)	78.982.704	79.983.212	79.140.744	86.222.036	80.477.547	83.754.209	92.109.324
General Indicators of Sector							
Production (m3)	165.134.119	173.715.391	180.677.039	194.852.384	205.829.810	209.671.804	221.877.843
Import Amount(m3)	28.983.776	29.956.309	30.061.483	34.067.246	54.464.603	43.716.782	46.405.855
Import Value (thousand USD)	15.107.288	17.272.452	17.530.929	19.199.051	20.020.670	13.343.843	13.865.919
Export Amount (m3)	46.467.081	49.174.096	50.778.101	53.568.323	55.784.765	55.784.765	49.429.279
Export Value (Thousand USD)	16.328.389	17.652.668	18.235.619	19.775.425	20.739.062	13.213.739	13.811.314
Consumption (m3)	164.262.430	170.333.771	177.918.156	193.689.142	204.509.648	204.830.209	218.854.419

Wood based panel production Quantity in Turkey is 9,35 billion m3. In 2017, the sector has growed 12%. Turkey is the fifth greatest sector in wood based production in the world, and the second greatest sector in Europe after Germany. Below tables have indicated the amount and value of the sector. (KEAS Business Service Report, 2017)

Table 4. 2017 Wood Based Panel Import to Turkey

Panel Type	Amount (m3)	Value(Euro)	Avarage Price Euro/m3 Change	2017/2016 m3	2017/2016 Euro Change
Raw MDF	82.172	18.238.390	222	-44%	-41%
MDF	8.681	7.363.636	427	-57%	-44%
Raw Particle Board	45.222	5.221.190	115	-4%	-3%
Particle Board	32.013	8.668.478	271	9%	3%
Laminate Parquet	71.310	35.431.254	497	-39%	-43%
Oriented Strand Board	185.966	39.412.887	212	3%	10%
Door Panel	33.975	14.631.723	430	13%	6%
Total Import	450.339	128.967.558	281	-20%	-21%
Total Consumption	8.650.876				
Import/Consumption	5%				

Table 5. 2017 Wood Based Panel Export From Turkey

Panel Type	Amount (m3)	Value (Euro)	Avarage Price Euro/m3	2017/2016 m3 Change	2017/2016 Euro Change
Raw MDF	218.588	42.790.333	196	102%	77%
MDF	578.266	224.563.745	388	35%	26%
Raw Particle Board	222.634	30.779.675	138	54%	49%
Particle Board	512.883	91.169.859	178	21%	19%
Laminate Parquet	70.354	33.334.130	473	50%	46%
Door Panel	22.674	8.795.710	388	13%	-6%
Total	1.625.549	431.433.452	265	46%	37%
Total Consumption	8.650.876				
Export / Consumption	19%				
Export-Import	1.166.210	302.465.894			

Swot Analysis Of Wood Based Panel Industry Sector

The Sector of Turkey has been examined with SWOT analysis below. (İstek, Özlüsoylu & Kızılkaya, 2017)

1- **Strengths**

- The firms in the sector have been founded after 2000s, and follow up the technology
- Production is made in accordance with production quality standards and variety of products are increased in new founded facilities
- The export to around countries are forwarded from Turkey
- The employee cost are lower than those in European countries so that it makes a rival advantage
- The firms in panel industry are in the places which are near forest and ports
- The conflicts and problems can be easily solved through the Sectorial Institutions
- The raw materials are under guarantee to be taken by firms from General Forestry Ministry
- The qualified engineers work in the sector.

2- **Weakness**

- The wood is more expensive in Turkey, than the price in the world
- The raw materials need is belong to import about 30%-35% amount in Turkey
- The forest cut amount is decreasing in winter so that storage cost becomes higher
- Taxes are high belong to Law and Legislations
- The lack of well-educated employee
- The cooperation between university and firms are not enough
- The time when the production cost is high, and currency rate is high, the import pressure in the country
- Input cost high and the problem of product transportations

3- **Opportunity**

- The employee cost is higher than Europe and the process joining EU.
- The location of our country
- Fair organizations and Presentations are much and visitors are more.
- The furniture firms quantities which use panel products are increased.

4- **Threats**

- The production problems due to EU legislation process and so that environment problems
- Recently although economic problems around the world are arisen, the panel producers are increased
- The wood price can be increased due to new legislation
- The firms can be eliminated which cannot follow up technology

About Kastamonu Entegre Ağaç San. Tic. As.

Kastamonu Entegre, who produces the raw and melamine coated particle boards, glossy panels, MDF, laminate flooring, tops, door panels and value added products for the needs of the furniture, decoration and construction sectors, has a consolidated turnover of 1.3 billion Dolar and is a global power positioned as the 1st of its sector in Turkey, the 4th in Europe and the 7th in the World. Today, with its 6000 employees and with its production power, knowledge and experience, with its exports made to 100 countries from Middle America to India, it is the 1st in its sector and the 40th among the first 500 Industrial enterprises listed by the Istanbul Chamber of Industry.

Kastamonu Entegre has 19 factories at 7 countries and 14 different locations such as in Turkey, MDF and particle board at Gebze and Kastamonu, particle board at Balikesir, Samsun and Tarsus, MDF at Adana and overseas, door panels and particle boards in Romania, kraft paper in Bosnia Herzegovina, particle boards in Italy and Bulgaria, MDF in Russia, particle boards and wood chips in U.S.A.

Kastamonu Entegre, the target of which is to continue the two digit growth rate maintained since many years, is continuing its activities with the vision of becoming one of the biggest 5 producers in the course of the coming 10 years. (KEAS website, 2018)

Interview Notes With Supply Chain Logistics Manager At Keas

Nail Tüzüner is supply chain logistics manager who works for about 20 years for KEAS. We have made an interview regarding KEAS and his strategy.This interview aims to determine the right strategy by examining the organization, targets, logistics process and finally storage policy. The outputs of this interview is that we understand the all process of supply chain and logistics at KEAS to indicate the right strategy. Below notes have been taken during the interview.

Organization: KEAS Supply Chain and logistics has foreign logistics, foreign trade, domestic logistics, customer services, demand and supply planning, factories logistics departments in his structure. Totally about 400 employees.

Targets: The success criteria of KEAS logistics department, aims to deliver requested goods with requested time, service, quantity, true price, without damage. Service quality is very important to KEAS. The Top management gives some targets to be achieved and in 2017, 85% has been reached. The goods of KEAS is heavy but cheap so that transport cost reducing is very important and critical. Logistics department is the best in the area of project improving among other departments of KEAS. Providing lower Cost and service quality with customer satisfaction is very important. Logistics department has increased the firm's profitability.

Inbound & Outbound Logistics Process: KEAS has to do great improvement for inbound and outbound logistics. The whole process from end to end must be recorded and followed, so that a project has come into consideration, which name is KESCO (Kastamonu Entegre Supply Chain Operations). With this project the all supply chain operations will be followed, recorded and tracked. KEAS logistics department choose his suppliers which provides price and service advantage. To procure the paper is critical issue, since JIT working conditions are on. The department aims to provide cheap and quality transport modes. At outbound side, the sales are arising. Container shipment is being 60/70% used. Fast, trustworthy and cheap transport is being provided. To be able to achieve this, selected suppliers are attended the tender website. The most three supplier's prices are compared and best service provider is chosen.

Storage Policy: KEAS has 6 facilities in Turkey. The storage cycle is 1 or 1, 5 months in all facilities. It is to prevent out of stocks condition and also to provide optimum stock degree.

CONCLUSION

The Supply chain management has critical importance for the wood based panel industry sector since the commodity is heavy and cheap. So that the transport cost must be as lower as possible. To be able to provide this, the all modes must be compared with a strategy. As indicated above the sector is growing year by year and has significant contribute to economy. The Sector of Turkey is the fifth in the world and second in Europe. The sector in Turkey as shown above with SWOT analysis also has a great role in the world. New established firms and technology follow up is a strength. On the other hand the employee cost is lower than EU countries. The furniture company's quantities are increased day by day. But there is some threats, also EU membership request from Turkey puts some rules to be obeyed.

KEAS is the market leader in Turkey. It means, KEAS is one of the biggest role player in the sector. Hıs transport and storage policy has harmony with efficient and responsive supply chain Strategy. Efficient supply chain aim minimum cost both in product and transport. And also responsive because fast response to provide customer satisfaction is aimed. At the same time buffer stocks are sometimes in consideration due to prevent out of stock situation.

For further studies we will search for the other sectors in Turkey whether the companies practicing the supply chain strategy by doing a survey in top 100 biggest firms in Turkey. After that we will make interviews face to face and try to be awared of companies to practice supply chain strategy. We will write an article about this.

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A REVIEW OF MATHEMATICAL PROGRAMMING MODELS FOR SUPPLY CHAINS IN THE FOREST PRODUCTS INDUSTRY

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Abstract *– Many companies and organizations dealing with forest products have used mathematical models in the context of Operations Research to support their supply chains. In this study, an overview of these applications on the forest product supply chains is reported to present the research opportunities in the field. For this purpose, papers published in the last 30 years related to lumber & sawmill, paper & paper pulp and wood panel & furniture industries are reviewed and classified. Papers are classified based on modelling approach as well as decision level and the purpose of the work. Our classification according to the modelling approach revealed that researchers mostly used mixed integer models.*

Keywords – Forest products industry, Supply chain, Mathematical programming, Review

INTRODUCTION

The forest products industry produces semi-finished products or products by changing the shape of wood raw materials through various operations. It is an integrated industry that transforms these products to raw materials or finished goods. The overall wood-flow starts with standing trees in forests and continues with harvesting, bucking, sorting, transportation to terminals, sawmills, pulp mills, paper mills and heating plants, conversion into products such as pulp, paper, lumber, and ends at different customers (Carlsson and Rönnqvist, 2005). Coordinating this flow by considering production related and raw material related constraints (timber freshness, etc.) is an important issue for many forest industry enterprises. Thus, supply chain management and optimization are gaining increasing importance in the forest industry (Melo et al., 2009). Faced with both supply and demand uncertainty, the forest products industry needs advanced supply chain management models that can significantly increase competitive power in global markets (Shahi et al., 2018). In the forest products industry, supply chain studies have shown an upward trend in the past 15 years (Campanella et al., 2018).

This aim of this study is to present a literature review of studies that used mathematical models for supply chains in the forest products industry. For this purpose, published work in the last 30 years has been searched. Key words such as "supply chain"," wood industry"," pulp and paper", " furniture " and "forest industry" were used during the search process. After the search process, a total of 41 articles were selected. These studies were mainly obtained from journals (78%). The distribution of these studies according to publishers is presented in Table 1. Among these journals only 4 of them were specific to forest research. This shows that the topic of supply chains for forest products is a significant research area for operations research and management science researchers.

CLASSIFICATION SCHEME

The aim of this study is to review supply chain literature by focusing on forest industry. We investigated previous reviews on supply chains to determine suitable classification criteria. Haung et al. (2003) reviewed supply chain models in the literature based on four classification criteria: supply chain structure, decision level, modeling approach and shared information. Mula et al. (2010) enlarged the set of review criteria by adding the headings purposes, limitations, novelty and applications. Motivated from previous work, supply chains of forest products are reviewed according to the following set of criteria namely; observed sectors, decision/planning levels, mathematical models and purpose of the study.

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Table 1. Distribution of Studies According to Published Journals, Book Chapters and Conferences

	Publishes	References	Total %
Journals and Book Chapters	Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT)	5	14,20
	European Journal of Operational Research	4	9,76
	Canadian Journal of Forest Research	4	9,76
	International Journal of Production Economics	3	7,32
	Information Systems and Operational Research	2	4,88
	Journal of Forest Economics	2	4,88
	Annals of Operations Research	2	4,88
	Mathematical and Computer Modelling	1	2,44
	International Transactions in Operational Research	1	2,44
	International Journal of Operations &Production Management	1	2,44
	Supply Chain Management: Models, Applications, and Research Directions	1	2,44
	Department of Business and Management Science	1	2,44
	Journal of the Operational Research Society	1	2,44
	Agriculture and Agricultural Science Procedia	1	2,44
	IEEE Intelligent Systems	1	2,44
	FSCN/System Analysis and Mathematical Modeling	1	2,44
	International Journal of Forest Engineering	1	2,44
Congress Paper	IFAC Conference on Manufacturing Modelling, Management, and Control	4	9,76
	10th International Conference on Modeling, Optimization and SIMlation	1	2,44
	4th International Conference on Information Systems, Logistics and Supply Chain	1	2,44
	44rd International Symposium on Forestry Mechanization	1	2,44
	2012 IEEE International Conference	1	2,44
	Paper making research symposium 2009	1	2,44
	Total	**41**	**100**

Forest industry is basically classified according to different types of wood processes (FAO 1982). However, in the literature there are different sectoral classifications. Grönlund, (1995) classified the forest industry as sawmill, pulp &paper, wood board and furniture; whereas D'Amours et al. (2008) classified the industry as paper & paper pulp, timber, wood panel and biofuels. Lately, Shahi and Pulkki (2013) presented a different classification of the sector as; wood panel, wood fiber, paper and biofuels. Another classification for the forest industry is; (Akyüz, 2006)

- Primary Manufacturing Industry (particle board, fiber board, veneer, plywood, paper pulp industry etc.)
- Secondary Manufacturing Industry (floorboard, furniture, paper etc. that use finished or semi-finished products as raw materials)
- Other forest products (biofuel, musical instruments, wooden toys, pencil industry etc.).

In this study, we classified the supply chains observed in different industries by considering the primary and secondary manufacturing industries namely; paper & paper pulp, lumber & sawmill and wood panel & furniture (see Table 2). When the reviewed papers are classified according to the sectors, it is observed that majority of the applications (87.8%) is conducted for lumber & sawmill and paper & paper pulp industries. On the other hand, we encountered only a few applications (12.2%) in the wood panel and furniture industry.

The forest industry supply chain optimization studies have mostly been done in Northland Central America and Europe; because Europe (46%) and North and Central America (25.7%) own the highest total forest land (BAKA, 2012). Consequently, USA, Canada, France, Brazil and Germany are in the first place of the production and trade in the forest industry (FAO, 2015).

Decision/ Planning Levels

Supply chain planning in the forest products industry extends from strategic decisions to operational decisions (Carlsson et al, 2006). Thus, supply chain in the forest industry are classified depending on planning horizons; operational, tactical and strategic (Bettinger, et al., 2016). Classification in terms of planning levels of the supply chain studies in the forest industry are shown in Table 2. It is observed that most of the studies (39%) are based on more than one decision level.

Table 2. Decision Levels of the reviewed works

Sector	Author and Years	Strategical	Tactical	Operational
Pulp and Paper	Philpott and Everett (2001)	✓	✓	
	Bredström et al (2004)	✓		✓
	Hultqvist and Olsson (2004)		✓	
	Bredstrom et al (2005)		✓	✓
	Carlsson and Rönnqvist (2005)	✓		✓
	Bredstrom and Rönnqvist (2006)		✓	✓
	Lehoux et al. (2007)		✓	
	Lehoux et al. (2008)		✓	
	Weigel et al. (2009)	✓	✓	
	Lehoux et al (2011)		✓	
	Kong et al. (2012)	✓	✓	
	Dai and Dai (2015)			✓
	Alayet et al. (2016)		✓	✓
	Vafaeenezhad and Tavakkoli-Moghaddam (2016)		✓	
	Shahi et al. (2018)			✓
	Alayet et al (2018)		✓	✓
Lumber and Sawmill	Weintraub and Epstein (2002)			✓
	Karlsson et al. (2004)	✓	✓	✓
	Troncosoa and Garrido (2005)		✓	
	Beaudoin et al. (2006)		✓	
	Vila et al. (2006)		✓	
	Singer and Donoso (2007)	✓	✓	✓
	Aydinel et al. (2008)	✓		✓
	Rummukainen et al. (2009)		✓	✓
	Chauhan et al (2009)		✓	✓
	Gaudreault et al. (2010)			✓
	Chauhan et al (2011)			✓
	Gerasimov and Sokolov (2011)	✓	✓	✓
	Arabi et al. (2012)		✓	
	Jerbi et al. (2012)			✓
	Boukherroub et al. (2013)		✓	
	Kong and Rönnqvist (2014)	✓	✓	
	Marier et al (2014)		✓	
	Bajgiran et al. (2016)		✓	
	Broz et al. (2016)		✓	
	François et al. (2017)		✓	
Wood Panel and Furniture	Feng et al. (2008)			✓
	Ouhimmou et al. (2008)		✓	
	Feng et al. (2010)		✓	
	Amorim et al. (2014)			✓
	Hisjam et al. (2015)		✓	

Decisions for strategic levels: The strategic level often describes decisions that concern several years or decades. Strategical decisions include investment planning and infrastructure planning (An et al. 2011). In the forest industry, strategic decisions include forest management strategy, silviculture treatment, conservation areas, road construction, opening and closing of mills, location of new mills or to be acquired mills, process investment, products and markets development, financial and operational exposure, planning and inventory location (Carlsson, 2006).

Decisions for tactical levels: Tactical level studies deal with planning decisions that focus on a somewhat longer time period (e.g., monthly) than addressed by operational level studies (Gunnarsson, 2007). Generally, those decisions prescribe inventory policy, annual production planning, budged processing, equipment and material flow etc. (An et al 2011).

Decisions for operational levels: The third level of planning is the short-term or operative planning, which is the planning that precedes and decides real-world operative actions (D'Amours et al., 2014). Operational-level supply chain studies deal with decisions that affect the short term (e.g., hourly, daily, or weekly) like staff scheduling, truck scheduling, vehicle routing, bucking, sawing, process control (Gunnarsson, 2007).

9.8 % of these models submitted for strategic and tactical levels, 14.6% of it was submitted for tactical and operational level and 7.3% of it is submitted for strategic and operational levels. Among these studies only in three works (Karlsson et al., 2004; Singer and Donoso, 2007; Gerasimov and Sokolov, 2011) all three decision levels are considered. All of these works were in lumber and sawmill industry.

It is also observed that 41.5% of studies focused only on tactical decisions whereas 22% of studies focused only on operational level. On the other hand, we did not encounter any work that focus only on strategic level. The most preferred combination is the tactical and operational decision level.

Modelling Approaches

Mathematical programming approaches used in supply chain planning are also investigated. Figure 1 presents the frequency of the used mathematical models. We classified the studies in the literature according to following approaches;

- Linear Programming (LP),
- Mixed integer/ Integer Linear Programming (MILP),
- Multi-objective Linear Programming (MOLP),
- Quadratic Programming (QP),
- Fuzzy Programming (FP),
- Dynamic Programming (DP),
- Stochastic Programming (SP),
- Heuristics Algorithms and metaheuristics (HEU) and
- Hybrid Algorithms (HYB).

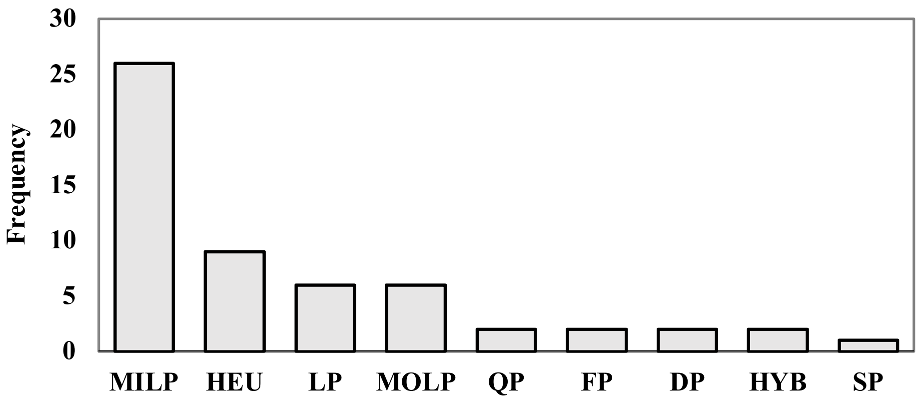

Figure 1. Frequency of the Used Mathematical Models

It is observed that most of the examined studies favor MILP models. Besides, heuristic and meta-heuristic algorithms have also been used. It is noteworthy that for all the heuristics models, an LP model is also available. To solve large scale models heuristics are used to help convergence of exact algorithms or to improve the solution quality of these approaches.

Column generation algorithm was the most preferred exact approach. Researchers selected this approach because the resultant mathematical models were having extremely large number of variables (Weitraub and Epstein, 2002; Bredström et al., 2004; Carlsson and Rönnquist, 2005; Chauhan et al., 2009, Chauhan et al., 2011). Other exact approaches were; Branch and bound (Bredstrom and Rönnqvist, 2006), and Lagrangian relaxation algorithm (Bajgiran et al., 2016).

Bredström et al., (2004) used column generation to solve their MIP model. In addition they applied a constraint branching heuristic. Bredstrom and Rönnqvist (2006) developed a MIP model for a combined supply chain and ship routing problem to distribute pulp to customers. They solved their model by using a rolling horizon based heuristic. Ouhimmou et al. (2008) presented a MIP model for a furniture company to define manufacturing and logistics policies. To solve their model they used a heuristic based on time decomposition.

Chauhan et al. (2009, 2011) offered models for a two-echelon timber supply chain. They used heuristics to improve the effectiveness of the column generation. Gaudreault et al. (2010) offered MIP models for planning the sawing, drying and finishing units of a lumber company. However, they could not solve the models for drying and finishing models and proposed problem-specific heuristics to solve these models. Kong and Rönnquist (2014) also used heuristics to solve their MIP model that involves harvesting, bucking, transportation, production, and sales decisions.

Metaheuristic algorithms such as Generic Algorithm (Bredström et al., 2005) and Tabu Search (Rummukainen et al., 2009) are also used. But their use is limited compared to exact and heuristic approaches. In addition, different approaches namely; dynamic programming (Chauhan et al., 2009; Gerasimov and Sokolov, 2011), quadratic programming (Hultqvist and Olsson, 2004; Kong et al., 2012), fuzzy programming (Dai and Dai, 2015; Vafaeenezhad and Tavakkoli-Moghaddam, 2016) and stochastic programming (Feng et al., 2010) were also utilized.

Our review indicated that multi-objective models are on the rise. Boukherroub et al. (2013) defined economic, social and environmental objectives to optimize the sustainability performance of a lumber supply chain and used weighted-sum approach to solve the offered model. Dai and Dai (2015) proposed a multi-objective model for a forestry paper supply chain to minimize risks and costs of the network under fuzzy environment. The proposed model was a quadratic mixed integer linear programming model but it is converted to a single objective linear model using the method of auxiliary variables. Hisjam et al. (2015) proposed a sustainable supply chain model between wood furniture producers, suppliers and customers. They used goal programming for 13 different goals to reach a solution by considering social, environmental and economic issues. Vafaeenezhad and Tavakkoli-Moghaddam (2016) offered a multi objective LP model for a wood and paper industry to integrate procurement, production and distribution planning. They used fuzzy-ranking method to solve this fuzzy multi objective model. Broz et al. (2016) also offered a multi objective model to manage the schedules of harvesting activities and the transportation of raw materials to the final transformation at several forestry industrial plants. Their models considers the maximization of the net present value of the production, the minimization of inter-annual variations in harvests, the maximization of carbon capture in the form of forest biomass and the minimization of variations in the mean annual distance covered in transportation to the industrial plants. They used extended goal programming to solve their model.

Purpose of the Models

We did not only review the literature by considering the type of used models but we also investigated the objectives offered for supply chains of forest products. The most frequently encountered objective was cost minimization as expected. The cost functions usually included objectives related to harvesting, production, transportation and storage costs.

Sector specific objectives and constraints are also observed. Karlsson et al., (2004) tried to minimize the harvesting cost by considering the costs related to road maintenance - mostly occurs in winter- and assign harvest teams. Hultqvist and Olsson (2004) even considered the cost of transporting harvest teams, the fixed cost of harvesting machines and the cost of transportation of harvesting equipment in their model. On the other hand, Alayet et al (2016; 2018) considered fiber freshness in the supply chain network. Their aim is to observe the effects of fiber freshness on supply chain costs. It is known that fiber freshness affects manufacturing costs.

Protecting nature is an important issue that should be considered in supply chain studies. However, only in a few studies (Boukherroub et al., 2013; Broz et al. 2016) environmental objectives were dealt. Boukherroub et al., (2013) proposed an integrated model that also considers environmental objectives such as reducing greenhouse gas (GHG) emission, reducing pollution and managing hazardous materials. Recently, Broz et al. (2016) considered the maximization of carbon capture in the form of forest biomass, as well as the minimization of variations in the mean annual distance covered in transportation to the industrial plants, the maximization of the net present value of the production, the minimization of inter-annual variations in harvests.

CONCLUSION

This work presents a review of mathematical programming models of supply chains for forest industry. To analyze the reviewed work, a classification based on four aspects has been proposed: forest industry sectors, decision/planning levels, mathematical models and purpose of the reviewed studies.

It is observed that most studies focus on tactical and operational levels in each sub-sector namely paper & paper pulp, lumber & sawmill and wood panel & furniture. Independent from the decision/planning level, MILP based models (63.4%) are mostly preferred. On the other hand, Heuristic algorithms and Linear Programming based approaches are also used. However, when the size of these models is considered, it is obvious that new algorithms (either exact or heuristic) that can handle these complex models are needed. We believe that the use of metaheuristics for these extremely large models could be an issue for further research.

The most popular objectives among the reviewed work were cost minimization and profit maximization, as expected. Only in a few studies environmental objectives are taken into account. The absence of environmental objectives in most of the studies (95.1%) is a remarkable issue for supply chains in the forest industry. Thus, there is a need for more realistic models that take into account economic, social and environment objectives that will both ensure the conservation of natural resources while reducing the operating costs. More, considering these objectives would lead to multi-objective models and solution approaches which is another fruitful research direction.

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IMPLEMENTATION OF PERFORMANCE BASED LOGISTICS AT THE DEFENCE SECTOR AND PERFORMANCE INDICATORS

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Abstract *– Performance Based Logistics was chosen by the US Department of Defense as a new logistics support approach and procurement strategy, and over time it has begun to be used in countries which have a strong defense industry. Its motto is to purchase the performance, not the spare parts. In this context, it has given the logistical support of systems to the contractor's responsibility, enabling state/user to concentrate on the operation of the system. For making it successful, 12 application steps must be implemented. The most important one of these steps is to determine the performance requirements that user expects from the system, i.e., which performance indicators/metrics will be requested at what level, and to transfer them to the Performance Based Agreement in coordination with the contractor. In this paper, awareness is raised by comparing performance indicators of Performance Based Agreement with indicators of the classical system and by giving the names and definitions of the mostly accepted performance indicators. At the end of this paper, I conclude that if the performance parameters are determined correctly and the optimum values have been assigned to these parameters, there will be a win-win solution for contractor and user.*

Keywords – Classical logistics system, performance based logistics, performance based agreement, performance indicators.

PERFORMANCE BASED LOGISTICS

The Performance Based Logistics (PBL) approach is improved by the United States, and it is started to be used by the United Kingdom, Canada, Israel, and some other developed countries in the defense industry. In the private sector, it is a business-management strategy that finds application in particular by commercial airline companies and motor manufacturers. The "Power by the Hour" approach is used by US airline companies for a long time and is also defined as the private sector counterpart of the PBL. (Ozdemir and Ozkan, 2016) In this approach, long-term contracts are signed with aircraft/engine manufacturer firms and the manufacturer is paid per hour that each system/engine is operative. This approach focuses on the work done by the aircraft, not on the aircraft. (Vitasek and Geary, 2008)

The most accepted definition of PBL is that purchasing logistics support as an integrated, acceptable cost-effective performance package designed to meet the desired performance goals of a system through long-term logistics support contracts, where the authority and responsibilities between user and contractor are precisely defined, and to ensure that the system is ready to operate at the optimum level. (Cicioglu, 2007)

According to the US Department of Defense, the PBL is designed as a package of integrated and affordable performance capabilities in which logistics support, long-term logistics arrangements, authority and responsibilities are clearly defined to meet system readiness and performance objectives. PBL according to another definition; is met with package project logic on a contractual basis that meets performance metrics such as sub-logistic support of a system, predetermined system activity rate and system availability. This contract establishes who will fulfill all responsibilities explicitly in providing logistical support. (Ucan, 2015)

The PBL aims primarily to provide logistic support of a weapon system as a package that covers long-term support contracts in which the limits of authority and responsibilities are clearly defined, aiming at optimizing the war-ready situation and achieving performance targets. In addition, the PBL is an approach that brings along

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difficult changes but when applied, provides a very significant benefit to complex structure of logistical support plans and solutions offered by all logistics activities and to reduce the system's operating cost. (Yildiz, 2016)

With the PBL, the obligation of ensuring the performance of the systems throughout the lifecycle has been transferred from user/state to the contractor/manufacturer in order to reduce project costs. In this context, the user will determine the performance metrics in coordination with the contractor and will track the contractor's performance, while the contractor will have the authority to manage the program with the responsibility of providing the logistical performance that will meet the metrics set in the Performance Based Agreement (PBA). (Dirican, 2016)

The PBL is a collaboration between user and contractor of a system, especially with regard to the flow of materials and services, by defining the business rules/procedures and selecting the desired level of logistical support. With the PBL the material flow will be provided by the contractor to a point where it will be determined. Payments at the end of the period (monthly) will not be made like in the classical system (purchasing of goods and services) they will be made through the use of the system (operating hours). Now in order to make these definitions of PBL more understandable, I will compare PBL with classical logistics system.

COMPARISON OF CLASSICAL LOGISTICS SYSTEM AND PBL SYSTEM

In classical logistics system, when there is a need for service with the aim of eliminating major malfunctions of the systems and maintenance, spare parts are purchased from the contractor and payments are made according to the spare parts requirement. In the PBL system, payments are made by the usage or activity basis of the weapon system (by multiplying the number of operating hours of the system for one month with an hourly operating expense of the system).

In the classical approach, logistical support providers for the maintenance of the system and the responsible authority is more than one. In the PBL system, one team/organization is held accountable at the government level and on the contractor side for the entire lifecycle of the program.

The nature of the classical approach is motivated by the variety and frequency of failures. In this context, the maintenance and operation costs of the supplied system and the cycle reserve, storage and personnel costs are very high. The contractor sees every failure of the system as opportunity/profit for him and he will not search the reasons leading to the failure. Since the profit margin of aging systems is lower than that of the old systems, the costs increase and the system reliability decreases day by day in the classical approach. Modernization needs arise due to outdated materials and reduced system reliability, which requires additional labor/cost for modernization activities. (Timur, 2013)

In the PBL approach, performance is purchased and the user is focused on the operating the system, and costs are minimized by the contractor. Minimum breakdown and maximum readiness are motivated by incentives. However, the increase in the operating costs of the systems coming to the end of the life cycle is not reflected to the user. This keeps the costs constant and prevents the user to face an unexpected situation and system reliability is increasing day by day. The user tends to modernize and upgrade in order to get rid of the additional costs that the contractor will charge for aging systems. (Yildiz, 2016)

In the light of basic differences between classical logistics system and PBL are explained in detail above, the differences of them are summarized in Table 1.

Table 1. Comparison of Classical Logistics System and PBL System (Onel & Kambur, 2013)

S/N	Classical Logistics System	Performance Based Logistics System
1	User purchases spare parts and services in varying levels from contractor.	User purchases performance in accordance with the performance metrics to be determined in advance.
2	Spare parts are bought by user, user has ownership and control.	Spare parts can be the property of contractor and contractor manages the distribution.
3	For warehouse level maintenance and repair, the contractor is paid per spare parts or service requirement.	Contractor is paid according to the performance of the system.
4	User is responsible for improving material management and reliability.	Contractor is responsible for material management and reliability improvement.
5	Different authorities are responsible for different levels of logistics management.	Contractor is the sole authority responsible for the development, production and maintenance of the program throughout the life cycle.

IMPLEMENTION OF THE PERFORMANCE BASED LOGISTICS

The PBL will be put into practice by establishing a business partnership by signing a PBA which will define authority and responsibilities clearly between contractors and users/governments. How PBL will be implemented is decided after the situation and the product support analyze for the system.

The 12-step methodology proposed by the US Defense Acquisition University for the implementation of PBL is shown in Figure 1. The following stages are the stages to follow in a general PBL product support strategy and may vary in stages depending on the nature of each project. The stages can be consecutive or parallel processes.

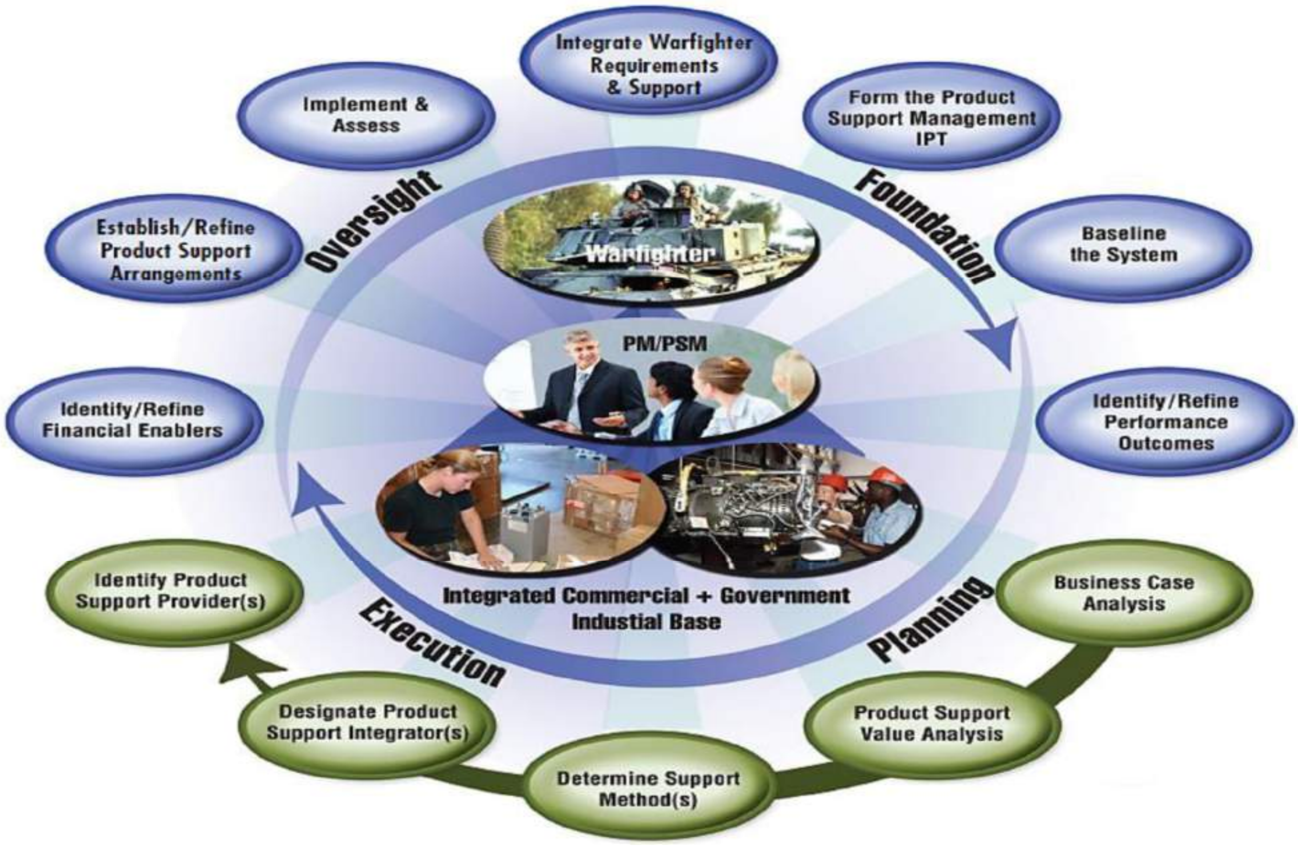

Figure 1. The US DoD Product Support Strategy Process Model (US Department of Defense, 2016)

PERFORMANCE BASED AGREEMENT

The PBL is implemented with an agreement (PBA) that meets predetermined metrics between user and project managers (the authority responsible for sustainment of the system). PBA is an agreement which is signed between user and contractor and foresees the purchase of performance to ensure efficient use of the system and payment in the event that the contractor meets the specified performance of the system. (Vitasek and Geary, 2008)

In the private sector, PBA is used in the form of "Power per Hour", which includes services specifically provided to aircraft engines. In this approach, price per hour of operating the system is agreed upon and the price is paid in advance on the basis of prescribed system usage time. Actual values are added to or subtracted from the amount of the following period by checking at the end of the period. (Vitasek and Geary, 2008)

The PBA sets the range of performance outputs at the targeted and minimum level and sets the target price for each level. It describes who will assume the roles and responsibilities in the logistics activities and also explains the performance determined after the negotiations between user and contractor and the appropriate logistical support needed to achieve this performance. (Ucan, 2015)

The PBA includes information on roles and responsibilities, benchmarks, incentives and performance measures for both parties. It also includes supply backups and a specific period support and includes delivery of the final product to the user. Once the performance indicators for the PBA have been identified, the financial dimension of the project is determined and budgeted. (Defense Acquisition University, 2005)

The PBL is expressed as the PBA-based cooperation between user and contractor in the management of weapons systems. There is no single solution to how the right mix of cooperation will be. The level of co-operation is shaped by legal arrangements, policy alignment and cost effectiveness. According to legal regulations and policies, firstly the boundary conditions of performance based logistics are established and then cost-effectiveness analyzes are carried out for each logistic activity. According to results of these boundary conditions and analyzes, the best cooperation between user and contractor is revealed. (Defense Acquisition University, 2005)

The PBL requires that this cooperation is formalized by a contract that is based on a win-win principle, in which user and contractor profit, and performance parameters are defined in an accessible and optimum manner. As a result of PBA, saving of infrastructure, investment, workforce and training costs made by the user for operating the system is reduced. Contractors receive incentives/premiums as they increase the availability level of the system. Incentives motivate the contractor in the form of prize premiums, incentive premiums, award periods, and reliability-based profits. If the performance cannot be achieved, the contractor can face free service of another service, reduction of the price, reduction or cancellation of the profit, not extending the contract and termination of the contract. (Cicioglu, 2007)

In the PBA, the roles and responsibilities of logistics activities between user and contractor are envisaged to be divided into four categories, as shown in Figure 2. (US Department of Defense, 2015) When Figure 2 is examined, the competence and responsibilities of the both sides are clearly seen as to how cooperation between the state / user and the contractor / product support provider in each category will be carried out in terms of the delivery performance, logistics performance and weapon system readiness.

In this context, in order for the PBL to be carried out successfully, it is crucial that the level of cooperation be determined at an appropriate category level between Category 1 (all liability user/state) and Category 4 (all liabilities belonging to the contractor), which will ensure that the system will be supported effectively by the contractor in close coordination with user.

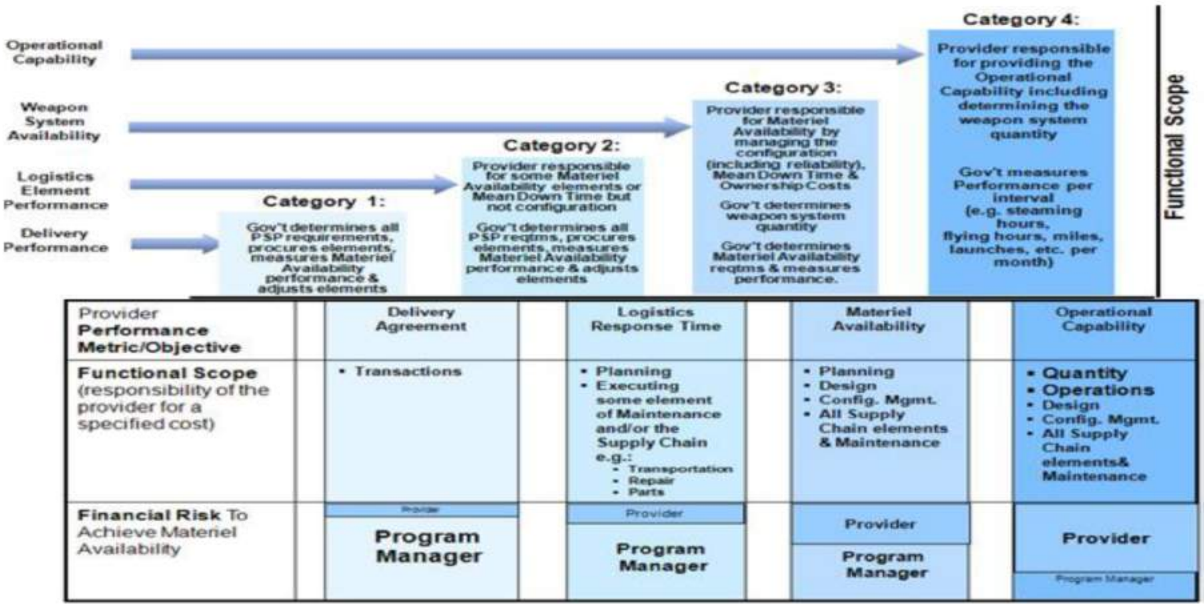

Figure 2. Performance-Based Life-Cycle Product Support Implementation Framework

PBA also vary in terms of payment conditions, duration of contract and level of support given. Depending on the nature of the service, public private partnership can be formed by sharing responsibilities at various levels between user and contractor. The aim here is to share investment, responsibilities, risk and profit. As a result of this cooperation, cost savings can be achieved through the combined use of user/state and private sector facilities. User-contractor partnerships are implemented in the form of the private finance initiative especially when the initial investment cost is high. (Cicioglu, 2009) Now I will elaborate on the performance indicators which is at the core of the implementation of PBL (especially PBA).

PERFORMANCE INDICATORS (METRICS)

In essence PBL aims to purchase the performance of system so metrics to determine performance level are required to be able to be monitored, measured and evaluated. In this context, determining top-level performance indicators (metrics) is the most important part of the PBA and these metrics are used to evaluate the performance of the contractor's logistics support. (Cicioglu, 2007)

The PBL metrics and its limit values are different for each system. For the better understanding of PBL metrics; firstly, the information about the most used metrics in classical logistics system will be given. As a logistic performance indicator/metric, the following metrics are generally used in the classical logistics system.

- Quantity of Spare Parts Supplied
- Man/hour Provided for The Technical Support by The Contractor
- Average Supply Time of Spare Parts
- Average Duration of Making System Available

Classical system metrics, as seen above in the form of purchasing of spare parts and services from the contractor, aim to make the system available as soon as possible. In the PBL, since the liability to sustain is given to the contractor, user checks whether performance metrics are realized or not and pays the amount of money invoiced.

Before counting performance indicators of PBL I will explain the process of setting PBL performance indicators. The first thing to do in this process is that the project managers (the contractor/engine manufacturers responsible for the system maintenance and operation) work with the users to determine the performance/operation requirements of the system. Then they will in coordination determine the performance indicators according to these requirements and transfer them to the PBA. However, what is important here is to determine the metrics that the contractor has ability to do and to evaluate these metrics through an information system. For each of the performance indicators, a threshold value that represents the minimum value that will meet the requirement and a target value that the user intends to achieve are determined. The sum of the performance levels to be determined for each metric constitutes the payment made by the user for the hourly system use. The change in the performance ratios will also change the amount of payments to be made to the contractor for the maintenance and operation of the system. (Cicioglu, 2007)

Since it is not possible for the PBL contractor to control all logistics activities, subclass logistics metrics can be set in the PBA to support these high-level performance indicators. The metrics to be used in the newly procured systems should be matured and finalized during the sustainment phase.

Now I will explain the mostly accepted high-level performance indicators and their definitions below which are stated in the sustainment contract of a combat aircraft in the US (Defense Acquisition University, 2005);

- Operational Availability (Ao)
  The percent of time that a system is available for a mission or the ability to sustain operations tempo. Aircraft Availability, Mission Capable and Full Mission Capable are sub-metrics.
- Operational Reliability
  The measure of a system in meeting mission success objectives (percent of objectives met, by system). A mission objective could be a sortie, tour, launch or other system specific metric.
- Cost Per Unit Usage
  The total operating costs divided by the appropriate unit of measurement for a given system. Depending on the system, the measurement unit could be flight hour, steaming hour, launch, mile driven, or other service and system specific metric. Logistics Footprint Delta is the sub-metric.
- Logistics Footprint
  Presence of deployed logistics support required to deploy, sustain, and move a system. Measurable elements include inventory/equipment, personnel, facilities, transportation assets, and real estate.
- Logistics Response Time
  The period of time from logistics demand signal sent to satisfaction of that logistics demand (systems, components, or resources, including labor, required for system logistics support).

CONCLUSION

PBL is widely used in developed countries which have strong defense industries such as USA while sustaining their complex and technology intensive defense systems and it will probably be used more widely in the defense projects in the forthcoming period.

It has been seen that from the PBL examples applied so far, cost savings are achieved in defense systems that cannot be managed cost effectively and efficiently with the classical logistics system, and the system activity rates are improved.

In conclusion the PBL provides win-win solution for both user and contractor through effective cooperation during the life cycle if the performance parameters are determined correctly and the optimum values have been assigned to these parameters. In this context, it is important to have a good understanding of the PBL approach from both perspectives of user and contractor and to implement 12 steps in coordination to make the best use of PBL for both sides.

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ENGAGEMENT OF LOGISTICS SERVICE PROVIDERS IN HUMANITARIAN RELIEF OPERATIONS

Berk Kucukaltan [1, a, b], *Zahir Irani* [b]

Abstract *– Over the past years, humankind has been facing many disasters where humanitarian relief operations, particularly logistics activities, are of great importance in alleviating sufferings of vulnerable people who are in need of basic supplies. Logistical operations play a vital role and, thereby, logistics service providers (LSPs) have become prominent. However, in spite of this vital position given to LSPs within the humanitarian context, existence of limited numbers of normative text causes a barrier to understand what LSPs can bring into the humanitarian field. Moreover, only a few LSPs possess capabilities and tools to provide strategic solutions for humanitarian relief operations. Accordingly, in this study, the authors aim to investigate the operations of LSPs in the humanitarian context through a strategic evaluation tool. In line with this aim, the Business Model Canvas is employed as a strategic multidimensional lens to scrutinise the recent activities of case LSPs located in Turkey. Thus, this study holds a novelty both in advancing the insights on strategic missions of LSPs in humanitarian relief operations and in proposing future opportunities for further studies in the humanitarian logistics field.*

Keywords – Humanitarian Logistics, Logistics Service Providers, Strategic Operational Mission

INTRODUCTION

In recent years, rise in natural disasters around the world have become more prominent (Swanson and Smith, 2013) and humankind has been usually considered as the main disadvantaged group in different types of disasters. The impacts of these disasters have not only been negative for humans, but also for the economies of affected regions (Bölsche et al., 2013). In this regard, there is a need of an effective solution by considering the entire system, the humanitarian supply chain, where problem appears. In dealing with this problem, various parameters, such as difficulty of estimating exact timing and location (Swanson and Smith, 2013), add more complexity to the solution. Under these compelling circumstances, the requirement of prompt responses on reaching to the success in humanitarian aid activities reveals the crucial role of logistics and transportation (Hirschinger et al., 2016), which organised by the companies providing logistics services, called logistics service providers (LSPs).

In contrast to the usual commercial operations of LSPs, their role in humanitarian relief operations is to undertake a non-profit strategic mission for providing high quality services (Dufour et al., 2018) and to contribute to each stage of a relief operation with their core capabilities (Cozzolino et al., 2017). The academic side of humanitarian logistics is the area to present the actual practices and information as well as offering substantial knowledge about operations performed by LSPs. Yet, despite their vital roles, existence of a small number of research regarding humanitarian operations of LSPs cause a barrier on elucidation of what LSPs can bring into the humanitarian context. Additionally, as Vega and Roussat's (2015) analysis on the articles related to LSPs indicated, there is a research gap in the humanitarian field about positioning of LSPs on the focal point. A fundamental reason behind this gap is that the unclear, risky, and acute nature of logistics services makes the humanitarian field a different area of application, compared to the commercial area (Gatignon et al., 2010). Therefore, although there appears a growing trend in the number of logistics companies that engage with humanitarian operations, only a limited number of LSPs possess capabilities and tools to provide strategic solutions in the humanitarian domain (Cozzolino et al., 2017) since there is an uncertainty concerning the use of performance systems and indicators in humanitarian logistics (Beamon and Balcik, 2008; Bealt et al., 2016).

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In this respect, specialised logistics knowledge considering the complexity of humanitarian operations is needed for practical initiatives (Abidi et al., 2015). Thus, we set out to seek answers for the following questions in this research: "what is the key role of LSPs in the humanitarian supply chain for providing practical and strategic solutions?" and "how do LSPs manage their activities and resources in humanitarian relief operations?".

In order to answer the revealed research questions under the denoted gaps and motivations, in this study, we aim to explore humanitarian operations of LSPs from the strategic management point of view. In line with this aim, we first investigated the importance and roles of LSPs in the humanitarian area. Afterwards, the Business Model Canvas (BMC) approach was selected as a comprehensive lens to be implemented in the case study strategy, which is based on LSPs operating in Turkey.

The rest of this paper is organized as follows. In section 2, related literature on LSPs performing in the humanitarian supply chain is discussed while, in section 3, the research method and the approach employed to meet the aim of this study as well as the rationales for deciding on the research context of this research are introduced. Section 4 presents the case study processes of this study applied in the Turkish logistics context. Finally, the conclusions and implications are explained in section 5.

LITERATURE REVIEW

LSPs are crucial players for delivering services at the right time and right place with the right quality and quantity and, this duty is even much harder due to the complexity in the humanitarian context. In this compelling environment, it is worthwhile to highlight the roles and activities of LSPs in humanitarian relief operations. From this point forth, we examined previous studies focusing on LSPs in the humanitarian context and our review analysis showed that only a handful papers incorporated activities that somehow related to LSPs in the humanitarian supply chain domain. What is more, studies taking roles and activities of LSPs on a focal point are remained even more limited among these studies.

With regard to the papers investigating LSPs with a slightly different point of view, diverse topics can be observed in the extant literature. For instance, Dufour et al. (2018) investigated the potential cost benefits of adding a distribution centre in Kampala to the network of the United Nations Humanitarian Response Depot, as a humanitarian LSPs, while Green et al. (2013) sought for dealing with how performed desludging can be made profitable for private service providers and become affordable for communities. Jahre and Jensen (2010) studied on the cluster system for coordination in humanitarian logistics. In another study, Bealt et al. (2016) focused on the challenges and barriers in disaster relief operations.

On the other hand, Heaslip (2013) highlighted four areas, namely, servitisation, service developments, service standardisation, and the role of humanitarian aid organisations as LSPs, and these four areas are tackled by some researchers in the literature either with a slightly different outlook (e.g. educational development role) or with a similar perspective (e.g. roles of humanitarian organisations as LSPs). For instance, regarding the role of education as a service development, Kumar et al. (2009) studied on an NGO as an example case study in order to explore the topic of education within the humanitarian supply chain whereas Bölsche et al. (2013) set sight on filling the gap in professionalisation of the logistics function in humanitarian supply chain in terms of education and training, skills, and competences.

With respect to the research focusing on the roles of humanitarian organisations (HOs) as LSPs, Schulz and Blecken (2010) explored benefits and impediments of horizontal logistics cooperation between HOs. Similarly, Baharmand et al. (2017) studied transportation risks for HOs and, their findings emphasised the importance of using LSPs both for improving the performance of HOs and for reducing in-country transportation risks. Thus, these studies demonstrated that the solution of using HOs as LSPs in relief operations does not present and effective solution and, therefore, LSPs needs to be taken on a focal point for an investigation within the context of humanitarian supply chain.

In addition to these studies, only a small number of papers remained relevant in accordance with the scope of this research. Among these, Abidi et al. (2015) examined the role of 4PL services in the humanitarian supply chain and their findings showed that managing 3PL service providers along the supply chain is a need and essential task in 4PL services. Regarding the roles of LSPs, Vega and Roussat's (2015) two-stage research brought out three main roles (member, operator, actor) and several sub-roles that may be undertaken by LSPs in relief operations. In another study, Cozzolino et al. (2017) focused on the way of engaging in humanitarian supply chain by LSPs and they highlighted the potentiality of LSPs in making contributions in disaster relief operations.

As a result of these, the LSPs-related studies reviewed in this section unveil that more basic LSP concepts (e.g. 3PL services) need to be initially examined in the humanitarian domain by following stepwise strategy, prior to the more complex LSP structures (e.g. 4PL services). In addition, as it was highlighted in previous studies, LSPs hold a substantial potential for contributing to the humanitarian relief operations and, therefore, it becomes a major motivation for this study to investigate the roles and activities of LSPs in these operations in order to increase the efficiency of entire humanitarian supply chain operations.

METHODOLOGY

Selecting an Interview Type

In the humanitarian context, acquiring reliable information generally includes some difficulties (Dufour et al., 2018) and, in such a case, an explorative outlook brings along a case study strategy when there is incomplete information (Jahre and Jensen, 2010). In case studies, although there are various techniques to be chosen for researchers, interview techniques are usually preferred to obtain potential data (Saunders et al., 2009). Among the broadly known three types of interview (structured, semi-structured, and unstructured), dominating advantages of applying semi-structured interviews (e.g. allowing to ask a list of questions prior to an interview, enabling probing questions) became the main motives to select the semi-structured interview type for this research. In this respect, by considering the importance of asking manageable number of questions and the nine dimensions of the BMC approach, we selected the semi-structured interview technique in this study.

Choosing the BMC as a Suitable Approach

Organisations and professionals use various frameworks and approaches for analysing their businesses and, among those, the BMC, developed by Osterwalder and Pigneur, holds a promising and powerful structure. The BMC is a modern management tool showing organisations how to outline their strategies (Frick and Ali, 2013). Furthermore, the BMC is a theoretical and practical concept that merges key components in a balanced way (Dudin et al., 2015).

In terms of its practicality, not only global companies use the BMC, but also start-ups (Osterwalder, 2013) and non-profit organisations (Osterwalder and Pigneur, 2010) implement it as a useful approach. During application of the BMC, researchers carry out their analyses based on its nine generic dimensions (value propositions, customer segments, customer relationships, channels, key resources, key activities, key partners, cost structure, and revenue streams) (Osterwalder, 2013). Accordingly, we used the original framework of the BMC approach, consisting of nine dimensions, in order to guide the semi-structured interviews with LSPs in a structured manner.

Deciding on an Applicable Research Context

As a research context, we chose Turkey based on several rationales. Firstly, Turkey is a vulnerable country to different natural disasters (Kılcı et al., 2015; Ozkapici et al., 2016) and makes significant provisions against negative scenarios while performing relief activities at different humanitarian operation stages. Secondly, concerning the responsiveness in humanitarian aid operations, as a potential indicator of preparedness, Turkey holds an important position since it has a role on managing refugee crisis in the Middle East and Mediterranean regions (European Economic and Social Committee, 2018). Lastly, Turkey is shown among the 20 countries, out of 139, that currently has active humanitarian operations (in Syria) (Logistics Cluster, 2018). As a result of these, we believe that focusing on humanitarian logistics in a country where humanitarian operations are actively and significantly carried out becomes a good starting point for investigating humanitarian operations of LSPs. Therefore, in order to provide actual information on the mentioned matters, we decided to investigate the LSPs operating in Turkey.

THE CASE STUDY STRATEGY IN TURKEY FOR HUMANITARIAN LOGISTICS

Although there are numerous players taking parts in different operational areas in the logistics service industry, in this research, we focused on LSPs providing humanitarian logistics activities. In the Turkish logistics context, although it is relatively difficult to obtain information from publicly available resources about humanitarian operations, compared to commercial business activities, we nevertheless first started searching on public reports and newspapers to learn which LSPs operating in Turkey provide humanitarian activities. Then, we further add the names of LSPs contained in the Logistics Emergency Teams (LET) into our list. Besides, we also approached to some humanitarian agencies and organisations in Turkey to obtain information about recently active LSPs in the humanitarian domain. Subsequently, we applied several elimination criteria to the listed LSPs, such as:

- Holding their headquarters in Istanbul or managing their operations majorly from Istanbul,
- For a multinational company, having a branch or an office in Istanbul,
- Providing transportation services with a high operational weight rather than focusing on other particular services (e.g. warehousing, customs).

After these elimination processes, we tried to contact with the remaining LSPs; however, we either could not reach to an authorised staff in some companies or, even if reached, could not get a response to our follow-up requests. Finally, among these listed LSPs, only three responded positively for participating in this research. Thus, as a preliminary outcome of this study, these three LSPs became our sample to investigate their humanitarian operations through the BMC approach.

CONCLUSIONS AND IMPLICATIONS

In recent years, there has been an increase in natural disasters and the negative impacts of different disasters affect both humans and the economies of the affected regions. In this respect, an effective solution based on the requirement of prompt responses is needed in the humanitarian supply chain. This being the case, the crucial role of LSPs in the humanitarian relief operations comes in sight more since they have a duty of delivering their services at the right time and place with the right quality and quantity. Despite this important role, the existence of a small number of research focusing on LSPs in the humanitarian area cause a notable limitation about what LSPs can offer in the humanitarian domain. In line with this, our literature review demonstrated that, notwithstanding the relevance of several articles, there is a shortage of particularly targeted research on humanitarian operations of LSPs and the main contribution of this paper lies on this gap. Besides, it is worth noting that every humanitarian operation is different and faces with its own challenge of culture, geography, response, resources, and local capability. Yet, when geographical location, possessing capability and resources, and the responsiveness to relief operations are considered, the Turkish logistics context holds a remarkable potential to provide practical and realistic information about humanitarian operations of LSPs. Thus, based on both the conducted literature review and the potential knowledge regarding the three LSPs operating in Turkey, this paper makes a significant contribution on what LSPs can bring into the humanitarian context and sheds light on future research as a potential reference study.

On the other hand, several limitations are confronted by the researchers in this study. First, finding a case company that has recent operations in the humanitarian domain is usually quite difficult. Second, both designing the BMC approach in accordance with the humanitarian context and obtaining information from LSPs based on the adapted BMC template require an intensive effort for the researchers. Although the presence of these difficulties, this research overcome these barriers, to a significant extent, and provides a reference list of perspectives to be followed by other researchers as well as showing a direction for future studies focusing on operations of LSPs in the humanitarian supply chain. Moreover, a comparison between the existing and emerging potential strategies can be further discussed in future studies.

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SUSTAINABLE BIOMASS SUPPLY CHAIN OPTIMIZATION: A REVIEW

Yeşim Gital[1], Bilge Bilgen[2]

Abstract *– The general biomass supply chain (BSC) consists of biomass harvesting and collection, biomass pre-treatment, storage, transport, and energy conversion. BSC focused on the uncertainty in biomass resources and availability, whereas the traditional supply chain manages market uncertainty to make availability of economic feasibility of the industry. SCM has a significant role in the management of bioenergy production processes, since the bioenergy production process necessitates the flow of the biomass feedstock from the supply sites to the demand centers. Improvements of economic, environmental and social performance should be considered for optimal design of BSC. The BSC management is an integrated management of bioenergy production from harvesting biomaterials to energy conversion facilities. The aim of the study is to present a literature review on sustainable BSC. Sustainability concept and its importance for BSC are presented. Previous literature review articles are investigated, and then a classification scheme is proposed to analyze the papers on sustainable BSC.*

Keywords – biomass supply chain, sustainability, survey

INTRODUCTION

Recent researches have showed that the energy consumption have been increased due to increasing of population in all over the world and the growth of the dependence of people on energy use. Today, the main part of energy demand is met from fossil fuels. But, the use of fossil fuels is no longer sustainable due to its negative effects in the atmosphere. The researches emphasize the negative environmental impacts of fossil fuels such as urban smoke, global warming and acid rain and shift their works towards sustainable and alternative energy source. Besides that, there is a concern that limited fossil resources will soon be consumed. In order to overcome this increasing energy demand and to reduce some negative environmental effects of energy use over the world, biomass is addressed as the one of the main resources of next century (Meyer et al. 2014; Sharma et al. 2013). Bioenergy is one of the renewable, environmental friendly energy and is potential substitute of fossil fuels with its sustainable supply chain. The term of sustainability in energy production can be defined as meeting energy needs by preserving environmental responsibility, economic aspect, and quality of life considering security of future generations' ability to meet their needs of energy (Awudu and Zhang 2012).

The general biomass supply chain (BSC) consists of biomass harvesting and collection, biomass pre-treatment, storage, transport, and energy conversion. Supply Chain Management (SCM) has a significant role in the management of bioenergy production processes, since the bioenergy production process necessitates the flow of the biomass feedstock from the supply sites to the demand centers. Improvements of economic, environmental and social performance should be considered for optimal design of BSC. The BSC management is an integrated management of bioenergy production from harvesting biomaterials to energy conversion facilities (Ghaderi et al. 2016; Gold and Seuring 2011).

The study aims to show an exhaustive literature analysis about sustainable BSC. For this purpose, some previous literature reviews on BSC are presented to better comprehending of this field, thereafter, papers, studying sustainable BSC, are analyzed by using a classification scheme to easier distinguish their key features. The major contribution of this study is to investigate the reasons of biomass use in energy supply as sustainability drivers of biomass.

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RESEARCH METHODOLOGY

The articles on sustainable BSC, written in English language and published peer reviewed journals, were collected for the period 2010 to November 2018 in online databases. The specific keywords were used for this research; "sustainable BSC", "sustainability", "bioenergy supply chain", "biomass" etc. The keywords of biomass, supply chain, bioenergy and types of biofuels were searched in keyword and title. Especially, the words of sustainable BSC and sustainability were searched both keyword/title and abstract.

Literature research provides more detailed information about the scope, scheme, and gaps on the field. Six previous literature reviews are analyzed to help better comprehending the general structures and related issues on BSC. Some characteristics of these reviews are presented regarding the scope, characteristics, such as time horizon, number of reviewed papers and conclusions. By using inferences of analyzing these previous reviews, a classification shame is purposed to analyzed quantitative papers.

Previous Literature Reviews

The investigation of previous works, the reviews, especially covering on the sustainable BSC, is considered. After a detailed analysis of these previous literature reviews, some inferences are obtained. These reviews generally point out that the sustainable BSC should be assessed in economic, environmental and social aspects. Moreover, these reviews add that the numbers of research on development of BSC models will gradually increase because of the benefits of using biomass in the bioenergy production. Only one review (Awudu and Zhang 2012) evaluates bioenergy generations in terms of sustainability and differences. Ghaderi et al. (2016) and Gold and Seuring (2011) analyze the type of feedstock used in the papers. Decision levels are studied by nearly all previous reviews. While, Cambero and Sowlati (2014), Espinoza Pérez et al. (2017) and Parada et al. (2017) assess the objectives of the papers in sustainability dimensions, Ghaderi et al.(2016) categorize both objective functions and, analyze the papers that consider sustainability concept. The aim of the analysis of previous literature reviews is a better understanding and observation to evaluating criteria and classifications of the field of BSC.

Literature Analysis According to Classification Scheme

Fifty-one papers, published from 2010 to now and studying on BSC in terms of sustainability, are analyzed and classified with regard to classification scheme. The classification scheme is formed based on various classifications in previous literature reviews. First of all, the papers are classified in terms of sustainability dimensions; economic, environmental and social aspects. Second, solution methodologies applied in the papers are analyzed. In following, bioenergy generations are specified depend on biomass types and sustainability consideration. The decision levels of the articles were assessed and classified. And then, the types of data used in the papers are evaluated.

Sustainable Dimensions: Literature on sustainable SCM has received increasing attention from research community in recent years. The developments on economics, environmental and social aspects are composed the three pillars of sustainability: The Triple Bottom Line (TBL). Especially in the energy sector, sustainability becomes a well-known concept, with concerns about limited fossil resources and adverse environmental impacts. Supply chain design is a complex structure and each element in the chain is affected by each other. The designing a sustainable supply chain is a challenge on the bioenergy field. Thus, sustainable BSC is considered in three dimensions (Hong, How, and Lam 2016; Rajeev et al. 2017; Seay and Badurdeen 2014).

Economic Dimension: Economic dimension of sustainability is the most popular objectives in BSC design. Almost all of the papers assess economic sustainability. Economic sustainability is related to profitability and cost reduction in the different segments of the chain such as feedstock type, distribution route, and facility location. In addition, economic sustainability is considered as long term benefits by using the resources in effective and responsible way. That is, economic sustainability necessitates that the use of resources, such as land, capital and labor, must be managed wisely and prospectively to ensure that the work continues for a period of several years in a healthy manner (Ghaderi et al. 2016; Parada et al. 2017; Yue et al. 2014).

Environmental Dimension: Environmental dimension is the issue that gained more attention due to the increasing negative environmental impacts of energy use. Environmental sustainability requires designing operations or processes by preserving resources of today and tomorrow from potential harms. Climate change and global warming potential (GWP) are those of the main drivers of environmental sustainability. And also, air and soil quality, water resources quality, waste management, greenhouse gas (GHG) emission, protection of wildlife, energy efficiency are other issues of the environmental sustainability (Hoang Duc and Do Ba 2016; Kolk and Pinkse 2004).

Social Dimension: Social sustainability is related the issues increasing and enhancing social welfare such as employment opportunities, poverty reduction, social resources security and technological developments. And also, it covers social rights, working conditions, health issues, fresh water and food security. The ratio of the papers on social sustainability is less than that of the present study. It can prove that, the importance given social dimension should be increased in sustainable (Espinoza Pérez et al. 2017; Hombach et al. 2016; Srinivasan et al. 2016). The distribution of the papers according to their sustainability dimensions is illustrated in Figure 1.

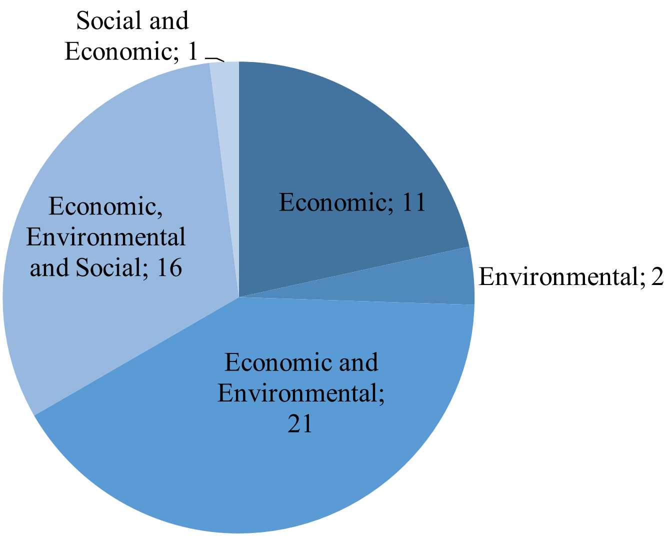

Figure 1. Distributions of 51 papers according to sustainability dimensions

Solution Methodology

The present study considers quantitative research on sustainable BSC. These quantitative research use different solution methodologies depending on objectives, decisions, uncertainty parameters and type of applications. In this section, different solution methodologies are analyzed and then, they are classified as optimization methods, simulation, hybrid methods, Multi criteria decision making (MCDM), fuzzy optimization, Life Cycle Assessment (LCA), stochastic methods. According to results of this study, mixed integer linear programming (MILP) models are the most used approach. This approach generally is applied to maximize net profit and to minimize total cost with binary and continuous decision variables with single economic objective. Some papers study under uncertain parameters such as demand, market, and price. Uncertainty is considered frequently in BSC. To overcome the different uncertain parameters, stochastic approach is used. Besides that, LCA perspective is used to assess environmental sustainability with comparing alternative biomass supply chain scenarios and evaluate resource and energy consumption, and emissions to air, water and soil.

Bioenergy Generations and Sustainability Evaluations

According to type of biomass used and related generation processes, bioenergy currently is classified into three generations. The common biomasses in first generation are agricultural crops, animal wastes oil plants and plant silage as feedstock. Despite these are the most widely used in bioenergy production, some biomasses in the first generation can be used also feedstock in food industry. That is, first generation bioenergy increase the competition on food prices due to its food resourced biomass. This adverse effect leads the second generation bioenergy become popular. The second generation bioenergy is obtained from nonfood feedstock; agricultural residues, woody crops, lignocellulose biomass with an advanced technology. Nonfood sources are abundant and they are obtained from plants. However, there are some barriers in the commercialization of second generation bioenergy. Its production process is more difficult than first generation. In the study, most of papers use second generation bioenergy, while, only two paper study on third generation bioenergy. The reason of this finding can be attributed the fact that third generation bioenergy is a newly developed subject compared to others. Third generation biofuels are derived from algae and microalgae. In the respect of food security, microalgae can be obtained from sea water or waste water such as industrial. And third generation has potential to be possible solution for energy sector. Most of the analyzed 51 papers use second generation feedstock, despite well-developed first generation bioenergy. The reason is that the negative effect of first generation bioenergy on the food sector is not seen as sustainable.

Decision Levels

Supply chain management (SCM) is a complex and comprehensive issue which comprising of all movements from the raw materials to end users. SCM aims to provide a more effective flow and network between chains. The more effective management requires some decision such as locations, road, distribution centers, shipment, inventory levels etc. In BSC, decision levels classified in three levels (strategic, tactical and operational), as in the SCM (Eskandarpour et al. 2015; Papageorgiou 2009; Shabani et al. 2013).

Strategic Decision Level: Strategic decision level considers long term decisions which are usually over one year. It interests the financial investment and development of the system. In general, number, location and capacities of facility and distribution centers, network design, and supply and demand contracts are some examples of strategic decision types. In BSC, type and source of biomass, location and size of bio refineries, conversion technology selection, distribution patterns are the key strategic decisions (Ba et al. 2016; Iakovou et al. 2010; Lin et al. 2014). BSC considers mostly strategic level decision. Facility (pre-processing site, processing site, biorefinery, etc.) decisions are most common one in BSC strategies. Selection of location, capacity or size of facilities is long-term issue and affects effective and economic execution of supply chain in the long run. Most papers determine facility location, capacity and technology, because these decisions directly impact investment, transportation cost and performance. Biomass related decisions also affect BSC costs and productivity. Selection of biomass type and determining the annual amount of biomass need are related expected cost and expected final product quantity. Annual transportation schedule is also considered in some papers. These decisions are flow rate or quantity of materials (biomass, byproducts or final products) among nodes (harvesting site, refinery or demand points etc.), and help to determine supply chain capacity, type of vehicle used, transportation route, distance and cost.

Tactical and Operational Decisions: Tactical decisions relate to medium-short term horizon; monthly or a few months such as production planning, inventory management, transportation methods in certain periods. Especially in BSC, biomass harvesting decision in short period can be related to tactical decisions such as which source is used to harvest or how much biomass is harvested (Ba et al. 2016; Iakovou et al. 2010). Operational decisions consider short term time horizon. These decisions are related hourly, daily or weekly issues. For instance, daily production scheduling, start times of operations, daily harvest scheduling are examples of operational decisions (An et al. 2011; Ba et al. 2016).

Sustainability Drivers of Biomass

Especially since the 2000s, biomass has a many causes for being preference and potential solution of energy sector. Environmental problems emerged by the use of fossil fuels are the primary of these causes. Also, the importance given to the use of renewable resources has increased in all over the world. However, besides biomass, it is available in other renewable sources that can be used to generate energy, such as the sun and wind. In this section, we investigate the reasons why biomass is preferred for energy production. For this purpose, in the present study, the preference reasons of biomass in sustainable energy supply are defined as “sustainability drivers of biomass”. This study also has the characteristic of distinguishing of biomass from different renewable and environmental friendly sources. To analyze sustainability drivers of biomass, the following questions are investigated in the reviewed papers.

- Why biomass use is recommended for sustainable energy supply?
- For which features, the papers use biomass in energy generation?

As a result of this analysis, most of papers choose the biomass use because of its positive impacts on GHG emissions. The second common reason is that biomass is renewable resource to energy generation. Some papers remark that biomass has vast domestic supply (VDS). Biomass can be available easily almost every rural and urban area from forest, waste or agricultural materials. Second generation forest biomass, especially, considers in terms of the food security issue. Several papers indicate that the biomass use in energy industry strengthens the economic development in rural areas increasing employment and job opportunities. And also, it is indicated that the security of energy supply can be provided and increased energy demand can be met with biomass use.

Some papers specify that biomass reduce oil dependence and dependence of energy import. Other papers mention generally positive environmental effects of biomass; GWP, Climate change potential (CCP).

CONCLUSION AND FUTURE RESEARCH DIRECTIONS

In recent years, the sustainability concept become crucial in energy supply when future generations' energy needs and environmental issues are considered. Increased trend in energy consumption accelerate find for new resources. Renewable energy resources and global warming issues gain importance in the course of time. The number of BSC studies has increased considerably, nevertheless, more studies still would be needed which addressing BSC issue by emphasizing sustainability concept. Sustainability concept is mostly associated with the environmental friendly features of biomass. Sustainability in the use of biomass should be more investigated in social dimension. There is a continuous and stable employment opportunity in bioenergy production. That is, the use of biomass in energy production can be considered to support social sustainability dimension in economic terms. The increased trend in first generation bioenergy studies, in time, has shifted towards second generation bioenergy production due to competition in food products. The issue of waste management in bioenergy production is not sufficient, thus, it should be assessed within the sustainability concept. More investigations on advantages and shortcomings between third generation bioenergy and second generation bioenergy should be conducted to clearly understand the motivations of third generation bioenergy.

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HAZARDOUS MATERIAL STORAGE AND EVOLUATION OF WAREHOUSE MANAGEMENT SYSTEM SELECTION CRITERIA WITH MCDM

Seyithan Yıldız[1], Batuhan Kocaoğlu[2]

Abstract *– A hazardous material is any item or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors. Transporting, storing, handling and using of these materials may expose them to a variety of accidental hazards which are flammable, burning, explosive, abrasive and poisonous in the environment. These products are dangerous on their own and can become dangerous by interacting with nearby products. For these reasons the storage and traceability of hazardous materials are very important. WMS is a system designed to manage all operations that can occur in a warehouse in an efficient and efficient manner, to ensure that operations are completed with minimum human and machine resources in the shortest time without errors, to make decisions, to perform online operations online and to present the information of the realized transactions in reports. In this study, hazardous materials and their storage will be explained; the criteria for WMS will be determined and these criteria will be assessed by AHP method.*

Keywords – Hazardous Materials, Warehouse Management System, MCDM

INTRODUCTION

A hazardous material is any item or agent (biological, chemical, radiological, and/or physical), which has the potential to cause harm to humans, animals, or the environment, either by itself or through interaction with other factors (Carson, 2002). Transporting, storing, handling and using of these materials may expose them to a variety of accidental hazards which are flammable, burning, explosive, abrasive and poisonous in the environment. These hazards may affect people working within the storage site, the emergency services in the event of an incident, the public off site and the environment.

Dangerous substances should be received into a chemical warehouse by a competent person who understands all the risks that they pose and can decide on where to store them and how to segregate them, having regard to their physical and chemical properties, the quantities concerned and the sizes of the packages. Therefore, the placement and location of hazardous material warehouses should have some well-defined criteria such as distances from adjacent properties, motorways and railways, and infrastructure such as utilities in order not to harm the environment and living beings (Benintendi & Alfonso, 2013).

Warehousing concept concerns inventory management activities that take place within the storage areas, and warehouses such as receiving of goods, purchasing, shipping of goods, order picking, collecting and sorting activities (Koster & Le-Duc, 2007). Warehouse Management (WM) is not just purchasing, storing, and shipping in the limits of a warehouse; it is much more complex and exceeds the physical boundaries of warehouses. Warehouse Management System (WMS) is used to increase the performance of the warehouse by directing efficient managerial implications and to develop precise inventory as a result of recording warehouse transactions. WMS is still gaining functionality and can be defined merely as a system to control storage of materials and movement in the storage area. The role of WMS is expanding in managerial areas such as transportation, order, and complete financial systems within warehouse. Those systems include functions for receiving, storage, order picking, packing, and shipping processes, inventory storage, order product mixing, cross docking and customer service, and material handling activities.

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In this study, hazardous materials will be introduced first and information about the storage of these substances will be given. Then, give information about WMS; the criteria of WMS should be selected as a precaution for hazardous material storage. These selected criteria will be evaluated by AHP method and their weights will be determined.

Definition of Hazardous Materials

Hazardous materials are solids, liquids or gases that could harm people, other living organisms, property or the environment. Some possible accidents/incidents that impose risk to people, property and the environment could be an explosion in storage or processing facilities, leak of hazmat from their containers directly to the atmosphere, an explosion or leak due to a traffic accident involving hazmat-carrying vehicles. According to the European Agreement concerning the International Carriage of Dangerous Goods by Road (commonly known as ADR), there are nine main classes of hazmat; (1) Explosive and pyrotechnics, (2) Gasses, (3) Flammable and combustible liquids, (4) Flammable, combustible and dangerous-when-wet solids, (5) Oxidizers and organic peroxides, (6) Poisonous and infectious materials, (7) Radioactive materials, (8) Corrosive materials (acidic or basic), (9) Miscellaneous dangerous goods (hazardous wastes). The warning signs and classifications are shown in Table 1.

Table 1. Hazardous Material Class and Warning Signs

Packaged dangerous goods have their own well-defined hazards, often detailed on the material safety data sheet (MSDS), and a specified safe method of storage. However, certain types of packaged dangerous substances may give rise to additional hazards within a warehouse. These different types of dangerous substances should therefore be assessed when considering a risk control strategy to ensure there is sufficient segregation etc. Interaction between different dangerous substances may create additional hazards.

Dangerous substances should be received into a chemical warehouse by a competent system which understands all the risks that they pose and can decide on where to store them and how to segregate them, having regard to their physical and chemical properties, the quantities concerned and the sizes of the packages.

Segregation is one of the most important risk-control measures in storage. Segregation rules for hazardous materials are shown in Table 2.

Table 2. Hazardous Material Segregation Table

SEGREGATION TABLE

The following table shows the general provisions for segregation between the various classes of dangerous goods.

SINCE THE PROPERTIES OF SUBSTANCES, MATERIALS OR ARTICLES WITHIN EACH CLASS MAY WARY GREATLY, THE DANGEROUS GOODS LIST SHALL ALWAYS BE CONSULTED FOR PARTICULAR PROVISIONS FOR SEGREGATION AS, IN THE CASE OF CONFLICTING PROVISIONS, THESE TAKE PERCEDEMCE OVER THE GENERAL PROVISIONS.

SEGREGATION SHALL ALSO TAKE ACCOUNT OF A SINGLE SUBSIDIARY RISK LABEL.

	CLASS	1.1, 1.2, 1.5	1.3, 1.6	1.4	2.1	2.2	2.3	3	4.1	4.2	4.3	5.1	5.2	6.1	6.2	7	8	9
Explosives	1.1, 1.2, 1.5	*	*	*	4	2	2	4	4	4	4	4	4	2	4	2	4	x
Explosives	1.3, 1.6	*	*	*	4	2	2	4	3	3	4	4	4	2	4	2	2	x
Explosives	1.4	*	*	*	2	1	1	2	2	2	2	2	2	x	4	2	2	x
Flammable Gases	2.1	4	4	2	x	x	x	2	1	2	x	2	2	x	4	2	1	x
Non-toxic, Non flammable gases	2.2	2	2	1	x	x	x	1	x	1	x	x	1	x	2	1	x	x
Toxic gases	2.3	2	2	1	x	x	x	2	x	2	x	x	2	x	2	1	x	x
Flammable liquids	3	4	4	2	2	1	2	x	x	2	1	2	2	x	3	2	x	x
Flammable Solids	4.1	4	3	2	1	x	x	x	x	1	x	1	2	x	3	2	1	x
Substances, liable to spontaneous combustion	4.2	4	3	2	2	1	2	2	1	x	1	2	2	1	3	2	1	x
Substances which, in contact with water, emit flammable gases	4.3	4	4	2	x	x	x	1	x	1	x	2	2	x	2	2	1	x
Oxidizing substances (agents)	5.1	4	4	2	2	x	x	x	2	1	2	2	2	1	3	1	2	x
Organic peroxides	5.2	4	4	2	2	1	2	2	2	2	2	2	x	1	3	2	2	x
Toxic substances	6.1	2	2	x	x	x	x	x	x	1	x	1	1	x	1	x	x	x
Infectious substances	6.2	4	4	4	4	2	2	3	3	3	2	3	3	1	X	3	3	x
Radioactive material	7	2	2	2	2	1	1	2	2	2	2	1	2	x	3	x	2	x
Corrosive substances	8	4	2	2	1	x	x	x	1	1	1	2	2	x	3	2	x	x
Miscellaneous dangerous substances and articles	9	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x

1 - "Away from"
2 - "Separated from"
3 - "Separated by a complete compartment or hold from"
4 - "Separated longitudinally by an intervening complete compartment or hold from"
x - "The segregation, if any, is shown in the Dangerous Goods List"

Warehousing Incident Case History

According to the International Labor Organization (ILO), 24% of major chemical accidents happen in warehouses. A long series of incidents related to storage of chemicals is reported in the literature.

On 4 January 1977, in Renfrew, Scotland, a chemical warehouse, the Braehead Container Clearance Depot, was destroyed by a fire and explosion. The event involved sodium chlorate under intense heat condition, as stated by the Health and Safety Executive. On 1 November 1986 a fire developed in a warehouse operated by Sandoz in Schweizerhalle, Switzerland. Thirty tones of the chemicals stored in the warehouse were drained along with water by the fire-fighting into the nearby River Rhine, resulting in a severe ecological damage over a length of about 250 km. This accident triggered serious concern in at least four European countries (Switzerland, France, Germany, and The Netherlands). On Tuesday, 21 July 1992, a series of explosions leading to an intense fire broke out in a storeroom in the raw materials warehouse of Allied Colloids Ltd, Low Moor, Bradford, West Yorkshire. The fire was preceded by the rupture of two or three containers of azodiisobutyronitrile about 50 minutes earlier.

On 8 August 2013 an explosion occurred in Opa-Locka, Florida, at the American Vinyl Company warehouse, which caused one fatality and five injured. According to police hazmat crews, a storage container in the building that held 20,000 gallons of liquid inexplicably exploded. The storage container blew a hole in the roof of the building.

Benintendi and Alfonzo (2013) have analyzed sixty-one major chemical disasters which happened since 1955 to 2002, which have been grouped by their occurrence during processing, transport and storage of reactive chemicals and by intentional or unintentional chemistry. The conclusion is that nearly 15% of the incidents occurred when material was being stored and that all of them underwent chemical reactions which did not belong to the design chemistry for the involved substances.

LITERATURE VIEW FOR WMS AND WMS FOR HAZARDOUS MATERIALS

In recent years, there have been many researches on WMS considering different aspects but not on evaluation of a general management system in warehouses. The main objective behind a WMS is to monitor the warehouse operations such as movement and storage of materials within an operation and process the associated transactions (Min, 2006). Receiving, quality control, order picking processes, packaging processes, bin-packing processes, demand and supply processes, allocating production, transportation, storage allocation and assignment, stock management (inventory control, inventory optimization, cycle count), decision support and reporting, are some important criteria that are considered in the management phase.

Also, direct picking, replenishment, and put away could be counted as some of warehouse management activities and should be considered while evaluating WMSs. In addition, we can also include to warehouse operations the tracking systems and communication systems between work stations (Apak & Tozan, 2016).

To designate a material in your warehouse as dangerous, you must first create a hazardous material record and then assign it to the material master record of the dangerous material (Bali & Eroglu, 2014).

In the WMS, the following tables should be included for the definitions of hazardous substances.

- Identification number – UN Number
- Dangerous Goods Class
- Flash Point
- Packing Group
- Additional Hazard Class
- Exemption

According to documents of SAP for storage of hazardous substances; before you can use WMS to manage hazardous materials, you need to maintain several hazardous material characteristics in the WMS configuration tables. These include:

- Hazardous material warning
- Handling instruction
- Aggregate stages
- Regions codes
- Storage classes

Facilities handling this type of inventory must have racking that can support the weight and size of industrial barrels, enough space to maintain material segregation and handling equipment designed to safely move these items (Benintendi & Round 2012). Afterwards, you need to maintain tables that control how the system handles the placement of hazardous materials into the desired storage areas.

Some of the top challenges in hazardous materials storage, encountered include material segregation, damage prevention, cleanup response and protocol, storage and retrieval equipment, and documentation management (Kabak & Keskin, 2018). Segregation hazardous materials inventory into their categories can help to create standards for the proper and safe handling and storage of these items. These mixing regulations have been put in place to prevent dangerous materials from coming into contact with each other. Supply chain departments must be able to follow these material segregation regulations and track all inventory history to prove compliance in the instance that an audit and recall occurs.

Documentation management, also closely regulated by governing bodies, must be properly managed to maintain accurate inventory records in case of product recalls. Documentation is not properly managed these HAZMAT facilities can face fines or temporary shutdown. In the management of hazardous materials, WMS have to provides several reports. These reports are fire department inventory list, hazardous materials stored in the warehouse, hazardous substance list.

According to the documentations of datexcorp which is asking od WMS company; WMS technology in hazardous materials can;

- Automate inventory segregation rules via directed putaway during receiving
- Automate handling protocol and rules to prevent damage
- Direct users to tasks associated with facility maintenance associated to cleanup
- Restrict material handling equipment use by inventory category or user
- Store detailed audit trail information and associated documentation as required

CONTENTS OF STUDY

In this study, the criteria to be used in WMS for hazardous materials will be determined. According to the above studies and explanations, these criteria should be as follows.

1. Segregation rules
2. Materials definitions / Master Data capabilities

3. Handling instructions
4. Documentations / Reports capabilities
5. Restrict rules for inventory, user or process

On the other hand, the criteria that should be in a standard WMS are as follows excluded from the above.

6. Receiving process
7. Quality control
8. Order picking and packing process
9. Replenishment
10. Allocation production
11. Storage allocation and assignment
12. Stock management (inventory control, cycle count, inventory optimization)

The selected criteria will be applied to the AHP method and the percentage weights of the criteria will be determined. In summary, the WMS criteria required for hazardous material storage will be determined and the WMS requirements will be determined by the applied AHP method.

Application of 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 (Timor, 2011).

Weights of criteria are shown in table 3. The evaluation of the criteria was carried out by an expert in the storage of hazardous materials.

- Binary comparisons are made for the criteria shown in each row and column.
- First, taking into consideration the criteria in the row, the comparison with each of the column criteria of this row criteria is recorded as the resultant intracell value.
- The result of comparing each criterion with itself is equal to 1.
- Criteria below the diagonal are calculated by dividing the criteria above the diagonal by 1.

Table 3. Weights for Criteria

		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
K1	Segregation rules	1	3	4	3	1	9	9	5	8	9	6	1
K2	Materials definitions / Master Data capabilities	1/3	1	1	1/2	1/5	5	7	1/2	3	6	1/2	1/3
K3	Handling instructions	1/4	1	1	1/5	1/3	3	6	1	3	6	1/5	1/5
K4	Documentations / Reports capabilities	1/3	2	5	1	1/3	5	7	1/2	4	7	2	1/3
K5	Restrict rules for inventory, user or process	1	5	3	3	1	6	8	3	7	9	3	1
K6	Receiving process	1/9	1/5	1/3	1/5	1/6	1	3	1/3	3	3	1/3	1/8
K7	Quality control	1/9	1/7	1/6	1/7	1/8	1/3	1	1/9	1/3	1/3	1/7	1/9
K8	Order picking and packing process	1/5	2	1	2	1/3	3	9	1	3	7	3	1/3
K9	Replenishment	1/8	1/3	1/3	1/4	1/7	1/3	3	1/3	1	2	1/5	1/7
K10	Allocation production	1/9	1/6	1/6	1/7	1/9	1/3	3	1/7	1/2	1	1/6	1/9
K11	Storage allocation and assignment	1/6	2	5	1/2	1/3	3	7	1/3	5	6	1	1/4
K12	Stock management inventory control, cycle count	1	3	5	3	1	8	9	3	7	9	4	1

The normalized matrix is shown in Table 4 which calculated from Table 3. The values of each column in the comparison matrix are divided by the total value of the column to obtain the normalized matrix value.

Table 4. Normalized Matrix

		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
K1	Segregation rules	0.21090	0.15119	0.15385	0.21527	0.19689	0.20455	0.12500	0.32778	0.17844	0.13776	0.29207	0.20243
K2	Materials definitions / Master Data capabilities	0.07030	0.05040	0.03846	0.03588	0.03938	0.11364	0.09722	0.03278	0.06691	0.09184	0.02434	0.06748
K3	Handling instructions	0.05272	0.05040	0.03846	0.01435	0.06563	0.06818	0.08333	0.06556	0.06691	0.09184	0.00974	0.04049
K4	Documentations / Reports capabilities	0.07030	0.10079	0.19231	0.07176	0.06563	0.11364	0.09722	0.03278	0.08922	0.10714	0.09736	0.06748
K5	Restrict rules for inventory, user or process	0.21090	0.25198	0.11538	0.21527	0.19689	0.13636	0.11111	0.19667	0.15613	0.13776	0.14604	0.20243
K6	Receiving process	0.02343	0.01008	0.01282	0.01435	0.03282	0.02273	0.04167	0.02185	0.06691	0.04592	0.01623	0.02530
K7	Quality control	0.02343	0.00720	0.00641	0.01025	0.02461	0.00758	0.01389	0.00728	0.00743	0.00510	0.00695	0.02249
K8	Order picking and packing process	0.04218	0.10079	0.03846	0.14352	0.06563	0.06818	0.12500	0.06556	0.06691	0.10714	0.14604	0.06748
K9	Replenishment	0.02636	0.01680	0.01282	0.01794	0.02813	0.00758	0.04167	0.02185	0.02230	0.03061	0.00974	0.02892
K10	Allocation production	0.02343	0.00840	0.00641	0.01025	0.02188	0.00758	0.04167	0.00937	0.01115	0.01531	0.00811	0.02249
K11	Storage allocation and assignment	0.03515	0.10079	0.19231	0.03588	0.06563	0.06818	0.09722	0.02185	0.11152	0.09184	0.04868	0.05061
K12	Stock management	0.21090	0.15119	0.19231	0.21527	0.19689	0.18182	0.12500	0.19667	0.15613	0.13776	0.19471	0.20243

Table 5. Priority Matrix, Weighted Sum and λ

Priority	Weighted Sum	λ
0.19968	2.79270	13.98614
0.06072	0.78509	12.93018
0.05397	0.69252	12.83223
0.09213	1.28335	13.92900
0.17308	2.33997	13.51983
0.02784	0.35264	12.66568
0.01189	0.14890	12.52683
0.08641	1.19886	13.87454
0.02206	0.27881	12.63905
0.01550	0.19029	12.27425
0.07664	1.04882	13.68537
0.18009	2.47068	13.71915

λ_{max}	CI	CR
13.2152	0.110471634	0.07464

Since this value of 0.075 for the proportion of inconsistency CR is less than 0.10, we can assume that our judgments matrix is reasonably consistent, so we may continue the process of decision-making using AHP. The results of priority matrix, weighted sum and λ are shown in table 5.

Since the inconsistency is within acceptable limits, the values of the priority vector can be interpreted which shown in Table 6 with ranking.

Table 6. Final rank of Criteria

	Criteria	Priority	Rank
K1	Segregation rules	20.0%	1
K2	Materials definitions / Master Data capabilities	6.1%	7
K3	Handling instructions	5.4%	8
K4	Documentations / Reports capabilities	9.2%	4
K5	Restrict rules for inventory, user or process	17.3%	3
K6	Receiving process	2.8%	9
K7	Quality control	1.2%	12
K8	Order picking and packing process	8.6%	5
K9	Replenishment	2.2%	10
K10	Allocation production	1.6%	11
K11	Storage allocation and assignment	7.7%	6
K12	Stock management inventory control, cycle count	18.0%	2

RESULTS AND RECOMMENDATION

The most important criterion by the respondent is the “segregation rule” (0,19968). This criterion is followed by “stock management (inventory control, cycle count, inventory optimization)” (0,18009), “restrict rules for inventory, user or process” (0,17308). The total value of these 3 criteria is 0,55284.

On the other hand, total value of first 5 criteria which are WMS criteria for hazardous material is 0,58. Rest of the 7 is 0,42. As we can see from these values, there are some special features of warehouse management system of hazardous materials. Due to the nature of these products, the values of hazardous materials criteria are quite high.

The second largest criterion seems to be stock management. The question to be asked here is whether this criterion is important for all WMSs or for dangerous substances. When the subject is hazardous materials, the value of stock management is higher. To protect against a possible danger, to protect human health, to ensure product and environmental safety; inventory control, cycle count, inventory optimization is relatively more valuable for these products.

When we need to choose a WMS for the storage of hazardous substances, the above study evaluates the features we want to have in WMS; it will also help us compare different WMS systems using with those criteria and rates.

For future study, It should be investigated that the weights of the other 7 WMS criteria, are to be found in other business lines. In this way, it can be understood whether these criteria are important for hazardous substances of just important for regular WMS.

This assessment can also be done using other MCDM and the results are compared. The number of participants in the questionnaire can be increased; the awareness can be tested by making a separate evaluation for people who doesn't work in hazardous materials.

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A CONSTRAINT PROGRAMMING APPROACH FOR THE PICKUP AND DELIVERY PROBLEM WITH TIME WINDOWS

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Abstract *– This paper considers the pickup and delivery problem with time windows (PDPTW). It is named as the single-commodity vehicle routing problem with pickups and deliveries, in which a fleet of vehicles satisfy a collection of customer requests. Each customer request requires the use of a single vehicle both to load a specified amount of one type of commodity at one location and to deliver them to another location. All requests must be performed without violating the vehicle capacity and the customer time windows specified for each location. The PDPTW is a widely seen NP-hard problem with the objective of minimizing the total cost that is comprised of the variable costs associated typically with the distances between the customer locations, and the fixed costs that are incurred for the use of the vehicles. In this study, we propose a novel Constraint Programming (CP) model for the PDPTW. CP is an exact solution approach which is well known for its abilities to express complex relationships and to obtain good quality solutions within reasonable computational times for densely constrained combinatorial optimization problems such as the PDPTW. In our model, we use interval variables that are capable of expressing several critical decisions such as start time, end time, duration and usage rate of a vehicle visit under one variable. On the other hand, global constraints (Alternative, NoOverlap, Pulse etc.) are used, which are extracted from IBM's CP Optimizer to reduce the number of variables and constraints. Moreover, interval sequence variables and alternative constraints are used to intelligently handle vehicle assignments to visits in such a way that a tour structure is maintained while subtours are prevented. The performance of the proposed CP model is evaluated using benchmark instances from the literature. The computational results show that the proposed CP model is effective in finding good quality feasible solutions for large size problems.*

Keywords – constraint programming, pickup and delivery problem, time windows, multiple vehicles

INTRODUCTION

The classical Vehicle Routing Problem (VRP) is very popular on research area because of its benefits to real world logistics and transportation applications. In recent decades, many new constraints have been added to this problem to meet real life needs. Some of these constraints are related with capacity, service times, time windows, loading, transshipment etc. One of the useful extensions of the VRP is the pickup and delivery problem which includes capacity, time windows and service time constraints. The pickup and delivery problem occurs for a single vehicle or a group of vehicles to satisfy a collection of customer requests. Each customer request requires the use of a single vehicle both to load a specified amount of goods at one location and to deliver them to another location. All requests must be performed without violating either the vehicle capacity or the customer time window specified for each location. The objective of the classic Pickup and Delivery Problems with Time Windows (PDPTW) is either to minimize the total travel distance of vehicles, or to first minimize the number of vehicles and then to minimize the total travel distance of vehicles.

Different variants of the PDPTW are studied in the literature and classified according to their structures, the number of deployed vehicles, and the pickup and delivery activities in the nodes. For example, one-to-one PDPTW is one type in which each vehicle has pairs of one pickup node and one delivery node. In the many-to-many scheme, any node can serve as an origin or as a destination for any commodity (Hernández and González, 2014).

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The PDPTW contributes to one of the most important classes of problems because its models have various logistic applications such as reverse logistics, shipping car-goes, dial-a-ride systems, distribution of beverages and collection of empty cans and bottles, bike repositioning operations, bus scheduling etc. (Sin et al., 2016).

In this paper, we propose a novel Constraint Programming (CP) model for the PDPTW. The performance of the proposed CP model is evaluated for small size problems using its Mixed Integer Programming (MIP) formulation over randomly generated problem instances. The CP model is also tested using benchmark instances from the literature. The computational results show that the proposed CP model is effective in finding good quality feasible solutions for large size problems.

The rest of this paper is organized as follows: In Literature Review Section, related literature of the problem is given. In Problem Description Section, an MIP model adapted from different literature sources is provided and the developed CP model for the PDPTW is introduced. The computational results are presented in the next Section. Finally, concluding remarks and future research are given in Conclusion Section.

LITERATURE REVIEW

Since the pickup and delivery problem (PDP) was introduced for the first time in Desrochers et al.(1988), several studies have been published, with focus on solving practical instances of the PDP, by means of several techniques, such as branching methods, decomposition methods (column generation, row generation), dynamic programming, heuristics and metaheuristics.

In most static applications, the typical objective functions to be minimized are, in first place, the fleet size needed to satisfy the demand with a determined level of service, and next, the total distance traveled by all vehicles, provided that the fleet size is fixed. The static PDP constraints can be classified as visiting constraints (each pickup and delivery has to be visited exactly once), vehicle capacity constraints, depot constraints, coupling constraints (stating that for a given request the same vehicle must visit the pickup and delivery stops), precedence constraints, resource constraints on the availability of drivers and vehicles, and time window constraints to be satisfied at each stop, if time windows are explicitly defined (Desrosiers et al., 1995).

Savelsbergh and Sol (1995) classified the PDP into static and dynamic cases, with single and multi-vehicle and, with and without time windows. In addition, Solomon and Desrosiers (1988) published an excellent review of the vehicle routing problem with time window constraints. Also, Toth and Vigo (2002) developed a very complete survey of the methods proposed to solve the PDPTW.

Li and Lim (2003) proposed a tabu-embedded simulated annealing algorithm which restarts a search procedure from the current best solution after several non-improving search iterations. They proposed six newly-generated different data sets for PDPTW problem with various distribution properties. Bent and Van Hentenryck (2006) proposed a two-stage hybrid algorithm for the PDPTW, where in the first stage the number of vehicles is minimized, while in the second stage the total travel cost is minimized by a large neighborhood search. An adaptive large neighborhood search heuristic was proposed by Ropke and Pisinger (2006). Numerous studies have been done on the PDPTW with the objective to minimize the total fixed cost of vehicles and the total travelled distance. For a survey on pickup and delivery problems until 2008, see Parragh et al. (2008). Nagata and Kobayashi (2010) successfully applied a Guided Ejection Search Algorithm to the PDPTW. Nalepa and Blocho (2016) proposed a parallel guided ejection search algorithm to solve PDPTW. In their approach, parallel processes co-operate periodically to enhance the quality of results and to accelerate the convergence of computations. (Noumbissi Tchoupo et al. 2018)

Furthermore, many extensions of the PDPTW problems motivated by real life problem were discussed in literature. Xu et al. (2003) proposed a set partitioning formulation to solve a practical heterogeneous fleet pickup and delivery problem with constraints to unloading sequence. In fact, unloading sequence must satisfy the nested precedence constraint: an order cannot be unloaded until all the orders loaded into the truck later than this order are unloaded. They also take into account practical aspects such as: multiple time windows, multiple depots, compatibility constraints between carrier and vehicles, orders and vehicles, and between orders. Qu and Bard (2013) introduced a variant of the heterogeneous pickup and delivery problem in which the capacity of each vehicle can be modified by reconfiguring its interior to satisfy different types of customer demands. They modelled the problem as a mixed integer program and developed a two-phase heuristic that makes use of ideas from greedy randomized adaptation search procedures with multiple starts. Bettinelli et al. (2014) proposed a branch and price algorithm to tackle pickup and delivery problems with soft time windows. In this study, a penalty is attributed when a time window is violated. Noumbissi Tchoupo et al. (2018) developed a Bender's decomposition algorithm for the PDPTW with heterogeneous fleet to minimize the sum of vehicle fixed costs and the total routing cost. For the homogeneous case, their proposed approach was able to solve optimally instances up to 100 demands in reasonable computational time.

PROBLEM DESCRIPTION

The PDPTW can be described with graph theory terms as follows: Let $G(N, A)$ be a directed graph having the node-set N and the arc-set A. For i and $j \in N$, we denote the arc from i to j as $(i, j) \in A$. We use the term ‘‘network’’ to mean a graph having additional data on its nodes and arcs. $N = \{n_0, n_1, . . ., n_{n+1}\}$ is the set of nodes in which n_0 represents the initial depot and n_{n+1} represents the final depot. d_{ij} shows the distance between customers i and j. Each customer $\{n_1, n_2, \ldots, n_n\}$ requires a nonnegative delivery quantity d_i and a nonnegative pickup quantity p_i. The objective of this problem is to find a set of minimum-cost vehicle routes for meeting all customer requests.

Mixed Integer Programming Formulation (MIP-PDPTW)

The basic model for multi vehicle pickup and delivery problems with time windows is an adapted three index vehicle routing problem formulation of the ones proposed in Ropke et al. (2007), Parragh et al. (2008) and Rais et al. (2014), which present MIP models for solving the PDPTW. The PDPTW can be formulated as the following mixed integer program;

Let r denote the number of requests to satisfy. The PDPTW can be defined on a directed graph $G = (N, A)$ with node set $N = \{0, \ldots, n+1\}$ and arc set A. Nodes 0 and n+1 represent the origin and destination depots (which may have the same location) while subsets $P = \{\ldots\}$ and $D = \{\ldots\}$ represent pickup and delivery nodes , respectively. With each request $r \in R$ is thus associated a pickup node $P(r)$ and a delivery node $D(r)$. With each node $i \in N$ are associated a load q_i and a non-negative service duration d_i satisfying $d_0 = d_{n+1} = 0$, $q_0 = q_{n+1} = 0$, An unlimited fleet of identical vehicles with capacity Q^k is available to serve the requests. With each arc $(i, j) \in A$ are associated a routing cost c_{ij} and a travel time/distance t_{ij}. A time window $[e_i, l_i]$ is also associated with every node $i \in P \cup D$, where e_i and l_i represent the earliest and latest time, respectively, at which service may start at node i. The depot nodes may also have time windows $[e_0, l_0]$ and $[e_{n+1}, l_{n+1}]$ representing the earliest and latest times, respectively, at which the vehicles may leave from and return to the depot. We assume that the triangle inequality holds both for routing costs and travel times. The notation for MIP-PDPTW is given as follows:

Sets

N: set of all nodes (customers and depots), $\{0,1,2,3, \ldots, n+1\}$
V: set of all vehicles, $\{1,2, \ldots, m\}$
P: $set\ of\ all\ pickup\ nodes$
D: $set\ of\ all\ delivery\ nodes$

Parameters

C^k : capacity of vehicle $k \in V$
c_{ij} : distance between nodes i and j, $i \in N, j \in N$
d_i : service duration of customer $i \in N$
q_i : load amount of customer $i \in N$
M_{ijk} : constant big number for beginning time of arc $i, j \in N$ and vehicle $k \in V$
W_{ijk} : constant big number for load of arc $i, j \in N$ and vehicle $k \in V$

Decision variables

x_{ijk} : if $arc(i, j)$ is traversed by vehicle $k \in V$, 0 $otherwise$
B_i^k : beginning time of service of vehicle $k \in V$ at node $i \in N$
Q_i^k : load of vehicle $k \in V$ when leaving node $i \in N$

With the introduced notation the following MIP formulation for the PDPTW can be given:

$$Min \sum_{k \in V} \sum_{i \in N} \sum_{j \in N} c_{ij}\, x_{ijk} \quad (1)$$

Subject to:

$$\sum_{k\in V}\sum_{j\in N} x_{ijk} = 1 \qquad \forall i \in N \tag{2}$$

$$\sum_{j\in N} x_{0jk} = 1 \qquad \forall k \in V \tag{3}$$

$$\sum_{i\in N} x_{i(n+1)k} = 1 \qquad \forall k \in V \tag{4}$$

$$\sum_{i\in N} x_{ijk} - \sum_{i\in N} x_{jik} = 0 \qquad \forall j \in N, \quad \forall k \in V \tag{5}$$

$$\sum_{j\in N} x_{P(r)jk} - \sum_{j\in N} x_{D(r)jk} = 0 \qquad \forall r \in R, \quad \forall k \in V \tag{6}$$

$$x_{ijk} => 1 \;\; B_j^k \geq B_i^k + d_i + t_{ij} \qquad \forall i,j \in N, \; \forall k \in V \tag{7}$$

$$B_{P(r)}^k \leq B_{D(r)}^k \qquad \forall r \in R, \; \forall k \in V \tag{8}$$

$$e_i \leq B_i^k \leq l_i \qquad \forall i \in N, \; \forall k \in V \tag{9}$$

$$x_{ijk} => 1 \;\; Q_j^k = Q_i^k + q_i \qquad \forall i,j \in N, \; \forall k \in V \tag{10}$$

$$max(0, q_i) \leq Q_i^k \leq min(C^k + q_i) \qquad \forall i,j \in N, \; \forall k \in V \tag{11}$$

$$x_{ijk} \in \{0,1\} \qquad \forall i,j \in N, \; \forall k \in V \tag{12}$$

The objective function (1) minimizes total routing cost/distance. Constraints (2) state that every vertex has to be served exactly once. Equalities (3) and (4) guarantee that every vehicle starts at the depot and returns to the depot at the end of its route. Note that this does not mean that every vehicle has to be used. A vehicle may only use the arc (0, n + 1), i.e. it does not leave the depot. Flow conservation is ensured by (5). Constraints (6) guarantee both origin and destination of a request must be served by the same vehicle. Time variables are used to eliminate subtours in (7), given that ($t_{ij} + d_i$) > 0 for all (i, j) ∈ A and delivery can only occur after pickup (8). Constraints (9) ensure not to violate time windows. Constraints (10) and (11) guarantee that a vehicle's capacity is not exceeded throughout its tour. It should be noted that this formulation requires the introduction of additional decision variables, Q_i^k, corresponding to the total load of vehicle k at vertex i.

Non-linear constraints, given in (7) and (10), can be linearized using a big M formulation with introducing constants M_{ijk} and W_{ijk} as follows (Cordeau, 2006):

$$B_j^k \geq B_i^k + d_i + t_{ij} - M_{ijk}(1 - x_{ijk}) \qquad \forall i,j \in N \quad \forall k \in V \tag{13}$$

$$Q_j^k \geq Q_i^k + q_i - W_{ijk}(1 - x_{ijk}) \qquad \forall i,j \in N \quad \forall k \in V \tag{14}$$

The validity of these constraints is ensured by setting $M_{ijk} \geq max\{0,\ l_i + d_i + t_{ij} - e_j\}$ and $W_{ijk} \geq \min\{Q_{ik}, Q_{ik} + q_i\}$.

Constraint Programming Model (CP-PDPTW)

Constraint programming (CP) is a powerful paradigm for solving combinatorial search problems that draws on a wide range of techniques from artificial intelligence, operations research, algorithms, graph theory and elsewhere. The basic idea in constraint programming is that the user states the constraints, and a general purpose constraint solver is used to solve them. Constraints are just relations, and a constraint satisfaction problem states which relations should hold among the given decision variables. More formally, a constraint satisfaction problem consists of a set of variables, each with some domain of values, and a set of relations on subsets of these variables. Constraint solvers take a real-world problem like this represented in terms of decision variables and constraints, and find an assignment to all the variables that satisfies the constraints. Extensions of this framework may involve, for example, finding optimal solutions according to one or more optimization, finding

all solutions, replacing constraints with preferences, and considering a distributed setting where constraints are distributed among several agents (Rossi et al., 2008).
In this section, we introduce a CP model for the PDPTW. We utilize (time) interval variables that are capable of expressing several critical decisions such as start time, end time, duration and usage rate under one variable (IBM, 2015). Interval variables are useful in order to represent complex scheduling and routing activities especially when they are optional. Laborie and Rogerie (2008) mention several advantages of interval variables. One is that the optionality is already modeled in the definition of the interval variable and there is no need for additional constraints in order to enforce this binary relationship, as the traditional integer decision variables require in scheduling problem formulations. As an example, if an optional interval variable is not present in the final solution, it is interpreted as its domain is empty and thus not considered in the final solution. However, in case of its presence in the final solution, we know that its domain contains a single value which is defined by its start and end time. Finally, its final status (absence or presence) can be queried by using $presenceOf(Interval\ Variable)$ in the problem formulation. In this work, the domains are the possible time periods when a location visit starts and ends. The duration of the visit is fixed and equal to the difference between the visit end time and start time (Gedik et al., 2017).
Start and end time represent service start and end time of a visit, respectively. Recall that start time is not necessarily the time the vehicle arrives to a location, as the vehicle may need to wait until the time window begins. Only one vehicle is needed to initiate and terminate a visit. Therefore, usage rate is equal to one. From this point forward, we represent an interval variable as a continuous line identified by the service start and end times.
x_{ik} is an optional interval variable that represents visiting node $i \in N$, using vehicle v and with a service time of d_i. Interval variables of customers are mandatory (must be present in the solution) whereas all customers' request must be satisfied. According to Time Windows constraints, start time and end time are specified.
$Q_k = \{x_{0k}, x_{1k}, x_{2k}, \ldots, x_{ik}, \ldots, x_{(n+1)k}\}$ is a set of interval variables that represent possible nodes $i \in$ N that can be visited by vehicles $k \in V$. This set of interval variables is called an interval sequence variable for $k \in V$ since it is used to evaluate the feasibility of a sequence for a vehicle (Gedik et al., 2017). The time interval variable and its optionality feature as well as several global constraints (*Alternative*; *NoOverlap*; *Pulse* etc.) used in this study are extracted from IBM's CP Optimizer. CP Optimizer's $Alternative\ \{y_i; \{x_{i1}; \ldots; x_{im}\}$ global constraint allows an exclusive alternative between interval variables $\{x_{i1}; \ldots; x_{im}\}$ (Laborie and Rogerie, 2008). This constraint ensures that exactly one of the interval variables from the arbitrarily defined set $\{x_{i1}; \ldots; x_{iV}\}$ will be executed if the arbitrarily defined interval variable y_0 is executed. Moreover, y_i will start and end together with the one chosen from set $\{x_{i1}; \ldots; x_{im}\}$. This feature is utilized to assign visits to vehicles.
Gedik et al. (2017) and IBM (2015) define Transition Distance as a function that records minimal delays between two successive non overlapping interval variables. This function is used as an input for another global constraint called $NoOverlap\,\{x_{i1}, \ldots x_{im}\}$. *TransitionDistance* that defines a chain of non-overlapping interval decision variables with minimal time between every two successive interval variables in the set $\{x_{i1}, \ldots x_{im}\}$. Transition distance is specified as a matrix M, which defines the minimal non-negative distance that must separate two consecutive intervals in the sequence. More formally, if $T(Q, x)$ denotes the non-negative integer type of interval x in the sequence variable Q: In this work, *TransitionDistance* is defined as a two dimensional array that stores the distance between each pickup and delivery point. Thus, the *NoOverlap* constraint assures that if a node is visited by a vehicle with fixed velocity, the time for the next location visit must occur after the necessary travel time elapses and the same vehicle cannot visit more than one location at any given time (or travel to more than one location).
Moreover, Laborie et al. (2009) also present another global constraint called *Cumulative* that keeps track of the cumulative usage level of the resource by the activities (in terms of interval variables) over time. Laborie et al. (2009) and IBM (2015) present numerous elementary cumulative functions in order to describe the impact of individual interval variables over time. For instance, *Pulse* is used to model cumulative usage, and *Step* is used to describe resource production/consumption. In this application, the *Cumulative* constraint and its *Step* function are used to limit the capacity of vehicles in use at any time to be less than or equal to the vehicle capacity.
Finally let c_k denote the cost of each vehicle k which starts to visit nodes from initial depot to final depot. This decision variable can depend on total time or distance. Given the interval variables and global constraints defined above, CP-PDPTW is defined as follows:

$$Min \sum_{k \in V} c_k \tag{15}$$

Subject to:

$$Alternative\ (y_i, \{x_{i1}, x_{i2} \dots x_{iV}\}) \qquad \forall i \in N \tag{16}$$

$$Cumulative\ (Step(x_{ik}, q_i | i \in N)) \qquad \forall k \in V \tag{17}$$

$$Nooverlap\ \left(Q_k, Transitiondistance\left(t_{ij} \middle| i, j \in N\right)\right) \qquad \forall k \in V \tag{18}$$

$$Q_k.First(y_0) \qquad \forall k \in V \tag{19}$$

$$Q_k.Last(y_{n+1}) \qquad \forall k \in V \tag{20}$$

$$StartOf\left(x_{D(r)k}\right) \geq StartOf\left(x_{P(r)k}\right) \qquad \forall k \in V \tag{21}$$

The objective function of CP-PDPTW seeks to minimize total cost of each vehicle (15). Constraint set (16) assures that each location except the depot is visited by at most one vehicle. This is made possible since the global Alternative constraint restricts only one of the set of x_{ik} interval variables to be in the solution when y_i is present in the solution. Cumulative global constraints (17) are employed to model the usage of each vehicle k during visits. They ensure the total capacity of each vehicle at any time cannot exceed the capacity of vehicle k. The vehicle usage over time is computed with the help of elementary sub-function *Step*(x_{ik}). It increases and decreases the cumulative usage of each vehicle by loading and unloading at the pickup and delivery nodes of interval variable y_j, respectively.

The time window for each location is defined in interval variables as start and end times. NoOverlap constraints (18) assure that the interval variables in Q_k represent the possible visits of vehicle k in order of the non-overlapping intervals. Furthermore, with the help of *TransitionDistance*(t_{ij}); *NoOverlap* global constraints create a minimal travel time (t_{ij}) between the end of interval variable x_{ik} and the start of interval variable x_{jk} for the pair of consecutive visit locations i and j. Constraints (19) and (20) make the depot the first and the last location to be visited by each vehicle k. Finally, constraint set (21) ensures both origin and destination of a request is served by the same vehicle and delivery can only occur after pickup.

COMPUTATIONAL RESULTS

We need small problem instances as time required by standard MIP solvers to obtain optimal solutions increases sharply with increasing size of the problem instances. From datasets of Li and Lim (2001) which include 100 nodes and 50 requests, we picked randomly 16 nodes to 30 nodes to create new small problem instances. The pickup-and-delivery requests are paired (one to one) and so the number of nodes in the network without the vehicle depots is even.

For computational analysis, the models were implemented in C#, and we used IBM ILOG CPLEX 12.6 for MIP-PDPTW, and IBM ILOG CP Optimizer 12.6 for CP-PDPTW model. All experiments were run on an Intel Core i5 equipped with 2.33 GHz and 12 GB of RAM. The models ended after the optimal solution is found. All computational results reported in the comparison of CP-PDPTW and MIP-PDPTW models are obtained by default settings except the settings on CP parameters which are "searchtype" and "logperiod". Additionally, we defined search phases to specify the order of the search moves and the order in which the values must be tested. We obtained best solutions from searchtype: restart, logperiod:10000 and searchphase(interval variable). As seen from Table 1, the problem specifications including the number of customers and the number of requests for each problem instance are given in the second and the third columns, respectively. For each model, we report the optimal solution and solution time observed from each instance, and the last column gives the solution time gap between the models. It is seen from the table that CP-PDPTW model requires in average 29.15% less time compared to MIP-PDPTW to find the optimum solution.

Table 1. Comparison of CP and MIP Model Solutions for the PDPTW

Instance	Number Of Customers	Number Of Requests	MIP-CPDTW		CP-PDPTW		Solution Time Reduction (%)
			Solution Value	CPU Time	Solution Value	CPU Time	
LC01	16	8	197	1.36	197	0.45	-66.91
LC02	18	9	193	1.62	193	0.55	-66.05
LC03	18	9	101	0.48	101	0.29	-39.58
LC04	18	9	173	3.28	173	0.43	-86.89
LC05	18	9	226	21.11	226	0.36	-98.29
LC06	20	10	160	2.14	160	0.25	-88.32
LC07	20	10	184	24.74	184	2.31	-90.66
LC08	20	10	303	16.24	303	10.8	-33.50
LC09	20	10	232	0.65	232	0.89	36.92
LC10	20	10	194	2.14	194	0.52	-75.70
LC11	20	10	223	0.74	223	0.55	-25.68
LC12	20	10	198	5.34	198	0.37	-93.07
LC13	20	10	253	24.09	253	1.9	-92.11
LC14	20	10	195	25.09	195	0.83	-96.69
LC15	20	10	217	23.26	217	2.08	-91.06
LC16	20	10	204	6.53	204	0.51	-92.19
LC17	22	11	279	60.22	279	2.08	-96.55
LC18	22	11	158	5.96	158	2.08	-65.10
LC19	22	11	264	71.21	264	276	287.59
LC20	22	11	105	0.78	105	0.41	-47.44
LC21	22	11	256	0.73	256	2.66	264.38
LC22	22	11	195	6.64	195	0.39	-94.13
LC23	22	11	140	6.03	140	1.75	-70.98
LC24	22	11	108	6.14	108	2.26	-63.19
LC25	22	11	184	1636.43	184	10.71	-99.35
LC26	24	12	317	1.06	317	1.12	5.66
LC27	24	12	284	5.17	284	1.75	-66.15
LC28	24	12	182	9.25	182	11.32	22.38
LC29	24	12	111	0.79	111	0.49	-37.97
LC30	24	12	249	0.98	249	2.95	201.02
LC31	26	13	220	1.25	220	1.87	49.60
LC32	26	13	324	24.09	324	0.41	-98.30
LC33	26	13	217	1.28	217	3.95	208.59
LC34	28	14	165	29.95	165	2.01	-93.29
LC35	28	14	193	34.9	193	9.14	-73.81
LC36	30	15	160	24.97	160	4.31	-82.74
AVERAGE	-	-	-	**57.96**	-	**10.02**	**-29.15**

The performance of CP-PDPTW was also compared in regard to related solution methods in literature with well-known Li and Lim (2001) problem instances. The datasets and best known solutions are available at http://www.sintef.no/Projectweb/TOP/PDPTW/. We compared those methods which are respectively, adaptive large neighborhood search of Ropke and Pisinger (2006) and hybrid algorithm of Mannel and Borthfeld (2016). CP-PDPTW model was run for two hours. As shown in Table 2, there are 36 instances for comparison, and in the second column of the table the best known solution values for the problem instances are given. In the third, fourth, and fifth columns, the solution values obtained from the respective methods and CP-PDPTW model are given. In the last column, the gap values between the best of existing solutions and ours are given. Since fractional distances create infinite domain ranges, it is impossible for propagation algorithms in CP to identify a feasible solution in finite time. To deal with this problem, the distance values between the nodes have been rounded, and this is why the solution values obtained from CP-PDPTW are integer. According to results, the CP model have found 21 best known solutions out of 36 instances and eight of these solutions are better than the existing ones. Besides, the average solution gap of CP-PDPTW is 1.01% compared to the best known solutions.

Table 2. Comparison of CP-PDPTW model and Related Algorithms

Instances	Number Of Customers	Number Of Requests	#BKN	Männel and Bortfeldt (2016)	Ropke and Pisinger (2006)	CP-PDPTW Solution Value	Solution Value Gap(%)
lc101	106	53	828.94	828.94	828.94	829	0.0
lc102	106	53	828.94	828.94	828.94	829	0.0
lc103	104	52	1035.35	1035.35	1035.35	**828**	**-20.0**
lc104	106	53	860.01	860.01	860.01	**852**	**-0.9**
lc105	106	53	828.94	828.94	828.94	829	0.0
lc106	106	53	828.94	828.94	828.94	829	0.0
lc107	106	53	828.94	828.94	828.94	829	0.0
lc108	106	53	826.44	826.44	826.44	827	0.0
lc109	106	53	1000.60	1000.60	1000.60	**829**	**-17.1**
lc201	102	51	591.56	591.56	591.56	590	0.0
lc202	102	51	591.56	591.56	591.56	590	0.0
lc203	102	51	591.17	585.56	591.17	590	1.4
lc204	102	51	590.60	590.60	590.60	590	0.0
lc205	102	51	588.88	588.88	588.88	588	0.0
lc206	102	51	588.49	588.49	588.49	588	0.0
lc207	102	51	588.29	588.29	588.29	588	0.0
lc208	102	51	588.32	588.32	588.32	588	0.0
lr101	106	53	1650.80	1650.80	1650.80	**1638**	**-0.8**
lr102	110	55	1487.57	1487.57	1487.57	1536	3.3
lr103	104	52	1292.68	1292.68	1292.68	1331	3.0
lr104	104	52	1013.39	1013.39	1013.39	1090	7.6
lr105	106	53	1377.11	1377.11	1377.11	1376	0.0
lr106	104	52	1252.62	1252.62	1252.62	1300	3.8
lr107	104	52	1111.31	1111.31	1111.31	1170	5.3
lr108	100	50	968.97	968.97	968.97	1012	4.4
lr109	106	53	1208.96	1208.97	1208.97	1231	1.8
lr110	104	52	1159.35	1159.35	1159.35	1270	9.5
lr111	108	54	1108.90	1108.90	1108.90	1225	10.5
lr112	106	53	1003.77	1003.77	1003.77	1158	15.4
lrc101	106	53	1708.80	1708.80	1708.80	1696	**-0.7**
lrc102	106	53	1558.07	1558.07	1558.07	1637	5.1
lrc103	106	53	1258.74	1258.74	1258.74	**1254**	**-0.4**
lrc104	108	54	1128.40	1128.40	1128.40	1179	4.5
lrc105	108	54	1637.62	1637.62	1637.62	1666	1.7
lrc106	106	53	1424.73	1424.73	1424.73	**1416**	**-0.6**
lrc107	106	53	1230.14	1230.15	1230.15	**1226**	**-0.3**
Average	**-**	**-**	**1032.44**	**1032.29**	**1032.44**	**1044.56**	**1.01**

CONCLUSION

In this paper, we developed a new CP model for the PDPTW and compared this model with the MIP model which is adapted from the existing literature. The new model, CP-PDPTW, has been shown to be competitive with MIP-PDPTW and can be a reference model for solving variants of vehicle routing problems. CP-PDPTW was also compared with the algorithms in related literature on the well-known existing problem instances. The computational results indicate that CP-PDPTW performs quite well to find out satisfying solutions. It is far too optimistic that CP-PDPTW competes with the metaheuristics algorithms as an exact algorithm in reasonable time but CP-PDPTW can also obtain high-quality solutions with a rather simple model formulation compared to complex design of metaheuristic approaches.

Future work for consideration is related to the development of efficient and effective CP models for variants of pickup and delivery problems by adding symmetry constraints, redundant and global constraints, and devising problem specific search strategies.

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DETERMINING TASK ASSIGNMENT PRIORITIES FOR DISASSEMBLY LINE BALANCING PROBLEM WITH ELECTRE

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Abstract *– Disassembly line balancing has a key role in reverse supply chains. Disassembly line balancing problem has a multi-objective nature. In the literature, there are only three studies which used multi criteria decision making (MCDM) techniques. AHP, fuzzy AHP, M-TOPSIS, PROMETHEE and multi-grouping hierarchy are the MCDM tools used in the disassembly line balancing literature. In this study, it is aimed to determine assignment priorities of tasks in disassembly line with ELECTRE. Criterias are determined according to the studies and clustered in structural (number of successors and part disassembly times), economic (demand and profit), environmental (hazardous and state of the material) and quality (fragility and remaining life) dimensions. Weights are determined via a unique methodology based on binary comparisons of experts across dimensions and factors in consistency with ELECTRE logic. Economic dimension and hazardous criteria are found the most important. ELECTRE gives opportunity to consider both concordance and disconcordance. Application results on the 10-part numerical example (McGovern & Gupta, 2003) shows that sixth part is placed in the first rank different from the other techniques.*

Keywords – Disassembly line balancing, reverse supply chain, multi criteria decision making, ELECTRE

INTRODUCTION

Research on disassembly line balancing (DALB) has been further developed in connection with the environmental regulations, public consciousness, scarcity of resources, and economic profitability of recovery operations over the last twenty-five years in the sustainability context (Esmailian et al, 2016; McGovern & Gupta, 2007). Disassembly can be defined as a "systematic process in which a product is separated to its parts, components, sub-assemblies and the other groups" is the critical, initial and the most time consuming step for all of end-of-life (EOL) products in choices (reuse, recycling, remanufacturing, storage and disposal) (Ding et al, 2010; Kalaycı & Gupta, 2013). Although disassembly can be done in one single work station or cells which are more flexible (Ilgın, 2010), work-load intensity and expensive activities makes disassembly lines are important in reverse supply chains (Özceylan & Paksoy, 2013; Prakash & Tiwari, 2005). Disassembly sequencing and disassembly line balancing are the major study areas in disassembly literature area (Koç et al, 2009). Disassembly line balancing problem (DLBP) which is proposed by Gungor & Gupta (2001) is defined as "assignment of tasks to workstations such that all precedence relations between the tasks are satisfied and some measure of effectiveness is optimized" (Ding et al, 2010). The research on disassembly line balancing is going on both metaheuristic approaches and exact solution approaches (Özceylan et al, 2018). By the way there are only three articles used MCDM techniques in solving DALB problem (Avikal et al, 2014 (a), Avikal et al 2014 (b), Ren et al, 2018). Fuzzy AHP & PROMETHEE, AHP & M-TOPSIS and multi-grouping hierarchy are the MCDM methods used in this context. Intuitiveness, the natural appeal of a semantic scale it employs for expressing relative importance, availability of the user-friendly software, and a hierarchical decomposition of the multiple criteria problems being efficient from both operational and computational viewpoints are the reasons of the popularity of AHP. TOPSIS's simple computation process is appreciated by the practitioners (Govindan et al, 2018). By the way, these approaches has also some major weaknesses. Avikal et al (2014-b) also stated their proposed method's computational complexity. ELECTRE methods can be used to overcome

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time consuming process of AHP and an arbitrary normalization of the original evaluations on different criteria scales into a common scale of TOPSIS (Govindan et al, 2018).

The first contribution of this study is using ELECTRE method as a new tool in DALB problem. To the best of our knowledge there isn't any study used ELECTRE in disassembly line balancing literature. The other contribution is combining ELECTRE with a novel and simple technique to determine the weights of the criterion. The criteria set used in this paper is also the largest set (8 criteria) in the literature.

The rest of the paper is structured as follows: In the second part of the study review of literature on MCDM in DALB is presented. ELECTRE method is presented in the third section step by step. The fourth part of the study id dedicated to the implementation. Finally, the conclusion section summarizes the implication results and draws some avenues for future research.

REVIEW OF LITERATURE ON MCDM IN DISASSEMBLY LINE BALANCING

In this section, we present recent research has been done in the area of MCDM usage in DALBP. There are only three articles used MCDM techniques in solving DALB problem (Avikal et al, 2014 (a), Avikal et al, 2014 (b), Ren et al, 2018). Fuzzy AHP &PROMETHEE, AHP & M-TOPSIS and multi-grouping hierarchy are the MCDM methods used in this context. In Table 1, we summarize the journal papers on MCDM usage in DALB.

Table 1 Summary of journal papers on MCDA usage in DALB

No	Year	Authors	Journal	MCDM method
1	2014	Avikal et al (a)	International Journal of Production Research	Fuzzy AHP &PROMETHEE
2	2014	Avikal et al (b)	Applied Soft Computing	AHP & M-TOPSIS
3	2018	Ren et al	Journal of Cleaner Production	Multi-grouping hierarchy

In the first paper, Avikal et al (2014-a) used fuzzy AHP and PROMETHEE method based heuristic for DALB problem. Number of followers, revenue generated, part demand, disassembly time and part hazardous are the five criteria have been considered in this paper. They applied the proposed heuristic for ten-part McGovern and Gupta (2003) problem. In the same year, the same researchers (Avikal et al, 2014-b) used fuzzy AHP and modified TOPSIS (M-TOPSIS) this time. State of the material and fragility are the new criteria added to model in this paper. This 7 criteria model implemented to the same computational example of McGovern & Gupta (2003). In the last paper, criteria are enlarged with remaining life and state of the material. A multi-grouping hierarchy is developed based on min-max normalization, fuzzy Choquet integral and 2-opt algorithm. The same case study (McGovern & Gupta, 2003) is used in this paper.

ELECTRE Method

In this section, we introduce the ELECTRE (ELimination Et Choix Traduisant la REalité -Eng. ELimination and Choice Expressing the REality) method step by step with additional equations, formulae and matrices.

Multi-criteria decision analysis (MCDA) has attracted increasing attention of researchers for more than half a century as a sub-field of operations research or management science (Govindan & Jepsen, 2016). According to the classification of Belton and Stewart (2002), MCDA methods can be categorised in three groups: Value measurement models, reference level models and outranking models. ELECTRE methods are popular in the context of outranking methods (Govindan & Jepsen, 2016).

ELECTRE is first introduced in early 1960s by Bernard Roy and some of his colleagues from SEMA consultancy group (Bezdrob et al, 2011). ELECTRE family is enlarged after the first article written by Roy (1968) in 40 years. ELECTRE II (Roy & Bertier, 1971), ELECTRE III (Roy, 1978), ELECTRE IV (Roy & Hugonnard, 1982), ELECTRE TRI (Yu, 1992; Roy & Bouyssou, 1993) and ELECTRE IS (Roy & Bouyssou, 1993) are some of the members of this family (Govindan&Jepsen, 2016). Decision maker should use one of these methods according to the problem type (ranking, sorting etc.). Nonetheless each method consists of aggregation and exploitation phases. Alternatives are compared with pairwisely according to concordance and non-discordance concepts (Govindan & Jepsen, 2016).

Govindan et al (2018) combined ELECTRE-I and Stochastic Multi-criteria Acceptability Analysis (SMMA) to select the most preferred service provider in outsourcing RL to third-party reverse logistics providers (3PRLPs). Galo et al (2018) combined ELECTRE TRI with hesitant fuzzy in supplier evaluation and categorization process. ELECTRE is used in virtual embedding problem by Zhang et al (2018). 153 of 544 papers (ELECTRE article number until 2016) are the applications of ELECTRE in natural resources and environmental management. Also there are 38 papers in logistics and supply chains. According to these results, it can be seen that ELECTRE is a suitable method in this paper (Govindan & Jepsen, 2016).

The steps of the ELECTRE algorithm are as follows (Zang et al, 2018; Supraja & Kousalya, 2016; Yaralıoğlu, 2010):

Step1: Calculation of Decision Matrix (A): Decision points are stated in rows and evaluation criteria are stated in columns of decision matrix. m denotes decision point number and n denotes evaluation factor number where each element *aij* represents the metric value of *i-th* evaluation criterion of *j-th* solution.

$$A_{ij} = \begin{bmatrix} a_{11} & a_{12} & \dots & a_{1n} \\ a_{21} & a_{22} & \dots & a_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ a_{m1} & a_{m2} & \dots & a_{mn} \end{bmatrix} \tag{1}$$

Step2: *Calculation of Normalized Decision Matrix* (X): The normalized matrix denoted by *X* can be obtained through the normalization of column vectors with the formulae:

$$x_{ij} = \frac{a_{ij}}{\sqrt{\sum_{k=1}^{m} a_{kj}^2}} \tag{2}$$

The aim of *this* step is to eliminate the impacts of different metric values in different dimensionalities.

$$X_{ij} = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1n} \\ x_{21} & x_{22} & \dots & x_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ x_{m1} & x_{m2} & \dots & x_{mn} \end{bmatrix} \tag{3}$$

Step3: Calculation of Weighted Normalized Decision Matrix (Y): Evaluation criteria's importance can be different according to decision makers. The first step of this stage is determining weights of each evaluation factor (w_i) to satisfy the $\sum_{i=1}^{n} w_i = 1$ constraint. The weighted normalized decision making matrix Y elements can be calculated with multiplying w_i values with X matrix.

$$Y_{ij} = \begin{bmatrix} w_1 x_{11} & w_2 x_{12} & \dots & w_n x_{1n} \\ w_1 x_{21} & w_2 x_{22} & \dots & w_n x_{2n} \\ . & & & . \\ . & & & . \\ . & & & . \\ w_1 x_{m1} & w_2 x_{m2} & \dots & w_n x_{mn} \end{bmatrix} \tag{4}$$

Step 4: Calculation of the concordance set (C_{kl}) and disconcordance set (D_{kl}): Consistent sets are defined according to the comparison of decision points via (….) relationship when the objective is maximization (the bigger is better).

$$C_{kl} = \{j, y_{kj} \geq y_{lj}\} \tag{5}$$

A non-consistent set is correspond to each concordance set. Disconcordance set elements are j values not belonging to consistent set.

Step 5: *Calculation of the concordance matrix (C) and disconcordance matrix (D)*

The concordance matrix *C* can be obtained by adding the weighted value of each element in each concordance set. C matrix is mxm dimensional and there isn't value for diagonal elements.

$$c_{kl} = \sum_{j \in C_{kl}} w_j \tag{6}$$

$$C = \begin{bmatrix} - & c_{12} & c_{13} & \dots & c_{1m} \\ c_{21} & - & c_{23} & \dots & c_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ c_{m1} & c_{m2} & c_{m3} & \dots & - \end{bmatrix} \tag{7}$$

The disconcordance matrix (D) can be expressed as follows:

$$d_{kl} = \frac{\max\limits_{j \in D_{kl}} |y_{kj} - y_{lj}|}{\max\limits_{j} |y_{kj} - y_{lj}|} \tag{8}$$

By the same token D matrix is mxm dimension and there isn't value for k=l

$$D = \begin{bmatrix} - & d_{12} & d_{13} & \dots & d_{1m} \\ d_{21} & - & d_{23} & \dots & d_{2m} \\ . & & & & . \\ . & & & & . \\ . & & & & . \\ d_{m1} & d_{m2} & d_{m3} & \dots & - \end{bmatrix} \tag{9}$$

Step 6: *Calculation of Concordance Dominance (F) and Disconcordance Dominance (G) Matrix:* mxm dimensional concordance dominance (F) matrix elements are obtained according to the comparison of concordance threshold value ($\underline{c}$) and concordance matrix (c_{kl}) elements. Based on the threshold value ($\underline{c}$),

$$\underline{c} = \frac{1}{m(m-1)} \sum_{k=1}^{m} \sum_{l=1}^{m} c_{kl} \tag{10}$$

The binary elements of the concordance dominance matrix F are next determined as follows: if $c_{kl} \geq \underline{c} \Rightarrow f_{kl} = 1$, else $c_{kl} < \underline{c} \Rightarrow f_{kl} = 0$. Correspondingly the discordance dominance matrix G is defined by using a threshold value d.

$$\underline{d} = \frac{1}{m(m-1)} \sum_{k=1}^{m} \sum_{l=1}^{m} d_{kl} \tag{11}$$

The binary elements of the disconcordance dominance matrix G are next determined as follows: If $d_{kl} \geq \underline{d} \Rightarrow g_{kl} = 1$, else $d_{kl} < \underline{d} \Rightarrow g_{kl} = 0$.

Step 7: *Calculation of Aggregate Dominance Matrix* (E): The elements (e_{kl}) of E is calculated with the product of element value in consistent matrix (f_{kl}) and the corresponding element value (g_{kl}) in non-consistent matrix. Besides E matrix is mxm dimensional and elements are 0/1. Solutions are sorting according to their weighted sum of the net dominating value.

MULTIPLE CRITERIA DECISION ANALYSIS METHOD FOR THE ASSESSMENT OF DISASSEMBLY LINE BALANCING PRIORITIES

This section describes a multiple criteria decision analysis method that has been used to evaluate DALB priorities. This section consists of three stages: criteria determination, weight determination and ELECTRE implementation.

Criteria Determination

First of all, criteria which used in previous research are analyzed. It can be seen from Table 2 that the criteria are DALB objectives used in objective functions in multi objective type problem. The last column consists of criteria used in this paper.

Table 2 Summary of criteria used

Criteria	Avikal et al 2014 a	Avikal et al 2014 b	Ren et al 2018	This paper
Number of followers	√	√		√
Revenue Generated**	√	√	√	
Part Demand	√	√	√	√
Disassembly Time (Task Time)	√	√		√
Part Hazardous	√	√	√	√
State of material (gas, liquid, solid)		√	√	√
Fragility		√	√	√
Workstation number*			√	
Line balance*			√	
Disassembly cost**			√	
Profit			√	√
Remaining life			√	√
TOTAL	5	7	6*,**	8

* **These criteria are not handled in MCDM method. They used in 2-opt local search algorithm to minimize.**
** **These criteria are reduced since profit is calculated with the difference of revenue and cost.**

Criteria (objectives) are classified in four factors in Ren et al (2018)'s article. Workstation number and line efficiency is stated in first dimension called efficiency factors. The second factor (economic) is consists of part demand, revenue, cost and profit. Part hazardousness and state of the material are classified in environmental factor (third) and fragility and remaining life are classified in the last quality factor. A criteria set is constituted from the previous papers. As a result the set has the largest number of criterion in the literature. In this study 8 criteria are distributed to four dimensions equally (Table 3)

Table 3 Dimensions of criteria

		O1	O2	O3	O4	O5	O6	O7	O8
A	structural	*	*						
B	economic				*	*			
C	environmental			*					*
D	quality						*	*	
	O1: number of successors, O2: part disassembly times, O3: hazardous, O4: demand, O5: profit, O6: fragility, O7: remaining life, O8: state of the material								

A Novel Technique to Determine Weights

ELECTRE needs to determine weights of criteria before the implementation. ELECTRE TRI Assistant is one of the software used to infer the criteria weights (Govindan & Jepsen, 2016). In this step, a smart questionnaire consists of 5 binary comparison (in AHP 20 binary comparison are needed) to rank the dimensions is developed. The roots of this approach is Deniz's (2016) PhD thesis and it was benefited from Gülmez (2005) and Büyüközkan et al (2011) studies. The first two questions are fixed but consequent questions are arise according to the answers of the first and second answers. This questionnaire is responded by 3 experts in Industrial Engineering Department of Eskisehir Osmangazi University. The general question is "Which dimension is more important? ….. or ….." The answers of each respondent can be seen in Table 4(a) and the results are in Table 4(b).

Table 4 (a). Weighting the Dimensions

Question Number				**Answer (1)**				**Answer (2)**				**Answer (3)**
Q1	A	or	B	A	A	or	B	B	A	or	B	B
Q2	C	or	D	C	C	or	D	C	C	or	D	C
Q3	A	or	C	A	B	or	C	B	B	or	C	C
Q4	B	or	D	B	A	or	D	D	A	or	D	A
Q5	C	or	B	B	C	or	D	C	B	or	A	B

Table 4 (b). Weighting the Dimensions

RESULT(1)		**(2)**	**(3)**
1	A	B	C
2	B	C	B
3	C	D	A
4	D	A	D

In the next step, factors in each dimension are binary compared. The general question is "Which criterion is more important? ….. or …..". The answers of the respondents are in Table 5.

Table 5. Weighting the Criteria

Question Number				**Answer (1)**	**Answer (2)**	**Answer (3)**
Q1	O1	or	O2	O1	O2	O1
Q2	O4	or	O5	O4	O5	O5
Q3	O3	or	O8	O3	O3	O3
Q4	O6	or	O7	O7	O6	O7

The answers used to determine weights of both criteria and dimensions. The logic behind this method is to be the first rank have twice importance of being in the second rank. Correspondingly being in the second rank has twice importance than being in the third rank. As a result being in the first rank has 0.533 and being the second has 0.267 weight. 0.133 and 0.067 are the third and fourth rank weights respectively. Weights of dimensions are determined with normalization in the last column of Table 6 (a).

Table 6 (a). Weigths of Dimensions

	1	2	3	4	Weights	Normalized Weights
A	1		1	1	0.733333333	0.255813953
B	1	2			1.066666667	0.372093023
C	1	1	1		0.933333333	0.325581395
D			1	2	0.133333333	0.046511628

The rank weights related to objectives in each dimensions are easily calculated again with the same logic. The weights are determined 0.067 and 0.33 according to the results. For example for structural dimension (A), O1 and O2 criteria weights are calculated after normalization.

Table 6 (b). Weigths of Criteria

	1	2	Weights	Normalized Weights
O1	2	1	1.666667	0.555556
O2	1	2	1.333333	0.444444

In the last stage, the weights of each criterion is calculated with the product of criteria weight with related dimension's weight. For example, O1's weight is calculated with the product of A dimension weight (0.2558) and O1 normalized weight (0.555) and it is found that 0.142. Table 7 shows all the criteria weight used in ELECTRE implementation.

Table 7. The weights of each criterion

Criteria	Overall Weights
O1	0.142119
O2	0.113695
O3	0.217054
O4	0.206718
O5	0.165375
O6	0.020672
O7	0.02584
O8	0.108527

The comparison with other studies show that there is a consistency in the most important criterion. For example, in Avikal et al (2014-a) paper in which weights are determined with fuzzy AHP, the weight of part hazardous is determined as 0.5055 and this means it has the most important weight. In Avikal et al (2014-b) paper the weight of part hazardous is decreased to 0.413009 but still it was the most important criterion. The part hazardous has the most important in Ren et al (2018) study with the 0.7435 degree but this isn't a normalized value. Also in our study, part hazardous get the higher weight with 0.217054. But there is differences in the other criteria weights. For example, state of the material has the lowest weight in Ren et al (2018) model but in this paper remaining life has the lowest value.

ELECTRE Implementation

The ELECTRE method is applied to the computational example given in McGovern & Gupta (2003). By this way it is aimed to make comparison because this case study is used in all three paper before. Table 8 consists of related data.

Table 8. The computational example data (McGovern & Gupta, 2003)

Part No	O1	O2	O3	O4	O5	O6	O7	O8
1	1	14	0.0454	0	-10	0.2365	0.5	2
2	0	10	0.1399	500	55	0.6223	0.3777	1
3	0	12	0.01399	0	-11	0.3777	0.2365	3
4	2	18	0.5	0	-5	0.0454	0.5	1
5	3	23	0.3777	0	-6	0.1399	0.5	1
6	3	16	0.1399	750	12	0.1399	0.5	1
7	2	20	0.7435	295	72	0.0454	0.1399	1
8	1	36	0.1399	0	-9	0.0454	0.7435	1
9	1	14	0.0454	360	15	0.6223	0.5	1
10	1	10	0.5	0	-8	0.1399	0.2365	2

Only seventh criterion is an objective to minimize and the others are needed to maximize. To make a simple calculation and use the same formulae in spreadsheet, we translate seventh criterion values to with 1 minus values. The normalized decision matrix (X) is generated in the first step (Table 9).

Table 9. Normalized Decision Matrix (X)

X	O1	O2	O3	O4	O5	O6	O7	O8
1	0,18	0.00	0.04	0.00	-0.11	0.23	0.26	0.41
2	0.00	0.49	0.12	0.49	0.58	0.61	0.33	0.20
3	0.00	0.00	0.01	0.00	-0.12	0.37	0.40	0.61
4	0.37	0.00	0.45	0.00	-0.05	0.04	0.26	0.20
5	0.55	0.00	0.34	0.00	-0.06	0.14	0.26	0.20
6	0.55	0.74	0.12	0.74	0.13	0.14	0.26	0.20
7	0.37	0.29	0.66	0.29	0.76	0.04	0.45	0.20
8	0.18	0.00	0.12	0.00	-0.09	0.04	0.14	0.20
9	0.18	0.35	0.04	0.35	0.16	0.61	0.26	0.20
10	0.18	0.00	0.45	0.00	-0.08	0.14	0.40	0.41

The weights calculated in the previous stage (Table 7) are used and the weighted normalized decision matrix is generated (Table 10).

Table 10. Weighted Normalized Decision Matrix (Y**)**

Y	O1	O2	O3	O4	O5	O6	O7	O8
1	0.03	0.00	0.01	0.00	-0.02	0.00	0.01	0.04
2	0.00	0.06	0,03	0.10	0.10	0.01	0.01	0.02
3	0.00	0.00	0.00	0.00	-0.02	0.01	0.01	0.07
4	0.05	0.00	0.10	0.00	-0.01	0.00	0.01	0.02
5	0.08	0.00	0.07	0.00	-0.01	0.00	0.01	0.02
6	0.08	0.08	0.03	0.15	0.02	0.00	0.01	0.02
7	0.05	0.03	0.14	0.06	0.13	0.00	0.01	0.02
8	0.03	0.00	0.03	0.00	-0.02	0.00	0.00	0.02
9	0.03	0.04	0.01	0.07	0.03	0.01	0.01	0.02
10	0.03	0.00	0.10	0.00	-0.01	0.00	0.01	0.04

(5), (6) and (8) formulae are used to define concordance & disconcordance sets and concordance matrix **(**C) (Table 11.a) and disconcordance matrix (D) (Table 11.b) are computed.

Table 11.a. Concordance Matrix (C)

1	0.25	0.845	0.475	0.48	0.155	0.13	0.618	0	0.5917
0.75	1	0.866	0.641	0.64	0.537	0.45	0.858	1	0.5065
0.48	0.28	1	0.475	0.48	0.155	0.13	0.475	0	0.4755
0.87	0.47	0.845	1	0.84	0.351	0.27	1	0	0.845
0.87	0,47	0.845	0.618	1	0.514	0.27	1	0	0.6486
0.87	0.79	0.845	0.783	0.78	1	0.59	1	1	0.6486
0.87	0.66	0.871	1	0.84	0.517	1	1	1	0.8708
0.84	0.47	0.845	0.45	0.43	0.326	0.13	1	0	0.4625
0.89	0.27	0.866	0.641	0.64	0.32	0.45	0.783	1	0.6486
0.98	0.49	0.871	0.693	0.69	0.372	0.13	1	0	1

Table 11.b. Disconcordance Matrix (D)

0	0.74	0	0.5755	0.421	1	0.94	0.1196	0.48	0.576
0.222	0	0	0.5966	0.667	0.667	1	0.2222	0.222	0.597
0.17	0.75	0	0.6153	0.509	1	0.95	0.1698	0.48	0.615
0.145	0.68	0	0	0.17	1	0.88	0	0.48	0.145
0.145	0.7	0	0.1548	0	1	0.89	0	0.48	0.155
0.19	0.64	0	0.5966	0.394	0	1	0	0.084	0.597
0.239	0.45	0	0	0.28	1	0	0	0,143	0.239
0.145	0.73	0	0.4559	0.34	1	0.92	0	0.48	0.456
0.164	0.52	0	0.6512	0.476	0.588	1	0.1354	0	0.651
0.013	0.72	0	0.1698	0.34	1	0.91	0	0.48	0

Concordance threshold value (0.61) is calculated with the product of sum of concordance matrix column sum minus 10 and 1/90 via formulae (10). Similarly disconcordance threshold value is found to be 0.358 from disconcordance matrix via 11th formulae. The concordance dominance (F) and disconcordance dominance (G) matrices are generated according to these threshold values. These matrices are in Table 12.a and Table 12.b respectively.

Table 12.a. Concordance Dominance (F) Matrix

1	0	1	0	0	0	0	1	0	0
1	1	1	1	1	0	0	1	1	0
0	0	1	0	0	0	0	0	0	0
1	0	1	1	1	0	0	1	0	1
1	0	1	1	1	0	0	1	0	1
1	1	1	1	1	1	0	1	1	1
1	1	1	1	1	0	1	1	1	1
1	0	1	0	0	0	0	1	0	0
1	0	1	1	1	0	0	1	1	1
1	0	1	1	1	0	0	1	0	1

Table 12.b. Disconcordance Dominance (G) Matrix

0	1	0	1	1	1	1	0	1	1
0	0	1	1	1	1	1	0	0	1
0	1	0	1	1	1	1	0	1	1
0	1	0	0	0	1	1	0	1	0
0	1	0	0	0	1	1	0	1	0
0	1	1	1	1	0	1	0	0	1
0	1	1	0	0	1	0	0	0	0
0	1	0	1	0	1	1	0	1	1
0	1	0	1	1	1	1	0	0	1
0	1	0	0	0	1	1	0	1	0

After all computational steps, we reach the aggregate dominance matrix (E) (Table 13)

Table 13. Aggregate Dominance Matrix (E)

E	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**Row sum**
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	1	1	1	0	0	0	0	0	3
3	0	0	0	0	0	0	0	0	0	0	0
4	0	1	0	0	0	0	0	0	0	0	1
5	0	1	0	0	0	0	0	0	0	0	1
6	0	1	1	1	1	0	0	0	0	1	5
7	0	1	1	0	0	0	0	0	0	0	2
8	0	0	0	0	0	0	0	0	0	0	0
9	0	1	0	1	1	0	0	0	0	1	4
10	0	1	0	0	0	0	0	0	0	0	1

According to the sum of each row in E, the sixth part has the first priority to assign in a line. The ninth part is the second and the second part is the third part. ELECTRE method is used for selecting the best out of alternatives. It doesn't sort alternatives but here we have a primitive sort [6, 9, 2, 7, (4, 5, 10), (1,3,8)] and this sort gives us a flexibility to use with precedence constraint. In Avikal et al (2014-a) paper, the seventh part is found to be the first rank to assign a station. Rank is [7, 2, 6, 9, 8, 3, 5, 4, 1, 10]. Again the seventh part has the first rank in Avikal et al (2014-b) study in [7, 6, 9, 2, 8, 4, 5, 3, 1, 10] and in Ren et al (2018) study in [7, 10, 2, 4, 6, 5, 9, 3, 8, 1].

CONCLUSIONS

Disassembly line balancing is a promising area in the sustainability context and has a key role in reverse supply chains. This problem is solved generally by exact solution methods and metaheuristic algorithms. There are only three papers used MCDM tools to solve DALB problem. Fuzzy AHP is used to determine weights and PROMETHEE, M-TOPSIS and multi-hierarchy grouping are used to rank tasks in previous papers. We presented a MCDM tool to solve DALB problem with combining a novel weighting approach and ELECTRE method to determine priorities to assign tasks to stations. This study differs from other studies with using different weighting and MCDM method.

To conclude this paper, we can summarize our findings that our weighting approach is consistent with the other approaches finding the most important criterion but it differs in the other criteria. The part which has the highest priority to assign the stations is different from the other studies.

From the application point of view, the research results in our study could be further validated by other computational examples and real case studies. From the methodological viewpoint, the proposed approach can be extended to a group decision making framework.

The limitation of this study is the expert numbers. It can be enlarged in the future studies. In the future, the study will be completed with assigning the tasks to stations according to the priorities found in this paper. Also the rank can be determined ELECTRE-III designed for ranking. By this way, MCDM methods can be compared with line efficiency indicators. ELECTRE method can be fuzzified. Hesitant fuzzy will be suitable for this case study. Also, Intuitionistic Fuzzy ELimination Et Choix Traduisant la RÉalité (IFELECTRE) method proposed by Erdebilli (2018) can be used in the future. Different MCDM methods can be used and compared with the others. Further improvements can be made adding new criteria in the MCDM methods.

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OPTIMIZING WAREHOUSE STORAGE ASSIGNMENT UNDER SEASONAL DEMAND PATTERN

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Abstract *− Picking is the most costly operation in the warehouse management. Picking effectiveness is linked to many interrelated factors, such as warehouse design, order batching, routing and storage assignment strategies. In this study, we investigate the effects of storage assignment on the order picking cost of an FMCG warehouse. The most frequently used assignment approaches are random, turnover-based and affinity-based assignment. Random assignment places items to any available place. Turnover-based assignment locates items with respect to order frequencies. Affinity-based assignment locates items with respect to each other based on the existence of multiple items together in the picking lists. Extensions to these traditional strategies have been studied in the literature. In this study, we aim to develop a hybrid storage assignment heuristic combining the turnover and affinity-based slotting strategies under the consideration of seasonality. We use a 12 month FMCG warehouse delivery data. First we explore the seasonality of the SKUs and then optimize the item assignments to storage locations with minimum seasonal rearrangement and order picking costs. We use an efficient heuristic algorithm to obtain near-optimal solutions and then explore the effects of various factors on the optimal solutions.*

Key words: heuristic optimization, seasonality, storage assignment, warehouse management

INTRODUCTION AND BACKGROUND

Warehouse operations have been gaining importance since the emergence of multi-national companies and off-shore production. This trend is continuing with the increasing share of online shopping in the world. As the warehouses grow in size, the number of SKUs and the amount of products increase and responsiveness to customers is required, effective management and planning of warehouses become crucial. In warehouses, there exists various interrelated operations such as item storage, retrieval, batching, picking, sorting, etc. Planning efforts to manage these operations may handle one problem area independently or focus on an integrated problem as a combination of multiple problems. In this study, we focus on storage operation and deal with the storage assignment (allocation), or slotting problem and evaluate its effect on picking operations.

Storage assignment problem influences the efforts required to place incoming material to the racks in the warehouses as well as it has a direct influence on the picking operations which includes the collection of the outgoing items from the racks in a warehouse. The storage assignment problem can be differently specified based on the assignment policy used by the warehouse. The most common policies are random, dedicated and class-based assignment policies. In dedicated or class-based warehouse storage policies, each SKU or each SKU class respectively has a specific address and can only be placed to their dedicated places. In this case, an assignment problem need to be solved to decide how to dedicate the locations to the items. There exist various methods used to decide the best assignments. In single-command operation, where only one place is visited per trip turnover-based assignment works very well. In this type of assignment, the fast movers (i.e. frequently ordered SKUs) are allocated to the closest points. Cube per Order Index (COI) slotting strategy (Mantel et al., 2007) is an approach validated in the literature to give well results for single-command picking. However not all operations are single-command in most of the warehouses. Commonly, customer orders include more than one type of product and they are collected in one trip. This type of picking is named as multi-command and in this case, the correlation or affinity among the SKUs gains importance. When the picking is not single command type, Schuur (2015) show that using only COI slotting may result in infinitely bad results. In multi-command cases if the items that are ordered together are allocated to locations close to each other, the picking distances

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can be reduced. To include the affinity issue, there are various approaches in the literature. (Mantel et al.) 2007 offer an order oriented slotting (OOS) where items are clustered into a zone using the joint probabilities of pairs of items to be in the same order. Trevino et al. (2009) report that OOS performs well when every SKU is picked in a fixed sequence among other items, meaning that a SKU should not appear in different picking sequences. To understand how this limitation affects the solution quality, they propose a mixed integer linear programming model to find the optimal solution for small-sized problems and make comparisons of OOS results with optimality for different order sequences. Tsige (2013) whereas show that when SKU distribution over the orders are uniform random slotting performs well. It is also concluded that when 20% of SKUs appear in 80% of orders in parallel to the Pareto principle, OOS gives better results. Kofler et al. (2010) propose PF/PA score which is a linear combination of COI based factor and OOS based factor for slotting. Wutthisirisart et al. (2015) propose a linear placement approach, namely the Minimum Delay Algorithm (MDA) that considers item relationships and order characteristics to generate an item storage layout. They claim that for frequently ordered items, the contribution of placing them close to I/O is more if they are not ordered with other items. Additionally, in MDA, they aim to consider the pick sequence by a linear placement concept. A model formulation and a 2-phase heuristic solution method are proposed. Zhang (2016) uses the item pair's correlation to include the affinities via a clustering based and an improvement based approach to show their better performance compared to turn-over based approach.

Another issue in the storage assignment is the seasonality of the SKUs. Some SKUs can be fast-movers during a time-period and then they become slow-movers in another time period. Thus, the seasonality of the SKUs is also a significant factor for reducing the picking distances. Kofler et al. (2015) propose that dynamic order pattern is important for slotting and define a multi-period storage location assignment problem. They develop a heuristic solution method that first constructs initial solution using random storage and COI and then make improvements by local search and simulated annealing using the PF/PA score.

In this study, we define the storage assignment problem as identifying the most appropriate location (address) of each SKU in the warehouse considering the location's distance to the input/output door of the warehouse and then evaluate the performance of the solution using picking distances. We deal with an order list including both multi-command picking. We define the problem considering both the turn-over and affinities between the SKUs. We do not cluster the items into groups as common in the OOS literature but we use a counting approach for quantifying the affinities. Then, we compute a score similar to the PF/PA score of Kofler (2010). Moreover, the seasonality factor is also included in the computed score using the variances of the seasonality indices. Then, we propose a one phase and a two-phase hybrid heuristic approach and present a case study for a multi-national FMCG company.

The paper is organized as follows: we first present our solution methodology. Next we describe the case study and report our computational results and finally make concluding remarks.

SOLUTION METHODOLOGY

We propose a heuristic algorithm for the storage assignment problem in a multi-command picking warehouse. The proposed algorithm has two main steps. In the first step, a placement rating for each SKU is calculated. The placement rating is calculated using two components, the order frequency and the affinity of the SKU with all other SKUs. The affinity of a pair of SKU is described as the number of orders in which two SKUs are ordered together. Each order is assumed to be picked in one trip. If the order has only one SKU, the trip will be going to the location of that SKU and coming back to the input/output point. If there exists more than one SKUs in the order, there will be multiple stops, that are the locations of the SKUs in the orders, in one trip. We will deal with multiple item picking trips so affinities will be considered in the proposed assignment algorithm together with the order frequencies. The order frequency and the affinity factors are first normalized to a scale between 0 and 1 and then combined linearly using a parameter, $0<\alpha<1$, to obtain the placement rating without seasonality effect. We also take the SKU seasonality into account. In parallel with the seasonal index calculation, we compute the monthly seasonal rates by dividing each month's order amount to the average monthly order amount. To obtain a single value that represent the seasonality of a SKU, we calculate the variance of the monthly seasonal rates. Then we divide the combined order frequency and affinity rating factor to the seasonality factor to obtain the placement rating values of the SKUs.

Then we propose two approaches to assign the SKUs to the locations (i.e. racks). The detail of the two approaches are as follows:

- In the first approach, we only use the placement rating and assign non-placed SKU with the highest placement rating to the available closest location one by one until all SKUs are assigned to a location. To do this, we first sort the SKUs in descending order of the placement ratings. In this sequence, assign each SKU to the available (empty) closest location.

- In the second approach, we aim to include the affinities between the placed and non-placed SKUs to make the assignments. We start to place a certain amount of SKUs only using the placement ratings, in other words using the first approach so that some items become assigned and some items are not assigned yet. After this point, we check the total affinity of the SKU to be placed with the SKUs that are already placed in each row of the warehouse. Then, the row that has the highest affinity between the SKU to be placed and the SKUs already placed in that row is chosen to be the row that the SKU will be placed. The closest available place in that row is chosen as the exact address of the placement. All SKUs are placed one by one until there exists no non-assigned SKU.

The details of the solution methodology are summarized as follows:

Notation

Total number of SKUs, n
The list of SKUs, P: $\{1,2, \ldots, n\}$
The number of rows in the warehouse, m,
The list of Rows, W: $\{1,\ldots, m\}$
B_u: number of storage locations in row u
F_i : order frequency (number of orders including SKU i)
NF_i: normalized order frequency, $0< NF_i <1$
AR_{ij} : Affinity Rating (number of orders including both SKU i and j)
$NTAR_i$: normalized total affinity rating, $0< TAR_i <1$
R_i: Placement Rating
$R=\{R_1, R_2, \ldots, R_n\}$
S_u: $\emptyset$ is the placement sequence of row u
S_{iu} : i^{th} SKU to be placed at row u
S_i : SKU i to be placed at row u
M_{it} : monthly seasonality rate of SKU i in month t
O_{it} :order amount of SKU i in month t
V_i: seasonality factor (variance of seasonality rate of SKU i)
i and j: indices of SKUs,
u: index of rows

Pseudo Code

Input Calculations

For i =1 to n, where $i \in P$

$$M_{it} = \frac{O_{it}}{\sum_{t=1}^{12} O_{it} /12}, \forall t = \{1,2, \ldots 12\}$$

$$V_i = Var\,(M_{it}), \text{where } t = \{1,2, \ldots 12\}$$

$$NF_i = \frac{F_i - \min\limits_{i=1,..,n} F_i}{\max\limits_{i=1,..,n} F_i - \min\limits_{i=1,..,n} F_i}$$

$$TAR_i = \sum_{j=1}^{n} AR_{ij}$$

$$NTAR_i = \frac{TAR_i - \min\limits_{i=1,..,n} TAR_i}{\max\limits_{i=1,..,n} TAR_i - \min\limits_{i=1,..,n} TAR_i}$$

$$R_i = [\alpha NF_i + (1-\alpha) NTAR_i]/V_i,\ 0< \alpha <1$$

Step 1

Sort R_i in descending order

For i =1 to n

Choose the SKU with the greatest R_i, i = 1,…,n

If ties exist, choose the one with greatest NF_i. If ties still exist break randomly.

Assign the SKU with the greatest R_i to the available closest location

S_i, P = P – { S_i}, R = R - {R_i}

Step 2

For i =1 to n, where i ∈ P

From among the SKUs in P, calculate the $TAR_{iu} = \sum_{j=1}^{n} AR_{ij}, j \in S_u, \forall u$

Choose $\max_{i \in P, u \in W} TAR_{iu}$

S_{iu}, P = P – { S_{iu}}

Insert S_{iu} in S_u, the placement sequence of row u

If $|S_u|=B_u$ Then $W=W$-{u}

Stop when $P=\emptyset$

CASE STUDY AND COMPUTATIONAL RESULTS

To evaluate the performance of the proposed heuristic algorithm and index based on affinity, frequency and seasonality values of each product, real data is gathered from an international FMCG (Fast-Moving Consumer Goods) company. This company has one of its distribution center located in Gebze, Turkey. According to sales reports of the last 3 years, there are 384 different products in this distribution center. However, in this case study, 284 products, which are sold frequently in higher amounts, are included to the product list. Layout of the distribution center is complicated, because of this, we simplify the layout which has one I/O and 20x20 rows and columns. To evaluate the performance of the proposed heuristic solution methodology, we develop four models based on the heuristic algorithm. In the first model, assignment of the half of the products is made according to Step 1 of the heuristic, and the remaining products are assigned to storage zones according to Step 2. Seasonality effect is included to the first model. In the second model, assignments are made similar to Model 1 but seasonality values are not included to the placement rating calculation. In model 3, all products are assigned according to Step 1 by using only their placement rating values which include the seasonality of the SKUs. In model 4, assignments are made similar to Model 3, but the seasonality values are not included. To compare the performance of these models in terms of the total travel distance, we develop six different order scenarios, which have different number of products to be picked up per trip by using the previous real order data. For each scenario, Euclidean distances between products are calculated and routes are constructed by using the nearest neighbor algorithm. All algorithms are coded and solved by using MATLAB. Results of the models are shown in Table 1-4. Total travel distances of each scenario based on the models are calculated by changing the alpha values between 0-1. While alpha equals to zero, models assign the products to zone according to affinity values. On the other hand, when alpha equals to 1, assignments are made according to only order frequency values of the products. A sample assignment of the model 1 based on scenario 2 when alpha is 0.9 is shown in Figure 1 with the picking route of the orders.

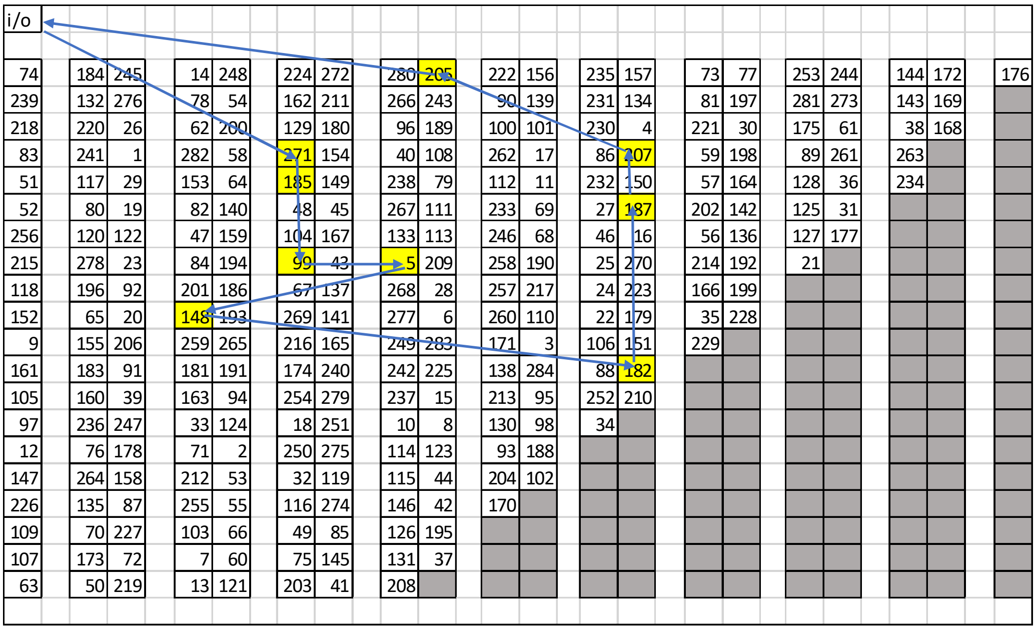

Figure 1. Sample assignment into zones and picking order

Table 1. Total travel distances of scenarios based on Model 1

Alpha	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
0	57.9866	53.2397	58.9041	92.3899	**85.9282**	89.8198
0.1	48.1881	59.4833	88.2836	**68.5523**	101.8165	**83.4879**
0.2	57.0452	64.9844	71.6498	84.8112	94.7611	100.787
0.3	52.6682	66.8415	64.5191	87.8405	108.9836	106.6117
0.4	51.5451	68.636	89.4703	92.6437	98.7832	102.1603
0.5	61.5914	76.6053	61.8796	82.2533	108.0018	88.2791
0.6	**45.0785**	70.1777	72.927	70.734	104.0241	86.3849
0.7	55.5377	76.3538	**58.1881**	70.2201	94.8002	88.562
0.8	67.2676	64.708	60.4648	100.8695	94.1276	91.9442
0.9	45.9636	**48.9582**	69.1521	81.8167	101.8517	112.8224
1	50.2101	68.1539	66.3567	79.6172	93.4065	85.9628
Average	53.916555	65.28562	69.25411	82.88622	98.77132	94.25655
Min	45.0785	48.9582	58.1881	68.5523	85.9282	83.4879
Std. Dev	6.7914015	8.615249	10.87238	10.31007	6.949741	9.707518

Table 2. Total travel distances of scenarios based on Model 2

Alpha	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
0	48.5763	54.427	63.8881	77.5795	**92.1677**	**73.4735**
0.1	45.8635	70.4201	63.2197	84.0557	94.7044	87.0148
0.2	37.8583	80.6717	64.4817	82.8277	103.1847	86.2829
0.3	45.6969	**45.4097**	70.9132	79.9005	94.7268	86.9962
0.4	60.4578	57.0408	74.7521	90.5156	107.091	97.1455
0.5	48.735	63.0212	**58.6547**	**75.7932**	115.0971	86.4294
0.6	43.8168	49.5201	67.1834	90.7775	105.3711	91.6103
0.7	**32.0767**	49.5379	70.8269	103.8926	97.4983	89.9885
0.8	32.935	47.3434	72.8676	85.0127	103.1738	100.8437
0.9	42.4663	53.7421	65.0274	86.5367	114.5576	108.7258
1	53.4819	58.1727	60.3383	91.4025	107.8918	100.6945
Average	44.724045	57.2097	66.55937	86.20856	103.224	91.74592
Min	32.0767	45.4097	58.6547	75.7932	92.1677	73.4735
Std. Dev	8.4227037	10.64917	5.202018	7.870596	7.814017	9.59354

Table 3. Total travel distances of scenarios based on Model 3

Alpha	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
0	59.2883	64.6781	45.0784	**56.3936**	**74.15**	79.6094
0.1	52.0656	73.3628	49.8551	65.4652	79.2085	102.3594
0.2	52.9435	58.561	54.1436	76.863	92.0249	87.7172
0.3	58.5862	56.6831	54.2095	72.7705	80.0736	85.209
0.4	64.2436	61.3189	60.0509	81.3513	88.8596	92.3059
0.5	41.7033	62.0816	62.8139	83.4101	86.3483	95.1207
0.6	**47.5542**	61.9418	**44.7667**	67.6738	84.5315	**78.2844**
0.7	47.859	**55.2574**	67.6454	78.7215	102.2013	103.9061
0.8	71.9416	67.1914	51.6233	85.1008	91.8826	84.5804
0.9	48.204	80.9272	65.1026	98.1635	97.4288	97.4046
1	50.4936	81.4985	64.725	82.5069	78.5262	86.8637
Average	54.08026	65.77289	56.36495	77.12911	86.83957	90.30553
Min	41.7033	55.2574	44.7667	56.3936	74.15	78.2844
Std. Dev	8.700439	9.116564	8.154803	11.26591	8.62689	8.625935

Table 4. Total travel distances of scenarios based on Model 4

Alpha	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
0	61.5526	67.0638	69.7407	85.0561	84.2589	87.9087
0.1	**44.8912**	70.3515	60.0473	78.6271	80.7097	96.9132
0.2	58.5839	63.2866	54.1451	71.0861	87.6225	**79.577**
0.3	56.063	75.038	61.0166	74.5721	**77.9417**	91.6191
0.4	61.8523	71.8562	73.2949	68.8219	86.5252	94.6486
0.5	68.2828	65.443	67.6756	92.5472	97.6379	98.6994
0.6	61.7381	73.2707	56.136	**68.2931**	89.1337	88.5894
0.7	53.951	**62.3637**	**53.7942**	87.2333	94.5821	90.0605
0.8	55.0942	71.6734	73.2944	88.1373	93.1295	77.6322
0.9	46.1199	68.7621	63.7946	89.2773	91.9405	101.5873
1	46.7293	67.7024	68.9777	85.055	110.6706	99.2171
Average	55.89621	68.80104	63.81065	80.7915	90.37748	91.49568
Min	44.8912	62.3637	53.7942	68.2931	77.9417	77.6322
Std. Dev	7.532744	4.076975	7.289145	8.826487	8.954041	7.812068

When we compare the four models, we observe that model 3 -where only step 1 with seasonality factor is used- gives the best results. We also conducted ANOVA to examine whether α plays a significant role for improving the results. We conduct two-way ANOVA, using the scenarios and α as the two factors. The generated scenarios have increasing product amount per one picking trip. Those are 4, 9, 19, 28, 40, 43 respectively for Scenario 1 to 6. The ANOVA results are given in Table 5.

Table 5. ANOVA results for model 3

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F critical*
Rows (α)	1703.714	10	170.3714	2.576003	0.013412	2.026143
Columns (Scenarios)	13041.41	5	2608.282	39.43704	3.26E-16	2.400409
Error	3306.895	50	66.13789			
Total	18052.02	65				

The results show that both α and the amount of SKUs per order are significant factors on the results obtained by the proposed storage assignment heuristic solution methodology. The minimum cost value of each scenario is marked in the results tables. A common pattern observed related to these two factors is that when the product amount per picking trip decreases relatively higher α values give a better result. Thus, for an order list with smaller orders, larger α values should be used in the solution methodology while smaller α values should be used for larger orders. When α value decreases the assignment decision is made using the order frequencies more importantly compared to the affinities. Thus, we can conclude that the affinities are less important for smaller customer orders which are collected with less amount of products per picking trip compared to larger customer orders.

CONCLUSION

We develop a new heuristic solution methodology for the storage assignment problem for the multi-command picking warehouse. The proposed two approaches, as well as seasonality, have been compared and shown that seasonality should be considered for storage assignment if the items have a seasonal demand pattern. Moreover, affinities have been considered in our two approaches in two different means. First we only consider the affinities together with the turn-over factor. Then we try to improve the assignment using a dynamic placement considering the affinities between the placed SKUs and to-be placed SKUs. This approach currently has not given better results. However, we aim to further investigate and improve our dynamic placement strategy by improving the heuristic methodology in our future studies.

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A MATHEMATICAL MODEL FOR IN-PLANT MILK-RUN ROUTING

Aydin Sipahioglu[1], Islam Altin[2]

Abstract *– Milk-run is one of the lean logistics implementations defined as a cyclic materials delivering system. As this system is widely used for in-bound and out-bound logistics, it is also used for in-plant logistics. In-plant milk-run system runs for the delivering materials within the plant from warehouse to assembly stations in a cyclic manner. In this system, routes and periods should be determined in terms of space requirements, number of vehicles and their capacity. In-plant milk-run system is implemented using Automated Guided Vehicles (AGV), which provide automated materials handling in plant. The objective of in-plant milk-run system is to minimize the total inventory holding and transportation cost so as to ensure no parts shortage will occur in assembly stations. In this study, a mixed integer mathematical model is proposed for the determination of milk-run routes and its period simultaneously for AGVs. Mathematical model is coded using GAMS software. The success of the proposed model is shown on randomly generated test problems and the results is discussed widely.*

Keywords – Logistics, In-Plant Milk-Run, Automated Guided Vehicles, Mixed Integer Programming

INTRODUCTION

Material handling system plays a very important role in manufacturing. The objectives of material handling are improving facility utilization, reducing unit cost of production, increasing efficiency of material flow and the usage rate of the material handling vehicles (Sule, 1994; Kulak, 2015). It can account for 30-75% of the total cost and proper material handling system can reduce a plant's operating cost by 15-30% (Sule, 1994). Furthermore, material handling composes the 25% of the workers, 55% of the factory area and 87% of the production time (Nagy and Salhi, 2005). Therefore, it is very crucial for reducing cost and eliminating waste.

On time delivery provided by efficient material handling system is one of the objectives of lean logistics. It is the logistics applications in lean manufacturing environment (Kilic et al., 2012), and consists of three parts as in-bound logistics, out-bound logistics and in-plant logistics. While in-plant logistics deals with logistics in the factory, in-bound and out-bound logistics deal with obtaining raw materials and delivering goods to the customer, respectively (Kilic et al., 2012).

Lean logistics ensure the delivery of the products at the right time to the right place and carry out these activities, effectively (Patel, 2013). There is a correlation between a just in time plan and a good logistics strategy (Ji-li et al., 2013). For in-plant logistics just in time material supply is a vital issue, because early material supply causes inventory holding cost and late material supply causes stopping assembly lines due to the parts shortage (Satoglu and Sipahioglu, 2018). Milk-Run system, cyclic goods taking, is able to reduce these kind of delays in manufacturing especially in assembly lines (You and Jiao, 2014). Since it is actually a lean logistics method, it is possible to be implemented for all three types of lean logistics.

In-plant milk-run system can be defined as one of the implementations of milk-run which helps to deliver materials from warehouse to assembly lines in plants in an easier way and possibly in shorter durations. It achieves delivery through cyclic manners and predetermined paths, which can be found through proper mathematical models.

In-plant milk-run system is implemented using Automated Guided Vehicles (AGV). AGVs use predefined paths along which they move from depot to destination point (Duinkerken et al., 2006). It is possible to increase the capacity of AGVs with additional trailers.

In plant Milk-Run systems has some certain advantages listed below (Sadjadi et al., 2008);

- Improved performance of the supply chain and logistics because of effective transportation

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- Lower inventory and reduced maintenance costs
- More effective use of buffer stock area
- More appropriate and reliable delivery times
- Increased capital turnovers
- Increased flexibility in supplying the parts.
- Smooth and well-established logistic operations

The remainder of this paper has the following structure. In Section 2, proposed Mixed Integer Mathematical Model is presented. In Section 3, proposed model is solved for a generated test problem and the results is discussed. Finally, conclusion and future work are presented in Section 4.

PROPOSED MATHEMATICAL MODEL

In this paper, a mixed integer mathematical model is offered, in order to maintain in-plant milk run system, optimally. The assumptions imposed on the proposed model are, the demand of the stations is known, the capacities of vehicles are known, there are limited number of vehicles on hand, heterogeneous vehicles are used, loads can be split, each vehicle starts its route from the depot and ends its route at the same depot. This model enables both the determination of milk-run routes and its period, simultaneously for AGVs. As in-plant milk run system is implemented by AGV, its properties are very important for this system. So, AGVs usage cost, capacity of AGVs and available total number of AGVs are considered. The entire demand of any stations cannot be satisfied by a single AGV. That's why, split deliveries is allowed for each station in this model. The proposed model is presented below.

Sets:

i, j: $Sets\ of\ stations$
k: $Set\ of\ vehicles$
l: $Set\ of\ trailers$
n: $Set\ of\ periods$

Parameters:

f_k: $Cost\ of\ using\ AGV-k$
q_k: $Capacity\ of\ AGV-k$
e_k: $Unit\ material\ handling\ cost\ of\ AGV-k$
r_i: $Distance\ between\ station\ (i)\ and\ station\ (i+1)$
$r0$: $Distance\ between\ warehouse\ and\ station\ 1$
p_n: $Duration\ of\ the\ period-n$
d_{in}: $Demand\ of\ station-i\ during\ period-n$
a_{kl}: $Capacity\ of\ additional\ trailer-l\ used\ in\ AGV-k$
b_{kl}: $Cost\ of\ using\ additional\ trailer-l\ in\ AGV-k$
m: $The\ total\ number\ of\ AGV\ on\ hand$

Decision Variables:

$$x_{kn} = \begin{cases} 1, & if\ AGV-k\ is\ used\ at\ period-n \\ 0, & otherwise \end{cases}$$

$$t_{kln} = \begin{cases} 1, & if\ trailer-l\ is\ used\ for\ AGV-k\ at\ period-n \\ 0, & otherwise \end{cases}$$

$$s_n = \begin{cases} 1, & if\ period-n\ is\ used \\ 0, & otherwise \end{cases}$$

w_{kn} : $Total\ amount\ of\ goods\ for\ AGV-k\ at\ period-n$
y_{ikn} : $The\ percentage\ of\ satisfying\ the\ demand\ of\ station-i\ for\ AGV-k\ at\ period-n$
v_{ikn} : $Amount\ of\ goods\ for\ AGV-k\ in\ station-i\ at\ period-n$
u : $Minimum\ value\ of\ obtained\ cost\ in\ each\ period$

Model Formulation:

$$Min\ Z = u$$

$$\sum_k y_{ikn} = 1 \qquad \forall i, n \tag{1}$$

$$\sum_k x_{kn} \le m \qquad \forall n \tag{2}$$

$$y_{ikn} \le x_{kn} \qquad \forall i, k, n \tag{3}$$

$$w_{kn} = \sum_{i} d_{in} * y_{ikn} \qquad \forall k,n \qquad (4)$$

$$w_{kn} \le x_{kn} * q_k + \sum_{l} t_{kln} * a_{kl} \qquad \forall k,n \qquad (5)$$

$$v_{ikn} = w_{kn} - \sum_{j\ (j \le i+1)} y_{jkn} * d_{jn} \qquad \forall i,k,n \qquad (6)$$

$$\sum_{n} s_n = 1 \qquad (7)$$

$$u \ge \left(\sum_{k} x_k * f_k + \sum_{k} w_{kn} * e_k * r_0 + \sum_{i} \sum_{k} v_{ik} * e_k * r_i + \sum_{k} \sum_{l} b_{kl} * t_{kl} \right) \Big/ p_n - \left(M * (1 - s_n)\right) \quad \forall n \qquad (8)$$

$$x_{kn} \in \{0,1\}\,, t_{kln} \in \{0,1\}\,, s_n \in \{0,1\}\,, w_{kn} \ge 0, y_{ikn} \ge 0\,, v_{ikn} \ge 0\,, u \ge 0 \qquad (9)$$

In this model, objective function minimizes the total cost, which includes vehicle (AGV and additional trailer) usage cost and material handling cost. Constraint (1) states demand of each station must be satisfied by the using AGVs at each period. Constraint (2) ensures that the total number of AGVs used is limited by the total number of AGVs on hand. Constraint (3) expresses the relationship between x and y decision variables. That is to say if an AGV serves any station, the related AGV is used. Constraint (4) represents the total amount of goods in each AGV at each period. Constraint (5) prevents the amount of goods handled by the AGV from exceeding its capacity. This constraint also permits the AGV's capacity to be increased with additional trailer. Constraint (6) indicates the amount of goods in the AGV at each station. The amount of goods in the AGV is reduced as long as it satisfies demand of the stations. Constraint (7) ensures only one period is selected among predetermined periods. Accordingly, constraint (8) states that the lowest cost period is determined. Constraint (9) is the sign constraints.

COMPUTATIONAL RESULTS

Test instance is generated to evaluate the success of the proposed mathematical model. This instance includes 20 assembly line's stations and 1 warehouse. A visual presentation of test instance is shown in Figure 1. Each station has material demands for a certain period. A fixed path, which AGVs trying to satisfy the demands of stations by following this, is determined in plant. A fixed path is shown with red arrows in Figure 1.

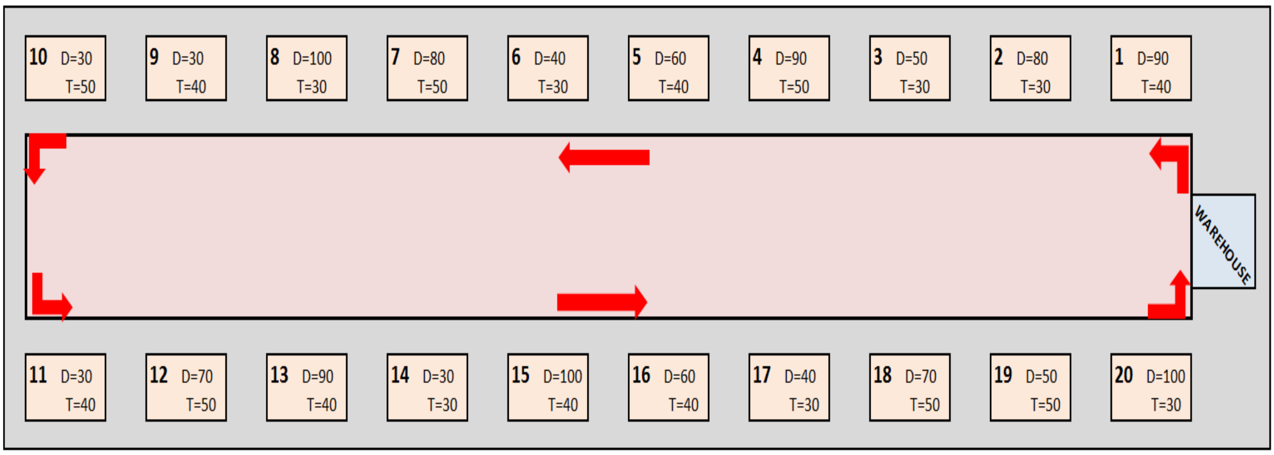

Figure 1. Generated In-Plant Instance

There are 5 heterogeneous AGVs are available in this instance. Capacity, usage cost and unit material handling cost of these AGVs are denoted in Table 1. Increasing the capacity of AGVs with additional trailer is allowed. Capacity and usage cost of additional trailer are denoted in Table 2.

Table 1. AGV Properties

AGV	Capacity	Usage Cost	Unit Material Handling Cost
AGV 1	400	1400	0.05
AGV 2	300	1600	0.011
AGV 3	550	1300	0.08
AGV 4	250	1500	0.09
AGV 5	300	1200	0.07

Table 2. Additional Trailer Properties

Add. Trailer	Capacity	Usage Cost
T1	100	50
T2	200	75
T3	300	100

Each station has demand at different period. In order that no parts shortage occur in stations, demands of stations are satisfied, timely. Demands of each station for a certain time period is presented in Table 3. While station-1 requires 90 units of material every 40 minutes, station-2 requires 80 units of material every 30 minutes.

Table 3. Demand and Time Period of Stations

Station	Demand	Time Period (min)	Station	Demand	Time Period (min)
1	90	40	**11**	30	40
2	80	30	**12**	70	50
3	50	30	**13**	90	40
4	90	50	**14**	30	30
5	60	40	**15**	100	40
6	40	30	**16**	60	40
7	80	50	**17**	40	30
8	100	30	**18**	70	50
9	30	40	**19**	50	50
10	30	50	**20**	100	30

Based upon in Table 3, firstly, the amount of materials required by each station for the periods are calculated. As an example, for 40 minutes time period station-1 requires 90 units of materials, station-2 requires 106 units of materials, station-3 requires 66 units of materials. In this instance, 4 different scenarios with 40, 60, 80 and 100 minutes periods are generated. Demand of station-1 is 90, 135, 180 and 225 at 4 different scenarios, respectively. Demand of the stations for these periods are presented in Table 4.

Table 4. Demand of Stations for Different Scenarios

Station	Demand	Period	Scenario 1 40 min. Period	Scenario 2 60 min. Period	Scenario 3 80 min. Period	Scenario 4 100 min. Period
1	90	40	90	135	180	225
2	80	30	107	161	214	268
3	50	30	67	101	134	168
4	90	50	72	108	144	180
5	60	40	60	90	120	150
6	40	30	53	80	106	133
7	80	50	64	96	128	160
8	100	30	133	200	266	333
9	30	40	30	45	60	75
10	30	50	24	36	48	60
11	30	40	56	84	112	140
12	70	50	53	80	106	133
13	90	40	40	60	80	100
14	30	30	90	135	180	225
15	100	40	60	90	120	150
16	60	40	100	150	200	250
17	40	30	56	84	112	140
18	70	50	53	80	106	133
19	50	50	133	200	266	333
20	100	30	40	60	80	100

Based upon the given parameters, the proposed mathematical model was solved by the GAMS optimization software's CPLEX solver with personal computer having Intel Core i7-5700HQ CPU and 16 GB RAM. The optimum solution can be found in approximately 1 second. The total cost is found as 3423,9 and the results are both summarized in Table 5 and shown in Figure 2. There are 3 AGVs and 3 additional trailers in the obtained solution. Milk run routes and its period for AGVs are obtained. The service period of each AGV is found as 80 minutes.

Table 5. The Results of Test Problem

Period	AGV	Add. Trailer	AGV Routes and The Percentage of Satisfying Demand
Scenario 3 80 min. Period	1	1,2,3	*6 (0.34)* -7-8-9-10-11-12-13-*14 (0.91)*
	2	1,2,3	*14 (0.09)* -15-16-17-18-19-20
	5	1,2,3	1-2-3-4-5-*6 (0.66)*

In this solution report, it is shown that split deliveries occur. In Figure 2, split deliveries for stations are shown with different colors. 34% of the demand of station-6 is satisfied by AGV-1 and the remaining 66% of the demand of station-6 is satisfied by AGV-5. %91 of the demand of station-14 is satisfied by AGV-1 and the remaining %9 of the demand of station-14 is satisfied by AGV-2. The entire demand of all other stations is satisfied by a single AGV.

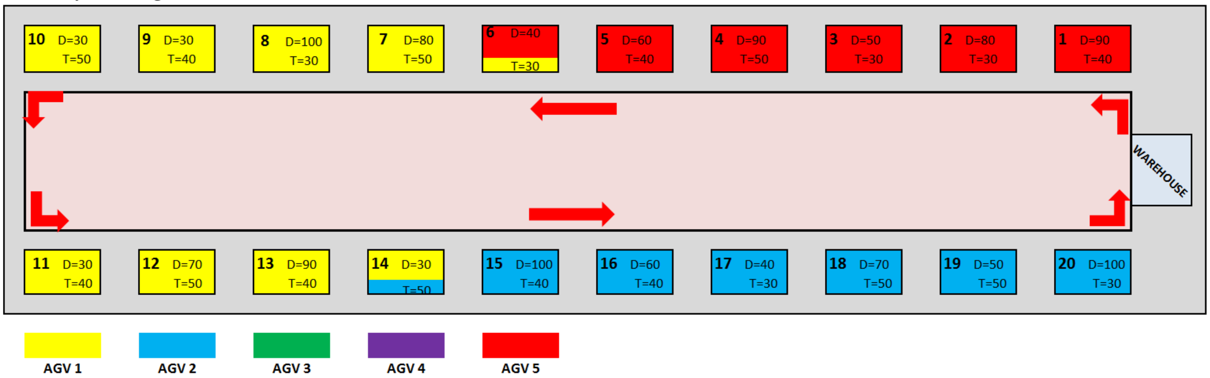

Figure 2. Visual Presentation of the Results

CONCLUSIONS

In this study, in-plant milk run which is a delivery system being run with cyclic manner in plants was investigated. A mixed integer mathematical model was proposed to determine milk-run routes and periods for AGVs. On account of analyses the performance of the proposed model a test problem was generated and the success of the model was shown on that problem. There are 3 basic advantageous of the proposed model: Firstly, allowing split deliveries for stations to obtain effective in-plant distribution plan. Secondly, obtaining the optimal solution short computational time because of there is no need to obtain vehicle routes. Finally, allowing analysis by using different parameters to obtain different routes and periods. On the other hand, in this model total material handling and vehicle usage costs were considered. In the future studies, mathematical model can be expanded by adding new constraints to ensure obtaining different periods instead of predetermined ones for each AGV.

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A DECISION SUPPORT SYSTEM FOR INDUSTRY 4.0 TECHNOLOGIES: A BUSINESS CASE

Batuhan Kocaoğlu[1], Ezgi Demir[2]

Abstract – *For the first time in 2011, industry 4.0 was started to be used at Hannover Fair. While industry 4.0 is often aimed at new developments in manufacturing, it is a clear goal for innovations, developments in the technology world and all aspects of life with legal regulations. People, systems, robots, and production will be linked to each other in the new level to be reached with digital transformation and industry 4.0. Industry 4.0 has the possibility to optimize itself according to various criteria such as low cost, low resource using, easy accessibility and high speed. In this study, a manufacturing process based on SCOR model will be examined, then related industry 4.0 solutions will be listed based on literature. The main purpose of this study is to choose the right technology for the specific process. At this point selection criteria, constraints, parameters and expert opinions will play an important role. As a result, it is aimed to make the most appropriate and optimal selection based on a mathematical model. In this respect, it is expected that this mathematical model will guide for enterprises who are on the way to Industry 4.0 applications and it may create a background for related projects.*

Keywords – *Digital Transformation, Industry 4.0, Scor, Technology Selection*

INTRODUCTION

The digitalization of the manufacturing industry can be defined as the process of using advanced technologies such as digital technologies such as internet, artificial intelligence, advanced analytics, robotic systems and joint manufacturing in increasingly varying proportions and different forms in the manufacturing industry. In order to understand the effect that digital transformation has on production, it is necessary to consider the industrial revolutions that have taken place and the basic technologies that trigger them (Republic of Turkey Science, 2017). The first industrial revolution occurred in the late 18th century when water and steam technologies were used and the second industrial revolution was used in the production of electricity. The second industrial revolution ensured that serial production could not be achieved by using the first assembly lines. The third industrial revolution provides significant advantages in quality, cost and efficiency through the use of programmable logic controller systems, automation and robots in manufacturing thanks to improvements in electronics and automation technologies. Each of the industrial revolutions influenced the way the manufacturing industry works. The digital transformation of the manufacturing industry is a new industrial revolution. For this reason, it is called the fourth industrial revolution. The fourth industrial revolution is of great importance, as it is in the previous industrial revolutions, as it has the potential to cause radical and global change in the functioning of the industry. Digital transformation not only affects the manufacturing industry but also other sectors of the economy and social life. It is therefore possible to consider the digitization process of the manufacturing industry as part of a more comprehensive digital transformation process. The process of digitilization affects all areas of health, education, agriculture, industry, social and economic life. The fourth industrial revolution, which has evolved in cyber-physical systems, has begun to talk about a new concept of digital economy that encompasses many fields, especially production, transportation and services. For example, Japan defines the digitization process as Community 5.0, which is the next step in the information society (Office C. , 2018). Since the birth of mankind, we can chart digitization as shown in Figure 1.

On the other hand, when the policies and strategies that different countries follow regarding the digital transformation of the manufacturing industry are seen, the digital transformation of the manufacturing industry

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seems to be handled together with the national digital transformation policies and strategies. In this reason, countries can not be thought apart from each other in terms of digital transformation.

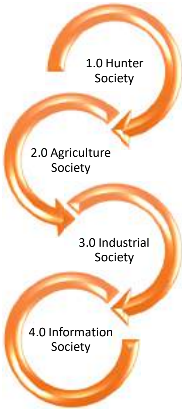


Figure 1. Digital Transformation (Office C. , 2018)

According to the World Economic Forum (2016) it is foreseen that the value to be generated from social and economic benefits will total 100 trillion dollars in 10 years period. The total net economic benefit of digitalization on a sector basis is estimated to be approximately $ 30 trillion (Figure 2) (Forum, Introducing the Digital Transformation Initiative, 2016). It is estimated that the economic value of the Internet, which is one of the most fundamental technologies of digital transformation, will reach between 4 and 11 trillion dollars a year (Institute, 2015).

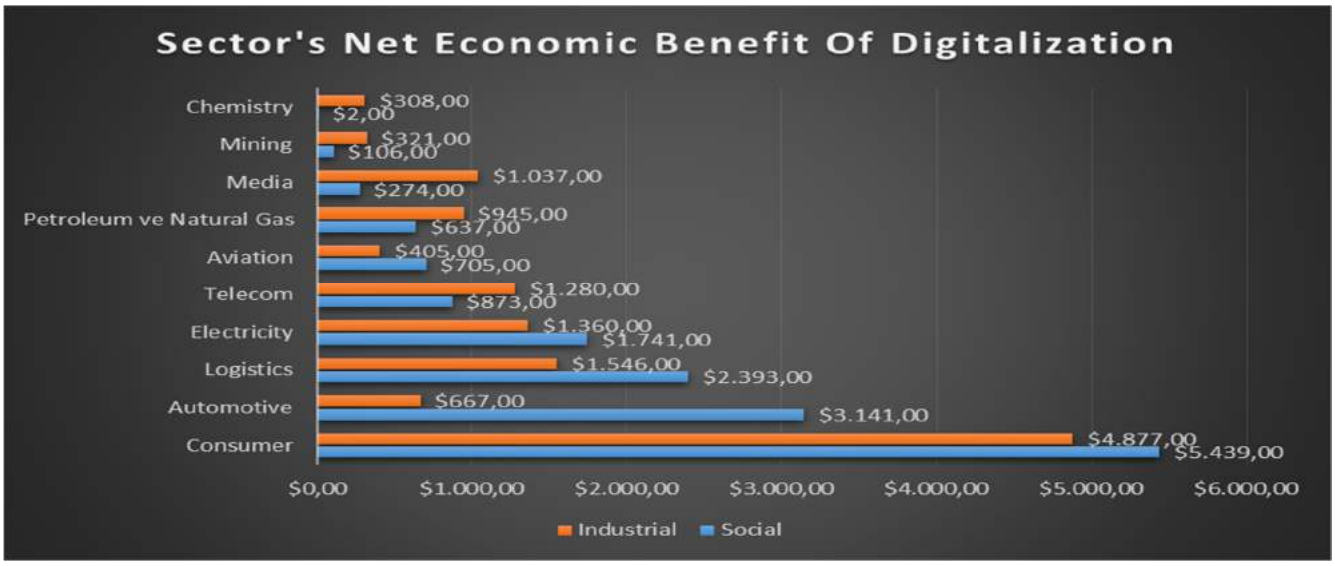


Figure 2. Sector's Net Economic Benefit Of Digitalization [2016-2025 Billion] (Forum, Introducing the Digital Transformation Initiative, 2016)

The impact of digitalization in industrial and social areas is clearly visible on consumers.

LITERATURE REVIEW

Industry 4.0 technology has become important at every stage of production since the beginning. In this study, the scor models were discussed in the manufacturing process. For this reason, the literature on manufacturing related to industry 4.0 is presented in Table 1.

Table 1. The Studies in Manufacturing Field (Yongxin Liao, 2017)

Digital Transformation Tools	Resource	Approach
Laser technology, addictive manufacturing, robotics	(Weck, Sarma, Schmidt, 2013)	Using on lean management and manufacturing technology level.
RFID (Radio Frequency Identification)	(Nukeaw, Pecharpa, 2013)	Using on the material level, e.g.semi-conductors, nano materials, carbon fibres, thin films, biomaterials on the information technology level.
Internet of things, industrial internet, cloud-based systems	(Gao, Wang, Teti, Dornfeld, Kumara, Mori and Helu, 2015)	Cloud-based manufacturing, smart manufacturing.
Internet of things (IoT)	(Atzori, Iera and Morabito, 2010)	Foundation about Internet of Things (IoT)
Cyber-physical systems (CPS)	(Khaitan and McCalley, 2015)	Design Techniques and Applications of Cyberphysical Systems
Steam-powered mechanical technology, the application of electrically-powered mass production technologies and electronics and information technology (IT)	(Drath and Horch, 2014)	Steam-powered mechanical manufacturing facilities, the application of electrically-powered mass production technologies through the division of labour and the use of electronics and information technology (IT) to support further automation of manufacturing
Cloud technologies	(Zhan, Xiao,Yue,Jun,Henryand Yun, 2015)	Cloud computing resource scheduling and a survey of its evolutionary approaches
Industrial wireless networks	(Li, Di, Jiafu, Athanasios, Chin-Feng and Shiyong, 2015)	Using wireles networks on industry 4.0
Industrial wireless networks standards	(Janak, Ludek, and Zdenek Hadas. 2015)	Usage Monitoring System
Industrial wireless networks standards	(Leitao, Jose, Maria-Eleftheria and Iakovos ,2015)	Using on cyber-physical systems
Integration technologies	(Bangemann, Matthias , Mario and Christian, 2016)	Integration of classical components into industrial cyber-physical systems
Integration technologies	(Schmidt, Arndt, Ronald, Daria, Matthias and Jan, 2015)	Identifying integration approach candidates for use in industrie 4.0.
Virtual engineering	(Shafiq, Cesar Sanin, Edward and Carlos, 2015)	Cyber physical system for industrie 4.0
Ubiquitous computing technologies	(Chen and Tsai 2017)	Ubiquitous manufacturing, robotics and computer-integrated manufacturing
Agent-based technologies	(Adeyeri, Mpofu, and Adenuga, 2015)	Integration of agent technology into manufacturing enterprise platform for industry 4.0.
Smart factory	(Shrouf, Ordieres, and Miragliotta, 2014)	Smart factories in industry 4.0 about energy management
Smart factory	(Hozdić, 2015)	Smart factory for industry 4.0
Smart manufacturing	(Kang,Seok,Lee,Choi, Kim,Park, Son,Kim and Noh, 2016)	Smart manufacturing: past research, present findings, and future directions

Digital technology has become popular in the field of manufacturing in recent years. However, the models do not include a mathematical model. The articles are mostly based on general information about introduction of digital technology systems and tools. And this full text contains the production process from beginning to end. This study only deals with a production process of the SCOR model.

Literature Review Of Scor

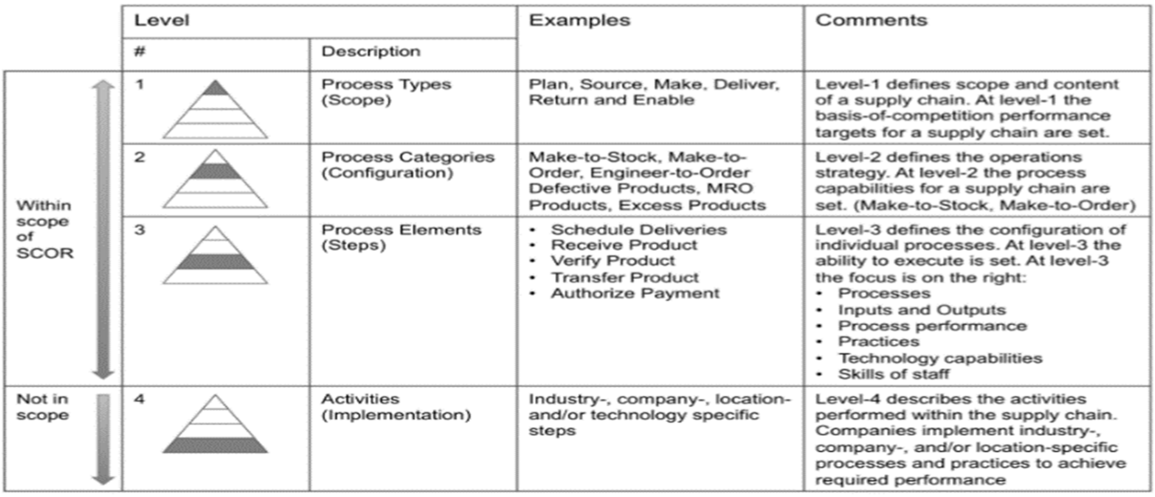
The Supply Chain Operations Reference model (SCOR®) is the product of Supply Chain Council, Inc. (SCC) a global non-profit consortium whose methodology, diagnostic and benchmarking tools help organizations make dramatic and rapid improvements in supply chain processes. SCC established the SCOR process reference model for evaluating and comparing supply chain activities and performance. The SCOR-model captures SCC's consensus view of supply chain management. It provides a unique framework that links business process, metrics, best practices and technology into a unified structure to support communication among supply chain partners and to improve the effectiveness of supply chain management and related supply chain improvement activities. SCC membership is open to all companies and organizations interested in applying and advancing the state-of-the-art in supply chain management systems and practices. SCC was organized in 1996 and initially included 69 practitioner companies meeting in an informal consortium. Subsequently, the companies of SCC elected to form an independent not for profit trade association. The majority of the SCC's members are practitioners and represent a broad cross-section of industries, including manufacturers, distributors, and retailers. Equally important to SCC and the advancement of the SCOR-model are the technology suppliers and implementers, academics, and government organizations that participate in SCC activities and the development and maintenance of the model. Supply Chain Council is interested in providing the widest possible dissemination of the SCOR model. The wide-spread use of the model results in better customer - supplier relationships, software systems that better support members through the use of common measurements and terms, and the ability to rapidly recognize and adopt practices no matter where they originate. Finally, this paper model methodology provided to the changes version 11.0. Version 11.0 of the SCOR-model is the thirteenth revision since the model's introduction in 1996.

SCOR MODEL

The SCOR-model has been developed to describe the business activities associated with all phases of satisfying a customer's demand. The model itself contains several sections and is organized around the six primary management processes of Plan, Source, Make, Deliver, Return and Enable (shown in Figure 3). By describing supply chains using these process building blocks, the model can be used to describe supply chains that are very simple or very complex using a common set of definitions. As a result, disparate industries can be linked to describe the depth and breadth of virtually any supply chain. The model has been able to successfully describe and provide a basis for supply chain improvement for global projects as well as site-specific projects.

Figure 3. SCOR Is Organized Around Six Management Processes

It spans: all customer interactions (order entry through paid invoice), all physical material transactions (supplier's supplier to customer's customer, including equipment, supplies, spare parts, bulk product, software, etc.) and all market interactions (from the understanding of aggregate demand to the fulfillment of each order). It does not attempt to describe every business process or activity. Specifically, the model does not address: sales and marketing (demand generation), product development, research and development, and some elements of post-delivery customer support. It should be noted that the scope of the model has change and is anticipated to change based on council member requirements. With the introduction of return, the model was extended into the area of post-delivery customer support (although it does not include all activities in that area). As shown in Figure 4, the model is designed to support supply chain analysis at multiple levels. SCC has focused on the top three process levels, which are industry neutral. SCOR does not attempt to prescribe how a particular organization should conduct its business or tailor its systems/information flow. Every organization that implements supply chain improvements using the SCOR model will need to extend the model, at least to Level-4, using industry-, organization- and/or location-specific processes, systems, and practices.



	Level #	Description	Examples	Comments
Within scope of SCOR	1	Process Types (Scope)	Plan, Source, Make, Deliver, Return and Enable	Level-1 defines scope and content of a supply chain. At level-1 the basis-of-competition performance targets for a supply chain are set.
	2	Process Categories (Configuration)	Make-to-Stock, Make-to-Order, Engineer-to-Order Defective Products, MRO Products, Excess Products	Level-2 defines the operations strategy. At level-2 the process capabilities for a supply chain are set. (Make-to-Stock, Make-to-Order)
	3	Process Elements (Steps)	• Schedule Deliveries • Receive Product • Verify Product • Transfer Product • Authorize Payment	Level-3 defines the configuration of individual processes. At level-3 the ability to execute is set. At level-3 the focus is on the right: • Processes • Inputs and Outputs • Process performance • Practices • Technology capabilities • Skills of staff
Not in scope	4	Activities (Implementation)	Industry-, company-, location- and/or technology specific steps	Level-4 describes the activities performed within the supply chain. Companies implement industry-, company-, and/or location-specific processes and practices to achieve required performance

Figure 4.SCOR Is A Hierarchical Process Model

It is important to note that this model describes processes not functions. In other words, the model focuses on the activity involved not the person or organizational element that performs the activity.

SCOR is a reference model. The purpose of a process reference model, or business process framework, is to describe your process architecture in a way that makes sense to key business partners. Architecture here means the way processes interact, how they perform, how they are configured and the requirements (skills) on staff operating the process. The SCOR reference model consists of 4 major sections:

- Performance: Standard metrics to describe process performance and define strategic goals.
- Processes: Standard descriptions of management processes and process relationships.
- Practices: Management practices that produce significant better process performance.
- People: Standard definitions for skills required to perform supply chain processes.

Problem Definition: As shown in the literature, there are no mathematical models for digital transformation tools. Furthermore, in this study model proposal including SCOR process was developed. This study was prepared in accordance with the methodology in Chapter 4 to eliminate the deficiency in the literature. The established methodology is discussed within the framework of the following questions.

METHODOLOGY

The aim in this work is to optimize the digitalization of the scor model make to order process section, which is an important step in the manufacturing sector, with industry 4.0 technology.

- What is the contribution of industry 4.0 technology to the make to order process?
- Why this make to order process is selected?
- How can the use of digital technology tools be optimized?
- Which digitalization technologies should be used in which steps?

Definitions Related to Developed Model

The process of manufacturing in a make-to-order environment (Table 2.) adds value to products through mixing, separating, forming, machining, and chemical processes for a specific customer order. Products are completed, built or configured only in response to a customer order, the customer order reference is attached to the production order, attached to or marked on the product upon completion of the make process and referenced when transferring the product to deliver. The product is identifiable throughout the make process, as made for a specific customer order. Examples of alternative or related names for Make-to-Order are: Build-to-Order (BTO), Assemble-toOrder (ATO), Configure-to-Order (CTO), and postponement (Council, 2012).

Table 2. Make-To-Order-Steps

MAKE-TO-ORDER-STEPS
sM2.1. Schedule Production Activities
sM2.2. Issue Sourced/In-Process Product
sM2.3.Produce and Test
sM2.4. Package
sM2.5.Stage Finished Product
sM2.6. Release Finished Product to Deliver
sM2.7.Waste Disposal

Definition Of Make-To-Order-Steps

sM2.1. Schedule Production Activities: Give plans for the production of specific parts, products, or formulations in specific quantities and planned availability of required sourced products, the scheduling of the operations to be preformed in accordance with these plans. Scheduling includes sequancing, and, depending on the factory layout, any standards for setup and run. In general intermediate production activities are coordinated prior to the scheduling of the operations to be preformed in producing a finished product (Council, 2012).

sM2.2. Issue Sourced/In-Process Product: The selection and physical movement of sourced/in-process products (e.g.,raw materials, fabricated components, subassemblies, required ingredients or intermediate formulations) from a stocking location (e.g., stockroom, a location on the production floor, a supplier) to a specific point of use location. Issuing product includes the corresponding system transaction. The Bill of Materials/routing information or recipe/production instructions will determine the products to be issued to support theproduction operation(s) (Council, 2012).

sM2.3.Produce and Test: The series of activities performed upon sourced/in-process product to convert it from the raw or semi-finished state to a state of completion and greater value. The processes associated with the validation of product performance to ensure conformance to defined specifications and requirements (Council, 2012).

sM2.4. Package: The series of activities that containerize completed products for storage or sale to end-users. Within certain industries, packaging may include cleaning or sterilization (Council, 2012).

sM2.5.Stage Finished Product: The movement of packaged products into a temporary holding location to await movement to a finished goods location. Products that are made to order may remain in the holding location to await shipment per the associated customer order. The actual move transaction is part of the deliver process (Council, 2012).

sM2.6. Release Finished Product to Deliver: Activities associated with post-production documentation, testing, or certification required prior to delivery of finished product to customer. Examples include assembly of batch records for regulatory agencies, laboratory tests for potency or purity, creating certificate of analysis, and sign-off by the quality organization (Council, 2012).

sM2.7.Waste Disposal: Activities associated with collecting and managing waste produced during the produce and test process including scrap material and non-conforming product (Council, 2012).

The purpose of this study is to find out which digital technologies need to be applied during production steps. For this reason, the tools of the technologies that can come up against the production steps are listed as in the Table 4.

Developed Model

Problem Definition → Solution Models (Table 2.) →Model → Parameters (Table 3.) → Decision Variables (Table 5.)

Table 3. Impact Potantial Values (Parameters)

LEVERS	DISCRIPTION	IMPACT POTENTIAL	IMPACT
Suppy-Demand Management	Production according to customer preferences with big data analysis	%80-85	Prediction Power
Work Force Efficiency	Using robot, Automatic process control	%45-55	Labor Productivity Increase
Asset Management	Maintenance only if necessary, Reduction of faults	%30-50	Effective management of assets
Stock Management	Smart storage systems	%20-50	Decline in Inventory Cost
Time to Market	Three-dimensional printing machines with rapid prototyping, Short product development times	%20-50	Shorter Access Time to Market
After Sales Services	Remote Access, Control and Repair	%10-40	Reduced Maintenance Cost
Quality Management	Root causes and solution of errors in production stage	%10-20	Drop in Quality Cost
Process and Resource Efficiency	Position detection with rfid technology, Automatic stock orders,	%3-5	Productivity Increase

Table 4. Digital Technology Counterparts of Manufacturing Steps (Kocaoğlu, 2018)

Manufacturing Steps	**Digital Tecnology Tools**
Procurement	Blockchain, Cloud, Control tower optimization, Language processing capable tools
Resource & Development	Sensors, Crowdsourcing, Rapid prototyping, 3D printing, Omnichannel
Manufacture	AR, Automated production, Predictive analysis, BI
Delivery	AR, Automated logistics, Self-driving trucks, Drones, 3D printing in truck, crowdsourcing, WMS, BI
Sales	Inventory-based dynamic pricing, Sensor-based remote control, Omni channel platforms, M-Trade, BI
After selling	3D Printing production, Predictive analysis, AR

Digital technology steps Table 4. also general. But the Table 5. shows how each digital tranformation technology can be applied in each make-to-order step in detail.

Table 5. Digital Technology Cunterparts of Make To Order Steps (Original In This Study)

	sM2.1. Schedule Prod. Activities	**sM2.2. Process Product**	**sM2.3. Produce and Test**	**sM2.4. Package**	**sM2.5. Stage Finished Product**	**sM2.6. Deliver**	**sM2.7. Waste Diposal**
Blockchain	*Usable*				*Usable Contracts Payments*	*Usable*	*Usable*
Control Tower	*Usable*				*Usable*	*Usable*	*Usable*
Omnichannel			*Usable*			*Usable*	
Artifical Intelligence (AI)	*Language Processing*					*Sales Forecast*	
Sensors, IOT, MES	*Design*	*Before Mass Production*	*Test*			*Test Before Sales*	
Crowdsourcing	*Research and Development*						*After Sales*
3D Printing		*Prototype Order Diplay*	*Usable*			*Production in Vehicle*	*After Sales Production/Parts Production*
AR	*Usable*	*Pattern*	*Usable*				*Support Services*
Self-driving Trucks						*Usable*	
Drones					*Stocktaking*	*Usable*	
Predictive Analytics	*Usable*		*Production/ Maintenance*			*Dynamic pricing*	*After-sales maintenance*
Mobilite						*Payment Device*	
Descriptive Analytics						*Location-based marketing*	
APS			*Usable*				
Real-time Optimization		*Inventory*	*Inventory*				
Iot			*Monitoring of production equipments*			*Monitoring of customer equip.*	*Service development*
Robots			*Machines*	*Vehicle loading*			

The available technologies in this study were transformed into variables and the use of digital technology at each step was aimed and constraint functions were regulated. There is a total of 43 variable 25 constraint functions in the built-in integer model. The integer model solution is solved with excel in the solver.

THE MODEL

Max Z = $\sum_{i=1, j=1}^{n} C_j X_{ij}$

Max Z= $C_1X_{11}+ C_2X_{12}+C_3X_{13}+\ldots\ldots\ldots\ldots\ldots\ldots\ldots+C_{68}X_{17,4}$

$a_{11}x_1 + a_{12}x_2 + a_{13}x_3+\ldots\ldots\ldots+ a_{1n}x_n \le b_1$

$a_{21}x_1 + a_{22}x_2 + a_{23}x_3+\ldots\ldots\ldots+ a_{2n}x_n \le b_2$

………………………………………………..

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$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots\ldots\ldots + a_{mn}x_n \leq b_m$

In this model, C_j coefficients are impact potential values. The model aims to maximize the technology used. The objective function is maximization and aims to achieve maximum efficiency from digital tranformation tools. The model includes 43 variables (X_{ij}). The variables express which digital technology tools to use in the steps. This form is linear programming form. The constraint functions are due to technology use limitations.

Technology Limitations

$a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \ldots\ldots\ldots + a_{1n}x_n \leq b_1$

$a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \ldots\ldots\ldots + a_{2n}x_n \leq b_2$

…………………………………………………...

…………………………………………………..

$a_{m1}x_1 + a_{m2}x_2 + a_{m3}x_3 + \ldots\ldots\ldots + a_{mn}x_n \leq b_m$

a_{ij} :used technologies

b_i : available technologies

The model has 17 constraint functions. The model, excel 2013 is also solved with the Solver add-in.

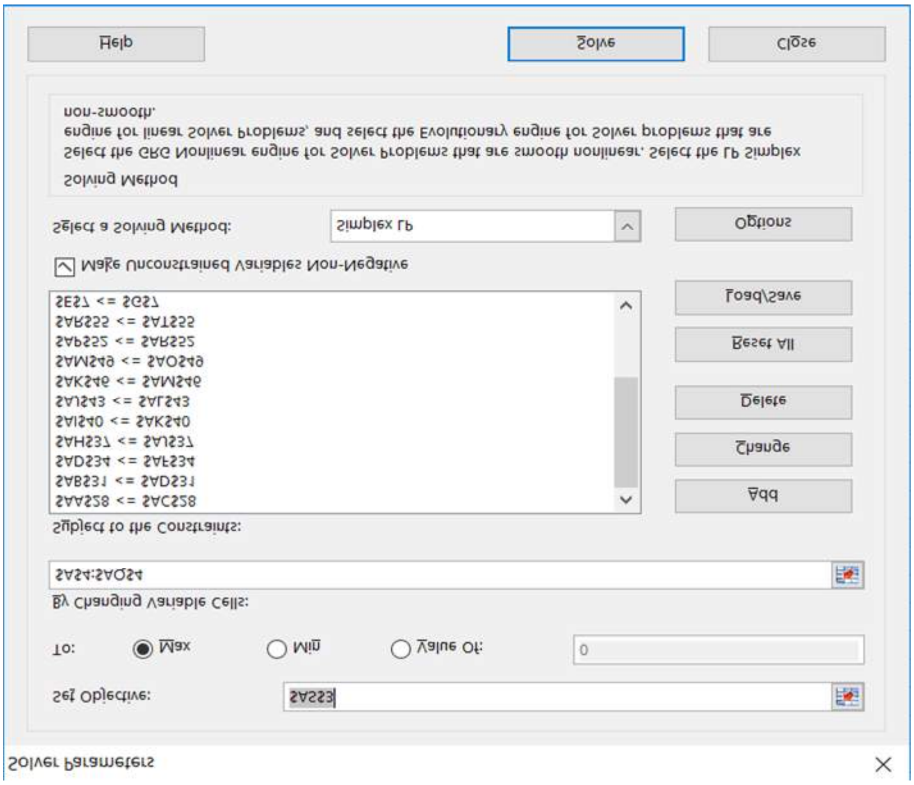
ANALYSIS AND RESULTS

The model was run in Microsoft excel office 2013 program on a computer with a windows processor and the resulting solution screen is as follows. (Table 6.)

CONCLUSION

The results in Table 7. show that optimal efficiency will be achieved when using the digital transformation tools specified in the production process. This means that the enterprise will benefit from digital transformation technologies to the greatest extent if the enterprise employs the specified technology resulting in a model outcome in the specified steps. In this way, every technology will not be applied in every production step. This situation plays a very important role in the efficiency of the business.

Table 6. The Model Solution



The model result is the excel form of the data obtained from the Table 7.

Table 7. The Optimal Digital Technologies Corresponding To The Make-To-Order Steps

	Digital Transformation Technologies
sM2.1. Schedule Production Activities	Crowdsourcing
sM2.2. Issue Sourced/In-Process Product	Sensors, IOT, MES
sM2.3.Produce and Test	Omnichannel
sM2.4. Package	Robots
sM2.5.Stage Finished Product	Control Tower
sM2.6. Release Finished Product to Deliver	AI, Predictive Analytics, Mobilite, Descriptive Analytics
sM2.7.Waste Diposal	Blockchain

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A LITERATURE REVIEW ON THE DEFINITION OF FOOD WASTE AND FOOD LOSS WITHIN SUPPLY CHAIN CONTEXT

Ebru Sürücü[1], Okan Tuna[2]

Abstract *– According to FAO, one-third of the world's overall food produced by weight is lost or wasted every year. Fruits and vegetables are the categories with the highest amount of losses and waste, which are followed by meat, fish and seafood, and milk. In developed countries, the highest contribution to food waste often occurs at household level due to cultural, social or economic decisions; while in developing countries food loss occurs mainly in the earlier stages of the food supply chain due to a lack of financial, technical and managerial resources. At every step of the supply chain, food waste has an impact on economic (direct loss for farmers, retailers, and consumers), social (failure to secure food for a wider population) and environmental aspects (soil, water, energy implications and GHGs: greenhouse gas emissions). Thus, elimination of food loss and food waste becomes more and more important. However, when we examined the literature, we saw that there is no consensus on definitions of food loss and food waste and quantification. We believe that defining food loss and food waste before eliminating food loss and food waste is important. Thus, this study is an explanatory study aiming to identify the difference between food loss and food waste. Finally yet importantly, this study tries to identify which type of quantifications were used in previous studies in calculating food waste.*

Keywords – Food Supply Chain, Food Waste, Food Loss, Literature Review

INTRODUCTION

In the year 2015, while world population was 7 billion, one out of every nine-person suffered from starvation (FAO et al., 2015). According to United Nations' estimations, in 2050 world population will reach to 9.8 billion people (UN, June 2017). Even today, the food sector is inadequate to meet the existing demand. In the coming years, it will face greater problems due to drought, climate change and reduced natural resources besides increased population.

Besides these factors, food losses in the food supply chain is another important factor in not meeting the food demand. According to FAO, an estimated 1.3 billion tonnes of food is lost or wasted annually in the various stages in the FSC (FAO, 2011). This amount is approximately one-third of food produced for human consumption (Steinfeld et al, 2006; Gustavsson et al., 2011).

When a food is wasted, not only the food is lost but also the all resources that are used for growing, producing, processing and transporting for that food is also lost (Gustavsson et al., 2011; Kummu et al., 2012). Food waste affects economic (direct loss for farmers, retailers and consumers), social (failure to secure food for a wider population) and environmental aspects (soil, water, energy implications and GHGe) (Alamar et al., 2018).

Food is wasted throughout the food supply chain (FSC). Waste can be occurred in each step of the FSC; agricultural production, postharvest handling and storage, processing and packaging, distribution and consumption (Gustavsson et al., 2011; Lipinski et al., 2013; Thi et al., 2015). Thus, eliminating food waste through FSC is a vitally important to have a sustainable FSC. To eliminate food waste through FSC, first we need to calculate food waste amount. However, in the literature there is a debate still going on about definitions of food waste and food loss, food waste quantification. Thus, this paper aims to examine the definition of food waste and loss and quantify the food waste.

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METHODOLOGY

For the methodology, a systematic literature review conducted. This review included Scopus and ScienceDirect. The literature review conducted between the times of 1998-2018. “Food loss”, “food waste”, “cause”, “driver” and “reason” were the main keywords. For each database, different combinations of each keywords used. Overall, we gathered 152 article. We deleted unrelated articles. As a result, 98 articles left. Then we excluded proceedings and book chapters. After this step, 86 articles left. Lastly, we removed duplications and we got 63 articles to examine.

DEFINITION OF FOOD WASTE AND LOSS

There is no definition agreed upon food waste and food loss in the literature. Differences in definitions can be traced back among others to (i) the chosen perspective from which food losses and food waste can be assessed, i.e. whether it is addressed from a waste or from a food perspective, (ii) the specific research questions tackled and (iii) the available data sources. Additionally, there are cultural differences in what is considered waste with intestines of animals being considered waste in some countries but not in others (Gjerris and Gaiani, 2013; HLPE, 2014). These differences have led to different definitions of food losses and food waste used in the available literature. Some of the researcher use these terms interchangeably. Furthermore, there are other researcher that use food waste and food loss in different meanings as well. Thus, we examined the literature about definitions of food waste and food loss.

Definition of Food Loss

Some of the authors use food waste and food loss interchangeably. Table 1 shows the definitions that define food loss and waste in same manner and writers who cited these definitions. From Table 1, we can say that mostly NGOs defined the concept as food loss and waste (FLW). Writers use food loss and food waste interchangeably because a distinction between wasteful behavior and other reasons for food losses was difficulty to perform.

Table 1. Most Commonly Used Definitions of Food Waste and Loss (FLW)

Who made the definition	Term	Definition	Who cited
FAO, 1981	Food waste and loss	*“the edible parts of plants and animals intended for human consumption that are not ultimately consumed by people”*	Lipinski et al., 2013; Berber et al., 2014; Yıldırım et al., 2016;
FAO, 1981	Food loss and/or waste	*“decrease in mass of wholesome food material intended for human consumption that is lost, degraded, spoiled or discarded at any stage of the food system”*	Dou et al., 2016
HLPE, 2014	Food loss and waste (FLW)	*“a decrease, at all stages of the food chain from harvest to consumption in mass, of food that was originally intended for human consumption, regardless of the cause”*	Teuber & Jensen, 2016;
WRI, 2015	Food loss and waste (FLW)	*“food, as well as associated inedible parts, removed from the food supply chain”*	Thyberg and Tonjes, 2016; Berber et al., 2014;

Resource: Compiled by authors

However, many of the definitions state that there is a clear difference between food loss and food waste. Table two shows the most commonly used food loss definitions and who cited these definitions in their studies.

Table 2. Commonly Used Food Loss Definitions

Who made the definition	Definition
Andersson et al., 2011	*"as the proportion of the food waste that could have been used for consumption if it was handled in a different way"*
Aschemann-Witzel et al., 2017	*"as loss or damage in early parts of the supply chain, as for example during harvesting, transport or storage"*
Buzby & Hyman, 2012	*"as a subset of post-harvest losses (or post-production) and represents the edible amount of food available for human consumption but is not consumed"* *"as a qualitative or quantitative drop in the food supply due to a reduced nutrient value of the food or to a decrease in its weight or volume"*
Kantor et al., 1997 & Tarasuk and Eakin, 2005	*"edible food lost at any stage of the supply chain, such as meats, bread, discarded or unserved restaurant-prepared food, or products that are unmarketable for aesthetic reasons, but otherwise edible and safe, and excludes only the inedible part that cannot be used for human consumption"*
HLPE, 2014	In some cases food loss is used to refer to *"the decrease in food quantity associated with harvest, handling, processing and transport"*
Gustavsson et al., 2011	*"losses due to poor infrastructure, low levels of technology and low investment in food production systems"*
FAO, 1981	*"change in the availability, edibility or quality of feed that makes it unfit for human consumption"*
Irani et al., 2017	*"to decrease in food quantity or quality, which makes it unfit for human consumption; occurring throughout the supply chain; from harvesting through to processing and distribution"*
Lipinski et al., 2013	*"food that spills, spoils, incurs an abnormal reduction in quality such as bruising or wilting, or otherwise gets lost before it reaches the consumer"* *"the unintended result of an agricultural process or technical limitation in storage, infrastructure, packaging, or marketing"*

Resource: Compiled by authors

Definition of Food Waste

Food waste definitions change on what food waste contains, how it is produced, and from where it is discarded. Moreover, cultural variations and norms are also important in defining food waste meaning that what is considered as a food waste in one country may not be considered as waste in others (Gjerris and Gaiani, 2013).

Table 3. Commonly Used Food Waste Definitions

Who made the definition	Definition
Göbel et al., 2012	*"everything that is suitable for human consumption by current state of the technology"*
FAO, 2013	*"any food discarded despite being appropriate for human consumption, whether it is kept beyond its expiration date or left to spoil"*
FAO, 1981	*"as any edible material intended for human consumption that at any point in the supply chain is discarded, degraded, lost, spoiled or consumed by pests"*
FUSION, 2014	*"any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bioenergy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea"*
WRAP, 2015	*"any food that had the potential to be eaten, together with any unavoidable waste, which is lost from the human food supply chain, at any point along that chain"*
Bloom, 2010	Food waste occurs when an edible item foes unconsumed as a result of human action or inaction and is often the result of a decision made farm-to-fork by businesses, governments and individual consumers
Buzby and Hyman, 2012	*"as the result of decisions made by consumers, supply chain actors or other stakeholders, and it represents a subset of the total food loss"*
Griffin et al., 2009	*"as food lost at any stage of the supply chain, including crops damaged during harvesting, food damaged during transport or food discarded and mixed with other wastes"*
European Commission, 2014	*"food (including inedible parts) lost from the food supply chain, not including food diverted to material uses such as bio-based products, animal feed, or sent for redistribution"*
United States Environmental Protection Agency, 2014	*"uneaten food and food preparation wastes from residences, commercial, and institutional establishments"*
United States Department of Agriculture, 2014	*"a subset of food loss and occurs when an edible item goes unconsumed"*
HLPE, 2014	*"related to consumer food behavior, with the latter conveying a negative connotation resulting from human choices"*
Parfitt et al., 2014	*"as the food loss occurring at the retail and final consumption stages and its generation is related to retailers' and consumers' behavior"*
Gustavsson, 2011	*"referring to losses occurring during retail and at the consumer's place due to the behavior of retailers and consumers"*
Stuart, 2009	*"a consciously destroyed or rejected potential source of food, including inedible parts that could be used for animal feed".* *"action to sort and discard deliberately or consciously a food source while it is perfectly edible."*

Resource: Compiled by authors

QUANTIFICATION OF FOOD WASTE

When the studies examined, we saw that different type of quantification methods have been applied to measure food waste. As previously mentioned, since definitions of food waste and food loss differs, this situation complicates the comparison of estimates across countries and identification of trends. Studies used different weight measurement unit to calculate food waste such as weight (Grainger et al., 2018; Kummu et al., 2012; Beretta et al., 2013; Salihoglu et al., 2018; Dias-Ferreira et al., 2015; Engström and Carlsson-Kanyama, 2004; Betz et al., 2015; Eriksson et al., 2012; Brancoli et al., 2017; Scholz et al., 2015; Cicatiello et al., 2016), monetary value (Buzby et al., 2011; Buzby and Hyman, 2012; Garrone et al., 2016), kcal (Kummu et al., 2012; Beretta et al., 2013) and GHG emissions (Strid and Eriksson, 2014; Brancoli et al., 2017; Scholz et al., 2015).

CONCLUSION

This study was an explanatory study. Considering the definitions above, some inferences can be made about food waste and food loss. Food loss is related with more technical issues such as lack of infrastructure and transportation network, poor technologies, etc. For calculating food loss, only the products, which are produced for human consumptions, were counted (i.e. banana skins, fodders are excluded).Food waste is more related with behavioral issues. Businesses', governments' and individual consumers' decisions mostly causes for waste. Food waste mostly occurs in the developed countries, generally at the consumer level.

Moreover, in medium- and high-income countries, food losses occur to a significant extent at the downstream stages of the supply chain and are related to a lack of coordination between different actors as well as consumer behavior and the fact that people simply can afford to waste food. In developing countries, food loss occurs mainly during the earlier stages of the FSC – i.e. production and industrial transformation – and are due to a lack of financial, technical and managerial resources, in developed countries loss usually occurs in the final stages of the FSC because of the cultural, social or economic decisions made by producers and final consumers.

As a future research idea, studies can be conducted on household levels, retailers level, production level or for the entire supply chain to eliminate/decrease food loss and food waste. Moreover, same studies can be applied on different product groups such as meat, dairy, bread and pastry and fruit & vegetable. In addition, to increase the effectiveness within the supply chain, models can be developed.

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CLASSIFYING CONTAINER SHIPPERS FOR VALUE ADDED SERVICES: A DECISION TREE APPROACH[1]

Gökçay Balcı[2], İsmail Bilge Çetin[3]

Abstract – *Container shipping market has been subject to serious challenges in recent years. Customer service has become very important, but the core services of shipping companies have become very similar to each other due to the strategic alliances. Value added services (VAS) of container lines can be the main focus for differentiation and a better customer service. By delivering superior value added services, container lines can achieve more satisfied customers. In this way, the lines can also enjoy premium charges. However, expectations of customers are heterogeneous, which means that not all customers attach equal importance to VAS. For an effective delivery of VAS, classification of customers is necessary. Thus, the purpose of this study is to classify container shippers in terms of their expectations in VAS. Based on a survey research in Turkey, the study first conducts scale development and explore the factor of VAS through exploratory and confirmatory analyses. Then, the study carries out chi-square automatic interaction detection (CHAID) by using factor score of VAS as dependent variable and several nominal company demographics as dependent variables. The analysis creates segments of shippers which are identified by industry of shippers, size of shippers, and delivery terms*

Keywords – *CHAID, decision tree, shippers, container shipping, segmentation, classification*

INTRODUCTION

Container shipping market has been growing since its invention in 1950s. The tonnage of world seaborne container cargoes has increased from around 102 million tons in 1980 to around 1.66 billion tons in 2015 (UNCTAD, 2017). The competition among container lines, on the other hand, is keen despite the growing number of containerized world seaborne trade. The profitability levels of container lines have diminished in the recent years that many container lines have been facing harsh financial conditions. One of them, South Korean Hanjin Shipping, even bankrupted in 2016.

The competition among container lines is keen and the lines must apply competitive strategies such as cost leadership or differentiation (Kotler, 1980). Cost leadership at a large extent does not seem very applicable because the lines share the same vessels when carrying out the regular services. For the same reason, differentiation is also very difficult in the market due to very similar services of container lines (Maloni et al., 2016). Basic services of container lines – the elements of port-to-port transportation – are especially very hard to make a difference against other lines (Balci et al., 2018). Thus, customers usually tend to prefer the line that offers the best freight offer, which, eventually, causes a destructive price war.

Unlike core services of container lines, value-added services of them can be more differentiated since the vessel sharing covers only port-to-port transportation. Shippers are not willing to pay for extra price for the identical basic services, as a McKinsey report also suggests, but they may pay premium charges for a better service that can add value to their businesses (Glave et al., 2014). Thus, it is of significant importance for container lines to assess value added services in their businesses.

Studying value-added services is recently very important in container shipping, but one important question remains: Which shippers do actually attach importance to value-added services? The identification of shippers attaching importance to value-added service is significant. However, no paper in the literature has so far studied this subject. Therefore, the main purpose of this study is to identify segments of shippers that attach more importance to VAS.

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[1] The analyses in this research are based on the data of the first author's ongoing PhD thesis.

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LITERATURE REVIEW

Albeit the rapid growth of container shipping market in the last decades, the market has witnessed several structural and operational challenges. Since liner shipping requires a regular service, whether a vessel is full or not, and a weekly regular service can only be accomplished by a certain number of vessels, the market has high fixed costs. The high fixed cost in the business structure of container shipping leads to a cooperative behavior among liner shipping companies. As a liner shipping service provider, container lines used to be allowed to establish a conference system in which the lines had significant powers such as price fixing and loyalty agreements. However, the lines are not allowed to operate conference systems in many parts of the world after some regulations in EU and the USA. The lines, now, can only cooperate through strategic alliances which mostly consists of vessel sharing between the companies. The vessel sharing brings several advantages to the lines such as extending global service coverage.

The lines build strategic alliances and continue cooperating with other lines, yet price fixing and customer loyalty contracts are not allowed anymore in the market. The competition among container lines exists both within and between the alliances. However, the core services of the lines – port-to-port transportation – has become very similar to each other due to the vessel sharing, and the market has become a commodity like one (Balci et al., 2018; Maloni et al., 2016). All these developments have actually increased the importance of marketing strategies of container lines.

Several studies in the literature have investigated the selection criteria or service quality within the container shipping domain. Collison (1984), for instance, investigates market segmentation in container shipping. Brooks (1982) and (1990) measure the expectations of Canadian shippers when they purchase service from container lines. In the following years, several more authors examine the expectation of shippers or freight forwarders from container shipping companies in 1990s (Menon et al., 1998; Murphy and Daley, 1997; Pedersen and Gray, 1998) as well as in 2000s (Kannan et al., 2011; Lu, 2003; Thai, 2008; Tuna and Silan, 2002).

More recent marketing studies in container shipping usually deal with customer satisfaction, retention, loyalty, and perceived performance of the lines. For instance, Chao and Chen (2015) measure how customer satisfaction, switching costs, and perceived service quality affect the loyalty of customers in container shipping. Jang et al. (2013), on the other hand, investigates the impact of logistics service quality and relationship quality on customer loyalty. Shin and Thai (2015) extend the loyalty research and examine whether corporate social responsibility facilities together with customer satisfaction influence the loyalty or not. Similarly, Yuen et al. (2018) study the influence of sustainable shipping practices on customer loyalty. These studies in the literature have indeed contributed a lot to the development of customer-oriented studies in container shipping.

Although several studies exist in customers' selection criteria, satisfaction, and loyalty, the literature has not studied the VAS in container shipping. Since core service in container shipping has become identical and the container lines are facing low profitability problems, the value-added services may help the lines. The study of Yang et al. (2009) demonstrate that value-added services, which is evaluated under logistics service capabilities in that paper, can actually increase the perceived performance of shipping companies. Similarly, Heaver (2001) underlines the critical role of shipping lines in international logistics and points out how value added services are important for lines to sustain in constantly developing business environment. Our literature reviews indicates that the literature in container shipping services has not attracted much attention among academia.

Another concern in terms of value added services is the fact that customers are heterogeneous (Brooks, 1995), which means that not all customers attach same level of importance to value added services. The heterogeneity of customers in container shipping can be understood by evaluating the results of service attributes studies. Respondents in some papers, for instance, score freight rate as one of the highest service elements (Kannan et al., 2011), but it has one of the lowest scores in the study of Lu (2003). The ranking of container shipping service attributes vary between the studies, most probably because of the differences in geographic patterns, industrial categories, and culture etc. In this rationale, not every customer seeks for the value-added services at the same level, thus, it is important to find out the segments that demand VAS more than others.

METHODOLOGY

This paper aims to find out the segments that attach more importance to VAS. The research first conducts scale development of container shipping services to reveal VAS construct. Then, Chi-squared Automatic Interaction Detection (CHAID) is applied to detect the segments majority of which scoring more than average in VAS. The data is collected from shippers (exporters) located in Aegean Region through an online self-administrative survey study. Total 356 responses have been received. The questionnaire includes several nominal questions such as industry of shippers, monthly container volume, most preferred delivery terms, cargo value, and frequency of seaway usage etc. The survey also includes a total of 25 service attributes asking the importance of them at 7-point scale anchored as "very low importance / very high importance".

Exploratory and confirmatory factor analyses (EFA and CFA) are used for the scale development. Regarding EFA, principal component analysis with eigenvalues greater than 1 option is chosen to extract the factors. Varimax rotation is employed. Total 4 variables are removed from the measure. The variables are removed whether they have high cross-loadings or very low factor loading (lower than 0,5) following the suggestion of Hair et al. (2013). Cronbach alpha values do not change significantly when items are deleted from the constructs. A total of five factors including 21 variables are revealed through the EFA. Then, CFA is applied to ensure reliability and validity of the factors extracted. AVE value is used to represent the convergent validity, MSV is used for discriminant validity, and composite reliability is used for reliability of the factors (Bagozzi and Yi, 1998; Hair et al., 2013). Among the factors, mean value of VAS is 4.78 and it generates 19.5% of the total variance. Cronbach's Alpha score and composite reliability score are 0.88 while AVE value is 0.56.

Table 1 Results of scale development of selection criteria

Factor	% of variance	Alpha	CR	AVE	MSV
Value added services (VAS)	19.5%	0,88	0,88	0,56	0,29
Responsiveness	15.8%	0,82	0,83	0,51	0,25
Cost	15.7%	0,90	0,90	0,70	0,25
Time	10.0%	0,81	0,85	0,76	0,11
Relational	9.6%	0,72	0,78	0,54	0,29

Fit Indices: CMIN/DF= 3.00 (462.0/154), CFI=0.92, TLI=0.90, RMSEA=0.075, SRMR= 0,071

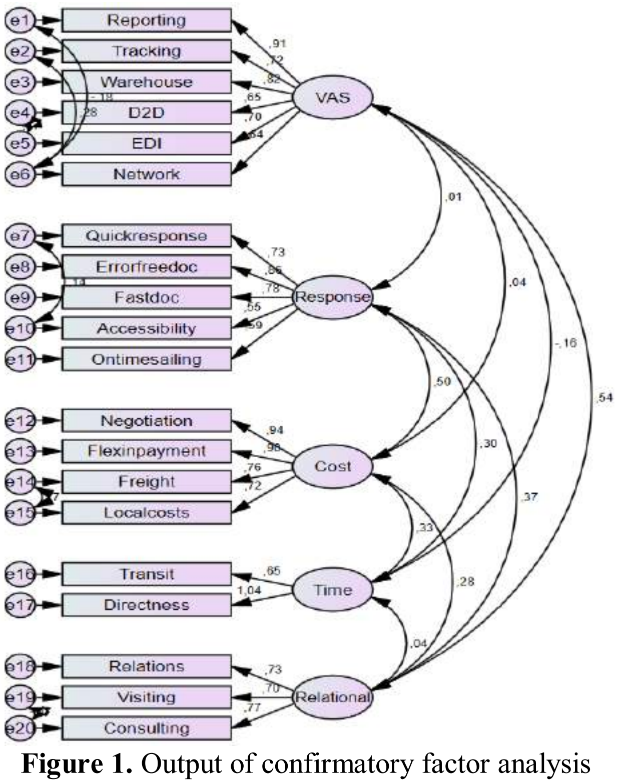

Figure 1. Output of confirmatory factor analysis

Upon revealing the value added services factor, next step it to conduct the CHAID analysis, which is a decision tree method. Decision tree is originally a data mining tool developed by Kass (1980) and it is used for classification and prediction. Decision trees apply thorough analysis yet provide easiness in interpretation of the data (De Ville, 2006). It is increasingly used in market segmentation studies in consumer markets (Chen, 2003; Han et al., 2012). Yet, the applications in B2B markets are somewhat limited.

There are several decision tree algorithms available in different statistical package. In SPSS 21, four algorithms exist: CHAID (Chi-square automatic detection interaction), Exhaustive CHAID, CRT (Classification and regression tree), and QUEST (Quick, unbiased, and efficient statistical tree). Readers are referred to different sources for comparisons of these methods (Loh, 2011; Sut and Simsek, 2011). In our study, we decide on using CHAID after comparing it to CRT. The reason for choosing CHAID over CRT is the fact that CRT always produces binary results (McCormick et al., 2017). Since the independent variables consist of usually more than three categories, it is anticipated that the results would have been easier to make comments and prediction.

The default options for parent/child node stopping rule in SPSS for CHAID analysis is 100 / 50. Since our sample is somewhat relatively smaller for the decision tree method, we select the parent node as 30 and child node as 15. This can allow us to achieve a finer result (Mccormick et al., 2017). The default depth of tree level in SPSS for CHAID is 3. We also change this criterion to 5 to achieve more detailed results. Factor score of VAS is selected as the dependent variable while monthly container volume, industry of shipper, number of employees, delivery terms, and type of cargo (ICB) are chosen as independent variables. The mean value of factor score is 0.00 and we converted the continuous VAS variable into a categorical one which has to categories: Above average and below average. Our target is to find the nodes that score higher than average.

RESULTS

According to the results, as shown in Figure21, there are total 10 nodes consisting of the root node, three parent nodes, and six child nodes. The accuracy rate of the model is 71.6%. The results indicate that the most important predictor variable is the monthly container volume. Node 3 includes shippers who ship at least 40 or more containers per month and around 72% of this segment scores higher than average on VAS. On the other hand, in Node 2, there are shippers who have maximum 5 containers per month. 73% of these shippers score below average. Node 2 is a parent node. It includes two leaf nodes: Node 6 and Node7. Delivery term is the variable that divides Node 2. Node 7 has the highest members that score lower than average (85.9%).

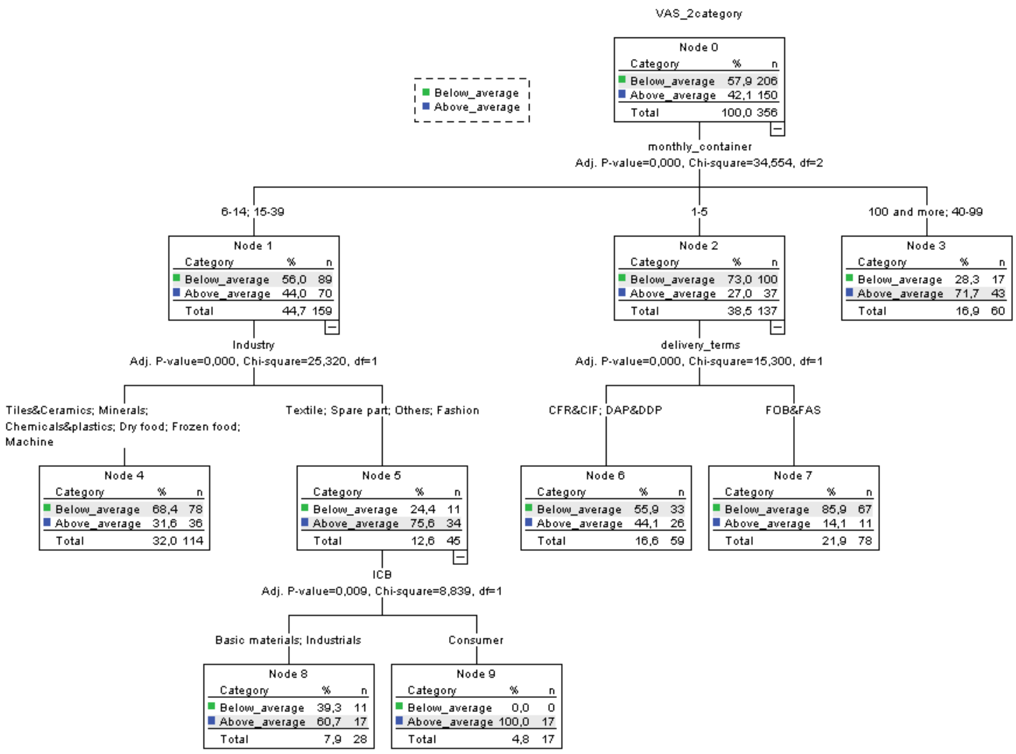

Figure 2. CHAID output

Node 1 is a parent node and it is divided into two by industry of shippers. Node 4 is a child node that includes shippers from minerals, chemicals, foods, and machines. Around 32% of Node 4 scores higher than average. On the other hand, Node 5 consists of respondents from textile, spare part, and fashion industries and 75% of the respondents score higher than average. Node 5 is divided into two other childe nodes (Node 8 and Node 9). All of the members of Node 9 scores higher than average while 60% of Node 8 scores higher than average.

DISCUSSION AND CONCLUSION

This study aims to find out the segments that attach importance to value added services. CHAID analysis is applied and shippers in Aegean Region are classified under total 6 terminal nodes. The most important predictors, in order, are monthly container shipment, industry, delivery term, and cargo type. The results indicate that the importance attached to VAS increases as the monthly container volume increases. The results also suggest that, among the shippers who ship between 6 and 39 container per month, textile, spare parts, and fashion industries have more shippers scoring higher than other industries. In the small shippers category (Node 2), shippers who mostly prefer CFR and/or DAP delivery terms score higher than FOB shippers.

The results have several implications for container lines. The lines should promote their value added services mostly to large shippers. The industries they should focus on are textile, spare parts, and fashion. They can also focus on consumer products rather than basic materials. The fact that CFR and DAP shippers attach more importance to VAS compared to FOB shippers is not surprising. FOB shippers are only responsible until loading the cargo to the vessel. Yet, these shippers still receive service from container lines and they also care about tracking of cargo as they need to check the delivery time of their shipments.

Future research may investigate not only exporters but also importers and freight forwarders as well, who are also the customers of container lines. The elements of value-added services may change depending on the geography and industry. Hence, these elements must be re-determined by the researchers through in-depth interviews before conducting such analysis.

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A PROPOSAL ON HOW TO DEVELOP A PERFORMANCE MEASUREMENT SYSTEM FOR FOURTH PARTY REVERSE LOGISTICS

Halil Hilmi Öz[1], *Bahar Özyörük*[2]

Abstract - *Reverse Logistics has increasingly become an important activity as a result of developments in economical, judicial and environmental factors. Fourth party reverse logistics, which is a subset of reverse logistics, establishes a reverse flow of goods from end-users to new potential users thereby offering strong potential to optimize the use of resources in society. Performance measurement provides important tools to managers in identification of problems and for the improvement of reverse logistics chains by facilitating measurement of efficiency and effectiveness of the system under consideration. When compared with a forward supply chain, reverse logistics has a more complex structure and therefore systems developed to measure the performance of reverse logistics are still in maturation stage. Furthermore, there are hardly few studies in performance measurement of fourth party reverse logistics. In this regard, there is a need in fourth party reverse logistics to have a comprehensive performance measurement system which uses both structural performance frameworks and procedural approach together to develop more valid performance measures, and to establish a strong linkage between those performance measures and corporate strategy.*

Keywords - Fourth Party Reverse Logistics (4PL), Measurement Frameworks, Performance Evaluation (PE), Performance Measurement (PM), Reverse Logistics (RL),

INTRODUCTION

The role of logistics in the organizational strategy has become a subject of interest in the logistics literature since the 1970's (Yellepedi, 2006, p.28), and in the 1980s this interest has been increased to include logistics in a broad spectrum. Reverse logistics (RL) has increasingly begun to take place in company / organization applications and strategic plans as it provides competitive advantage for companies (Newman and Hanna, 1996). Fourth party logistics (4PL) is a mode of reverse logistics, in which a logistics service provider acts like “a control tower over other parties, taking responsibility of all the users’ outsourced operations, thereby serving as a single interface between the client and multiple logistic service providers” (Büyüközkan, 2009; Skjoett-Larsen, 2000).Krakovics et al. (2008) state there is hardly limited research available in 4PL, moreover it is uncertain whether they can be applied to 4PL operations or not, therefore there is a need for development of performance measurement (PM) frameworks for 4PL.

This paper focuses primarily on the systematic review of literature on PM in RL and the development of a PM system for the 4PLthat has recently started drawing attention from academia. The structure of the article is based on six section, the first being introduction. The second section gives fundamental information regarding reverse logistics; the third presents PM approaches; the fourth presents research methodology and the findings of systematic literature review regarding reverse logistics, and the fifth section presents a proposal for the development of PM systems for fourth party reverse logistics. Finally, conclusions of findings are summarized, followed by references at the end.

REVERSE LOGISTICS (RL)

Contemporary issues and trends regarding globalization's impacts, technological developments, the increasing awareness and requirements of environmental responsibility, and sustainability force people and organizations to make changes in their work as well as in their personal lives. RL has become an increasingly important activity due to improvements in logistics, economics, legal and environmental factors. Open and

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closed loop reverse logistics' chain design and operations have attracted the attention of both academia and industry over the last 30 years. There are two basic reasons for this. The most important of thereof is the fact that reprocessing activities made through remanufacturing and renewals have a serious economic potential (Beullens, 2004). Many companies attach greater importance to RL strategies, since they understand that RL enables significant cost savings (Tonanont, 2009). The second one is that companies that produce reusable products through remanufacturing and renewal are held accountable for the ever-increasing environmental sensitivity in public, or in other words, national laws put them responsible for the planning and implementation of reuse activities (Hwang, 2004). Yellepedi (2004, p.9) states, in a larger context, the main factors affecting RL can be grouped into economic interests, legal regulations, customer loyalty, customer service and product / brand protection.

According to Min et al. (2006), RL is a complex process due to its nature and a specialized area of a supply chain. Rogers and Tibben-Lemke (1999) defines RL 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". While traditional supply chain designs focus on the efficient and effective production and delivery of products from supply points to demand points, through one or more transfer points, RL refers to a similar, but reverse flow in the reverse route for the reuse of products through reprocessing and renewal (Hwang, 2004, p.8). In this sense, the reverse flow in the supply chain means that products' life cycles do not really end with the delivery of product but continues till end of use of products (Shaik, 2014, p.10). Through back flow, products move upstream from customers to the manufacturer or to the suppliers in the supply chain for reuse, repair, recycling and destruction (Alvarezgil et al., 2007). RL deals with the management of products in the reverse direction where there is a value to be recovered (Yellepedi, 2006, p.1). When product returns enter reverse flow, they follow four-steps process (collection, examination and processing, recovery, and redistribution) through upstream (Pinna and Carrus, 2012). Hillegersberg et al. (2001) point out the importance consumers' behavior in introducing uncertainties in quantity, quality and timing of product returns, which triggers different RL operations from that of traditional forward logistics.

PERFORMANCE MEASUREMENT (PM) APPROACHES

PM has passed several stages since the 1970s, with initial studies accounting used, particularly budgeting as an instrument for PM, and in the 1980s the focal point became budgeting process and its impact on performance (Yellepedi, 2007, p.32). However, dissatisfaction and criticism regarding the PM system related to the widely applied budget planning and control approach did not come to an end (Wilcox and Bourne, 2003). The shortcomings of traditional measurement systems have triggered serious regeneration in PM (Neely, 1999). Among the first studies to go beyond the accounting and budgeting measures and provide more balanced performance measurement are Performance Measurement Matrix (Keigan et al., 1989), Performance Pyramid (Cross and Lynch, 1992), Balanced Scorecard (Kaplan and Norton, 1992) and Performance Prism (Neely et al., 2001). These measurement frameworks, as a common feature, very strictly state which performance criteria should be included in PM systems and present a performance framework. In this context, the term framework refers to a coherent structure used to identify and define elements of logistic chains, and these elements are used to derive performance measures (Luger and Herrmann, 2010). When compared to financial criteria alone, the contemporary measurement frameworks offer structural PM systems by suggesting a wider and more balanced model to some extent. On the other hand, some studies suggest that a PM system should be uniquely identified for a company and in this regard, they provide a step-by-step guide for designing performance measures for practitioners (Nizaroyani, 2010, p.31). It is useful to look at least one example in order to understand this process-oriented (procedural) approach. In this context, nine step process, as given in Table 1, proposed by Wisner and Fawcett (1991) for developing a PM system is a good example, although there are plenty of procedural guides in this regard.

By examining the examples of the procedural approach such as given above in literature, Bourne et al. (2000) conceptually say that there are three stages, namely design, implementation, and use while Neely et al. (2000) add everlasting the management stage as a fourth one. Franco-Santos and Bourne (2005) proposes of the inclusion of the scope / content criteria as crucial factor for development the PM system in the procedural approach.

In summary, there are two main approaches in the development of performance measures in reverse logistics. The two approaches are not contradicting, but complementing each other, as it can be observed in some recent studies of done by Yellepedi (2006) and Shaik (2014). While the use of existing PM frameworks makes it easy to include and assess the contribution of already proven performance measures in literature, the procedural (process-oriented) approach helps to guarantee measures are closely linked to the company's goals, thereby their relevance as well.

Table 1. The Procedure for Development of Performance Measurement Systems (Wisner and Fawcett, 1991)

1) Clearly define the firm′s mission statement.
2) Identify the firm′s strategic objectives using the mission statement as a guide (profitability, market share, quality, cost, flexibility, dependability, and innovation).
3) Develop an understanding of each functional area′s role in achieving the various strategic objectives.
4) For each functional area, develop global performance measures capable of defining the firm′s overall competitive position to top management.
5) Communicate strategic objectives and performance goal to lower levels in the organization. Establish more specific performance criteria at each level
6) Assure consistency with strategic objectives among the performance criteria used at each level.
7) Assure the compatibility of performance measures used in all functional areas.
8) Use the PM system to identify competitive position, locate problem areas, assist the firm in updating strategic objectives and making tactical decisions to achieve these objectives, and supply feedback after the decisions are implemented.
9) Periodically re-evaluate the appropriateness of the established PM system in view of the current competitive environment.

RESEARCH METHODOLOGY AND SYSTEMATIC LITERATURE REVIEW

Fink (2014) defines literature review as a method for identification and synthetization of existing body of work done by researchers or scholars. He also EMPHASIZES the method chosen needs to be systematic and reproducible. Brocke et al. (2009) identifies the documentation of the research process as the crucial part of a successful literature review, that is why we followed a concrete and reproducible research procedure as specified in following paragraphs.

Figure 1. Review Process

While making a systematic literature review, a methodology depicted in Figure 1 was employed. First main step was to frame research activity, in which sub-activities such as Database Selection, Key Word Selection, Language Selection and Time Period Specification are carried out. Database Bases and Research Engines used during the research were Web of Science, Ebsco Discovery Service, Science Direct, Emerald, Springer Link, IEEE Xplore, Google Scholar and Google.

Three key words (performance measurement, performance evaluation, and reverse logistics) were and variations and different combinations thereof were welcomed in evaluation of research English language was used as the research language. The time period for the research was taken between 2008-2018.

Through literature review process defined above, overall 46 scientific sources were identified which were written between 2008 and 2018, as listed in Table 2. The average of scientific sources per year is about 4.2, whereas the highest number of scientific sources per year is 6 in 2011 and 2014, as can be seen at Table 2. Only 13 studies out of 46 used an existing measurement framework, a modified framework or hybrid framework in the development of PM systems. BSC is the most preferred framework having been utilized in nine studies out of 13, where it is used as stand alone, modified or together with another framework.

As seen at Table 2, a large variety of Analysis Methods were used in PM studies between years 2008-2018 in RL. The largest group of analysis methods used was Multi Criteria Decision Making (MCDM), most probably due to multi-perspective characteristics of PM in RL. MCDM techniques (i.e. AHP (Analytic Hierarchy Process), ANP (Analytic Network Process), TOPSIS (Technique for Order Preference by Similarity to the Ideal Solution), and DEMATEL (Decision Making Trial and Evaluation Laboratory)) were used 24 times (out of 63 in total) in these studies.

Table 2. Identified Scientific Sources Regarding Performance Measurement in Reverse Logistics

Year	Author	PE/PM	Performance Measurement Frameworks	MCDM / Analysis Methods
2008	Tuzkaya, G., and Gülsün, B.	PE		Fuzzy TOPSIS, ANP
2008	Tonanont, A.; Yimsiri, S., Jitpitaklert, W., and Rogers, K. J.	PE	BSC	AHP, Data Envelopment Analysis
2008	Zhang, F.R., Fet, A.M.	PE		Empricial Example, TOPSIS
2009	Olugu, E.U., Wong, K.Y., and Shaharoun, A.M.	PE		
2009	Pochampally, K. K., Gupta, S. M., and Govindan, K.	PM	QFD	Linear Physical Programming (LPP)
2009	Jianhua, Y., Lidong, Z., and Zhangang, H.	PE	Revised BSC	Fuzzy AHP
2009	Tonanont, A.	PE		Simulation, DEA, Statistical Experiments
2010	Nizaroyani, S.	PM	SCOR	Case Study
2010	Huang, R. H., Yang, C. L., Wuang, M. S., and Tsui, C. S.	PE		Collection of Studies, Expert Interviews, ANP
2010	Xiong, G., and Li, X.	PE		Fuzzy AHP
2011	Mohammed N. Shaik & Walid Abdul-Kader	PM		AHP
2011	Geethan, K.A.V., Jose, S., and Chandar, C.S.	PE		Case study, ANP
2011	Ping, H.	PE		
2011	Shen, Y., Nie, Q., and Yuan, Q.	PE		Questionnaire Survey, SEM)
2011	Lambert, S., Riopel, D., and Abdul-Kader, W.	PE		
2011	Olugu, E. U., and Wong K. Y.	PE		Case Study, Fuzzy Logic
2012	Shaik, M., and Abdul-Kader, W.	PM	BSC and Perf. Prism	AHP
2012	Huang, Rong-Hwa., Yang, Chang-Lin., Lin, Chia-Chen and Cheng, Yu-Ju.	PE		Collection of Studies, Expert Interviews
2012	Skapa, R., and Klapalova, A.	PM		Statistical Analysis
2012	Su, Li-xia., Wang, Zhao-hua., and Su, L.	PE		Canonical Correlation Analysis
2012	Petersson P., and Zantvoort, T.	PM	BSC and EFQM Excellence	Expert Interviews
2013	Nagalingam, S.V., Kuik, S.S., and Amer, Y.	PM		Six Sigma Methodology
2013	Shaik, M.N., Abdul-Kader, W.	PM		AHP
2013	Hall, D.J.,Huscroft, J.R., Hazen, B.T., and Hanna, J.B.	PE		Questionnaire Survey, Goal-Setting Theory
2013	Nikolaou, I. E, Evangelinos, K. I., and Allan, S.	PE	Triple Bottom Line	
2013	Umeda, S.	PE		Simulation
2014	Shaik, M.N., Abdul-Kader, W.	PM	BSC and Perf. Prism	DEMATEL
2014	Bouzon, M., Miguel, P.A.C., Rodriguez, C.M.T.	PE		Literature Review
2014	Shaik , M.	PM	BSC and Perf. Prism	DEMATEL, Fuzzy ANP, AHP
2014	Bansia, M., Varkey, J.K., and Agrawal, S.	PM	BSC	Case Study , Fuzzy AHP
2014	Momeni, E., Tavana, M., Mirzagoltabar, H., and Mirhedayatian, S.M.	PE		Fuzzy Data Envelopment Analysis (DEA)
2014	M.B. Butar Butar , D. Sanders, G. Tewkesbury	PM		Case Study
2015	Yogi, K.S.	PE		Case Study
2015	Bouzon, M., Govindan, K.	PM		Empricial Res., Questionnaire Survey, AHP
2015	Guimarães, J. L. S., and Salomon, V. A. P.	PE		ANP
2016	Outmal, I. ; Kamrani, A. ; Nasr, E.S.A., and Alkahtani, M.	PE		Supply Chain Analytical Modeling
2016	Hazen, B.T., Overstreet, R.E., Hall, D.J., Huscroft, J.R., and Hanna, J.B.	PE		Surveying and Hypotheses Testing
2016	Agrawal, S., Singh, R.K., and Murtaza, Q.	PE	Triple Bottom Line	Fuzzy AHP
2016	Agrawal, S., Singh, R. K. Murtaza, Q.	PE		Literature Review,Fuzzy TOPSIS
2016	Butar Butar, M. B.	PM		Literature Review, case studies
2017	Pandian, G.R.S., Abdul-Kader, W.	PE		Simulation
2017	Butzer, S., Schötz, S., Petroschkea, M., and Steinhilpera R.,	PM	Revised BSC	AHP, Literature Review
2017	Jung, H.	PE		Fuzzy AHP
2018	Govindan, K., and Bouzon M.	PE		Literature Review
2018	Hana, H., and Trimi S.	PE		Fuzzy TOPSIS
2018	Fernandes, S. M., Rodriguez, C. M. T., Bornia, A. C., Trierweiller, A. C. Silva, S. M., and Sá Freire, P.	PE	Revised BSC	AHP, ANP

There is not a study, among 46 scientific sources identified during the literature review process, which studies performance measurement of fourth party reverse logistics. Even more as discussed by Krakovics et al. (2008) there is hardly limited research available in 4PL, and moreover it is uncertain whether they can be applied to 4PL operations or not, therefore there is a need for development of PM frameworks for 4PL. Petersson and Zantvoort (2012) also state that PM frameworks for 4PL have not been developed so far. In summary, there is a gap in literature for the development of PM systems for fourth party reverse logistics as well as 4PL. In the next section, we propose the use of PM frameworks and the procedural approaches simultaneously to develop a PM system for fourth party reverse logistics.

DEVELOPMENT OF A PERFORMANCE MEASUREMENT SYSTEM FOR FOURTH PARTY REVERSE LOGISTICS

"As the competition has increased in rapidly globalized world in last several decades, companies have developed understanding that RL is a process of its own and requires to develop competency to successfully fulfill it" (Lieb and Bentz, 2004). Therefore, companies have been increasingly forced to outsource it to stay competitive in their core competency. According to Gattorna (1998), "While outsourcing third-party logistics is now an accepted business practice, 4PL is emerging as a breakthrough solution to modern supply chain challenges…to provide maximum overall benefit".

As discussed in fourth section, there is a gap in literature for the development of PM systems for fourth party reverse logistics, and in this regard, we propose to use existing measurement frameworks and procedural approach together to develop a performance measurement system. In this hybrid application, the use of PM frameworks helps to include already proven PM perspectives in the study while the procedural approach guarantees a close link between chosen measures and the company's goals, thereby their relevance as well. However, we assess there is a need for further development of existing PM frameworks and some adaptations are required for procedural approaches such as offered by Wisner and Fawcett (1991). As can be seen from results of literature review discussed in the fourth section, BSC is the most preferred measurement framework, either alone, by modification or together with another measurement framework. However, BSC is criticized for not offering a full PM system (Sinclair and Zairi, 1995), and is not capable to facilitate the understanding of strategy development and operative level objectives through stakeholder analysis, nor does it contribute to determining the factors that will lead to customer satisfaction (Liu and Qu, 2009). Therefore, we propose to use of the BSC and the performance prism measurement frameworks together. The Performance Prism highlights five different but interconnected performance perspectives (i.e. stakeholder satisfaction, strategies, processes, capabilities and stakeholder contributions). It reflects relevant stakeholders during the development of performance measures and considers stakeholders' contribution to firm performance as well as it uses strategies, processes, capabilities as measurement perspectives which are instrumental to the development of close links between corporate goals and developed measures.

Some features of 4PL can also contribute to the development of some additional PM perspectives. For example, Crowley (1998) states that competitive advantage in 4PL will be more and more dependent on value creation via information and communication technologies (ICT). In other context, Pianna and Carrus (2012) state that RL can be regarded as part of sustainable development. So, we propose to include ICT, and Social and Sustainable Development as separate perspectives to add value to PM framework under development.

When taken together above comments regarding BSC, performance prism and some underlying features of fourth party reverse logistics which is a sub-set of reverse logistics, the aligned PM perspectives given in below list can be taken together to develop a PM framework for fourth party reverse logistics:

- Financial,
- Capabilities,
- Processes,
- ICT, Innovation and Growth,
- Stakeholders,
- Social and Sustainable Growth,
- Environmental,

We think the use of MCDM methods as analysis method is mandatory for the PM perspectives we propose since there are soft measures which can't be directly measured by conventional measurement systems, in addition to directly measurable hard measures. AHP and ANP are well known methods in this regard.

CONCLUSIONS AND OUTLOOK

This paper firstly described fundamentals of RL and PM approaches in literature to build a basis for further discussion. It secondly described the results of the systematic review of the literature on PM in RL to highlight current trends and approaches in this regard. The results showed the ongoing interest in development PM in reverse logistics. The paper lastly identified the need for the development of a PM framework as well as a measurement system for the 4PL. As a result, a PM framework with six perspectives was defined.

The development of PM system is the initial stage in the holistic assessment of the 4PL which can effectively manage challenges and provide creative logistics in reverse logistics. When based on non-profit mode, the 4PL also provides a very promising RL alternative in support of sustainable growth in social and economic dimensions. In future research, further refinement of PM system for 4PL when based on non-profit mode will be studied as a second step, in which calculation of PM index will be developed and strategies for implementation and management stages will be discussed.

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PRESENT STATUS AND FUTURE TRENDS IN ELECTRIC VEHICLE ROUTING

Yusuf Yılmaz [1], Can B. Kalayci [2]

Abstract *– The engine technology used in vehicles has been recently evolving from conventional to plug-in hybrid and fully-electric. In the near future, electric vehicles will completely take place of the internal combustion motor vehicles. Therefore, electric vehicle routing studies gained an increasing importance in the last decade building on top of well-investigated vehicle routing literature. The computational load to solve the electric vehicle routing problem is even greater than the original vehicle routing problem because of the added complexity of electric vehicle routing problem variations. In this study, the electric vehicle routing problem literature is examined. Vehicle types, problem assumptions and constraints, problem variations, factors on energy consumption and various solution approaches are evaluated and finally, future research directions are presented.*

Keywords – Electric vehicle routing, review, present status, future trends

INTRODUCTION

Various vehicles and animals have been used in logistics and transportation since ancient times. In the 18th century, the effects of new inventions on production and the increase of steam powered machines have led to the industrial revolution. The first internal combustion engine is developed in Europe in 1859 with this revolution spreading from Europe to the world. One of the reasons behind the great progress in production, transportation and logistics is the development of engine technology. With the widespread use of internal combustion engines, diesel engine vehicles have taken the place of steam engines in logistics and transportation.

Environmental and socio-economic problems have arisen in the world due to the increasing use of fossil fuels for 150 years. Greenhouse gas emissions resulting from the use of fossil fuels create a warming effect by absorbing the light reflected from the earth. In terms of environmental sustainability, it is necessary to reduce carbon dioxide released into the atmosphere. It is important for fossil fuel technologies, which have the most share in this issue, to leave their place to sustainable technologies.

Increased environmental concerns and government decisions to reduce dependence on fossil fuels have spurred research and development efforts in the area of electric engine and battery technology.

Long-term research and applications are being carried out in the scientific field regarding the routing of internal combustion engine vehicles. There are many books, theses, articles and papers written on this subject. However, the number of studies carried out for the routing of hybrid and electric vehicles which have specific constraints is relatively at the limited quantity.

In the literature, there are various studies about electric vehicles considering the types of problems such as vehicle routing, vehicle energy consumption forecasting, battery swap station selection, and recharging decisions under a fixed route (Figure 1). Vehicles examined in the literature are categorized in terms of engine type in Figure 2.

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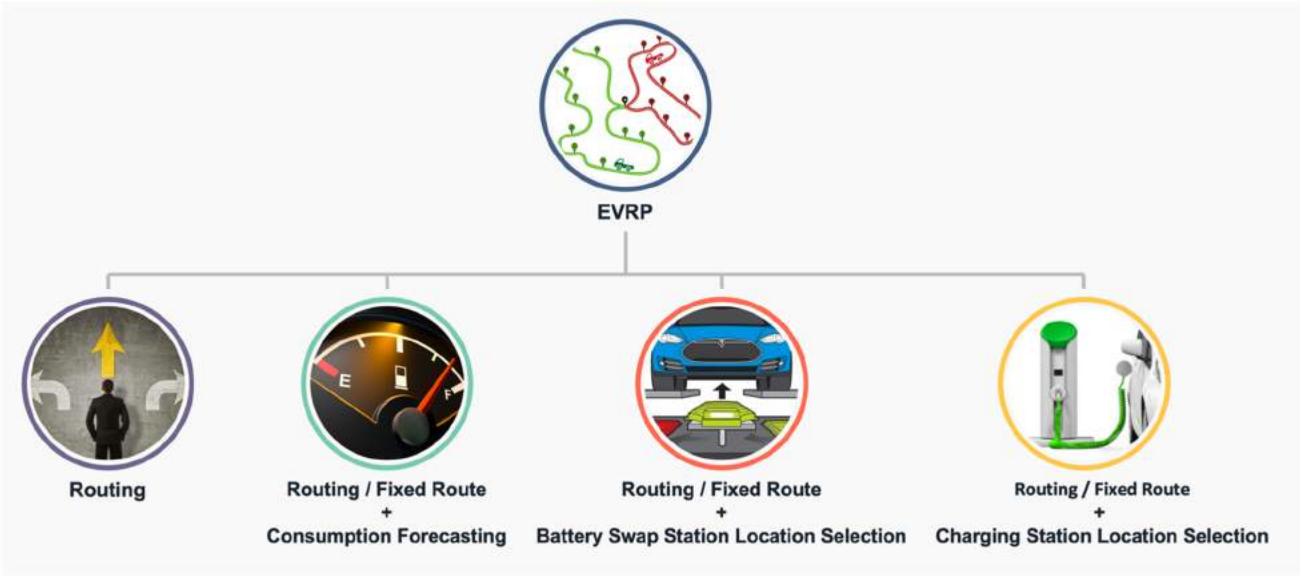

Figure 1. EVRP Approaches

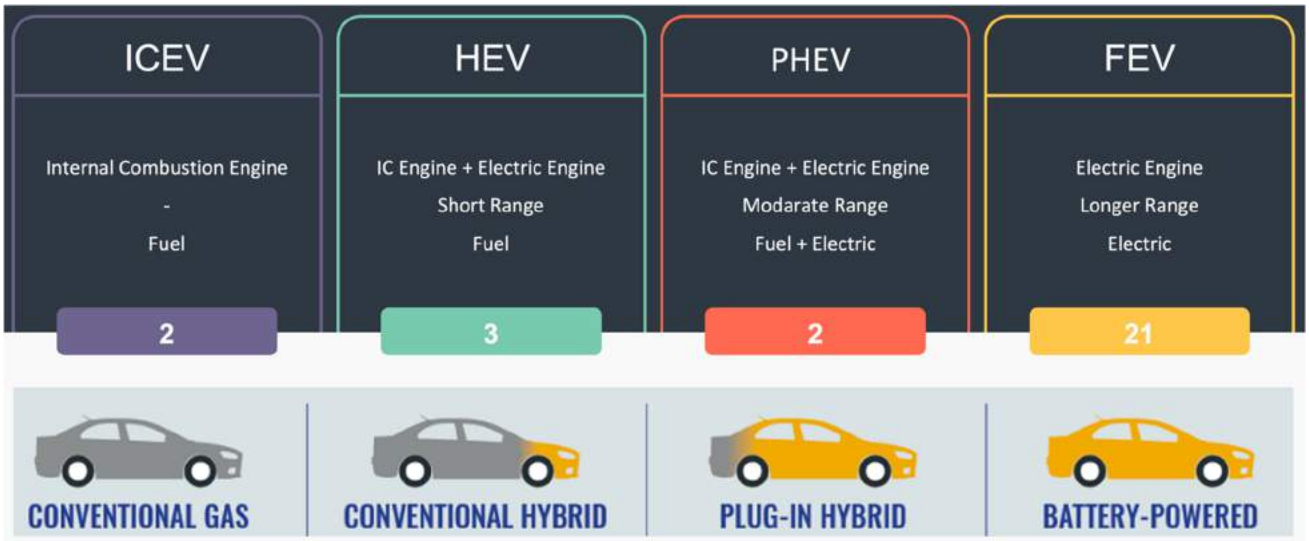

Figure 2. Vehicle Types

LITERATURE

Energy Consumption Forecasting and Energy Management

There are several studies about energy management and consumption forecasting besides the routing of electric vehicles (Agrawal, Zheng, Peeta, & Kumar, 2016; De Cauwer, Verbeke, Coosemans, Faid, & Van Mierlo, 2017; Genikomsakis & Mitrentsis, 2017; Larsson, Johannesson Mardh, Egardt, & Karlsson, 2014; Tianheng et al., 2015; Wang, Jiang, & Mu, 2013; Zeng & Wang, 2016). In these studies where different concepts are used to optimize energy management, it is often necessary to consider the factors such as weather conditions, topography, traffic density, etc. on the route to be traveled.

Larsson et al. (2014) introduced an energy management system for an optimized route, where the computations were performed on a server. The concept of the study is to identify commuter routes from historical driving data, and then precompute an optimal solution to the energy management control problem with dynamic programming. De Cauwer et al. (2017), presented an energy consumption prediction method for EVs. It was designed for energy-efficient routing. The methodology combines real-world measured driving data with geographical and weather data to predict the consumption over any given road in a road network.

Simultaneous Location Selection and Routing

There are several studies to solve two types of problems which are Battery Swap Station Location Selection Problem (BSS-LSP) and Electric Vehicle Routing Problem (EVRP) simultaneously (Hof, Schneider, & Goeke, 2017; J. Yang & Sun, 2015). Similarly, Paz, Granada-Echeverri, and Willmer Escobar (2018); Schiffer and Walther (2017) tried to find a solution to both recharging station location selection problem (RS-LSP) and EVRP.

J. Yang and Sun (2015) aimed to solve both BSS-LSP and EVRP simultaneously under battery-based range limitation. A mixed integer programming model was developed to solve Multi-Depot Electric Vehicle Location Routing Problem with Time Windows (MDVLRPTW) by Paz et al. (2018). In the model; i) the number and location of recharging station (RS), ii) the number and location of the depots, iii) the number and routes of EVs. In the recharging stations (RS), there are also battery swap stations (BSS) where the batteries are exchanged.

The details of the studies on EVRP have been obtained from Web of Science, and the number of published articles according to years is shown in Figure 3. Although the number of EVRP studies has increased rapidly in recent years, the research has not been adequately built up. There is a huge gap for research.

Electric Vehicle Routing

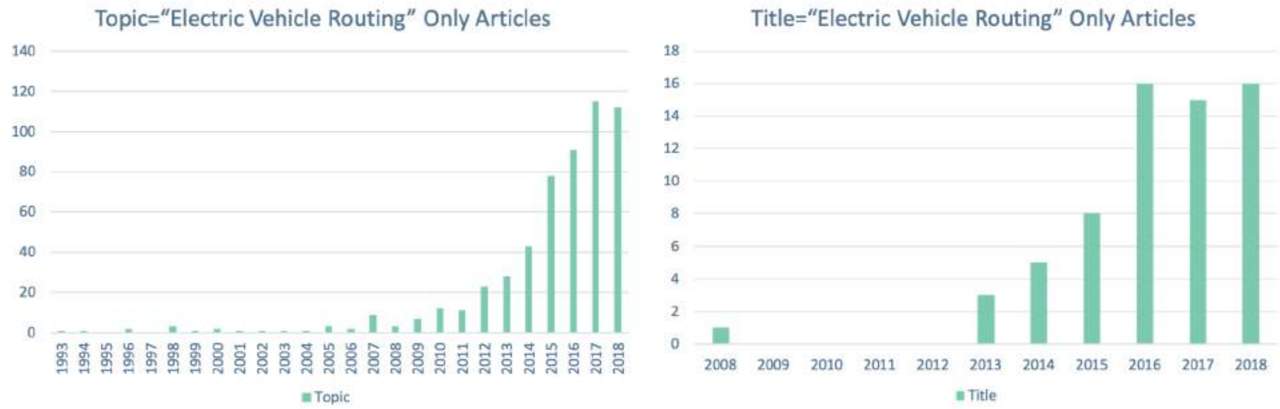

Figure 3. EVRP Literature

Bruglieri, Pezzella, Pisacane, and Suraci (2015) proposed a mixed integer linear programming (MILP) formulation for routing a homogeneous EV fleet, addressing the EVRPTW. The objective function tries to minimize; the number of EVs used, the total travel time, the total recharging time and the waiting time. Variable Neighborhood Search Branching (VNSB) has been applied to the model to find good solutions in terms of computational time in large scale problems.

Goeke and Schneider (2015) proposed the Electric Vehicle Routing Problem with Time Windows and Mixed Fleet (EVRPTWMF) to optimize the routing of a mixed fleet of EVs and internal combustion vehicles (ICVs). A realistic model has been developed to predict energy consumption for EVs and fuel consumption for ICVs. The model was considering vehicle speed, road characteristics, payload and weather. Adaptive Large Neighborhood Search (ALNS) algorithm was used to solve the problem.

H. Yang et al. (2015) tried to find a solution to the EVRP from a different point of view. Minimization of time-based recharging cost was aimed under fast and standard recharging decisions. The effect of the payload carried on the vehicle on the energy consumption per unit distance was also taken into consideration. For the solution of the proposed model, a learning parthenogenesis algorithm (PGA) has been developed.

In their study, J. Yang and Sun (2015) tried to solve BSS-LSP and EVRP simultaneously under battery-based range limitation. The problem was formulated as an integer programming model and solved by four-stage heuristic called SIGALNS and two-stage heuristic called Tabu Search-Modified Clarke and Wright Savings (TS-MCWS). In the objective function of the developed model, it was aimed to minimize the total cost of establishing and operating the BSS and the freight transport costs of the EVs. Two different model descriptions have been made, assuming that in the first model, each EV can visit BSS only once, while in the second model there is no such limit.

Hiermann, Puchinger, Ropke, and Hartl (2016) focused on fleet size and fleet mix while considering EVRPTW. However, recharging times and recharging station decisions were also given. Finding a solution to the combination of the EVRPTW, the RS-LSP and the EVRPTWMF was tried. Each vehicle can visit the recharging point at most once. Vehicles arriving for recharging do not leave the station without full recharge. Recharging time is determined linearly with the empty part of the battery, recharging speed is standard. It was assumed that each customer has a recharging station. Local search and labeling procedures have been used to solve the problem, with Adaptive Large Neighborhood Search (ALNS) meta-heuristic.

Keskin and Çatay (2016) dealt with a scenario in which EVRPTW permits partial recharging (EVRPTW-PR) and developed a mathematical model within this context. It was assumed that the vehicle fleet is homogenous, partial recharge is allowed at a standard recharge rate, and that the energy consumption is directly proportional to distance. EVRP and EVRP-PR were solved by using ALNS heuristic. To test the efficiency of the proposed method, data sets of Schneider, Stenger, and Goeke (2014) were used and better results were obtained from best results in some problem types.

Lin, Zhou, and Wolfson (2016), presented a general EVRP that finds the optimal routing strategy with minimal travel time cost and energy cost as well as number of EVs dispatched. EVRP model considers the effect of vehicle load on energy consumption. When the formulation is examined; The objective is to minimize the sum of three different costs, the cost of recharging, the cost of travel, the cost of waiting for recharging. The cost of recharging equals the cost of energy consumption. Each recharging station (RS) may be used one or more times by the same or different vehicles or may not be used at all. It was assumed that the vehicles are waiting for a fully charge and have a mixed fleet. The inter-point speed was assumed constant. Time windows were not considered. Although the developed model was solved with small test data, a heuristic method for large problems has not been developed. Different scenarios can be operated by considering a mixed fleet of EVs with internal combustion engine vehicles (ICEVs).

Sun and Zhou (2016) proposed a cost-optimal algorithm (COA) to minimize fuel consumption for plug-in hybrid vehicles (PHEVs) instead of EVs. The energy obtained from the regenerative braking system was considered.

Hof et al. (2017) used the AVNS algorithm for simultaneous solution of EVRP and BSS-LSP defined by J. Yang and Sun (2015). The homogeneous vehicle fleet, distance-based linear energy consumption and time windows assumptions were taken into account and the data of J. Yang and Sun (2015) were used. The results showed that the computation time is shorter when compared to J. Yang and Sun (2015) and CPLEX results.

Montoya, Guéret, Mendoza, and Villegas (2017) introduced the EVRP with nonlinear charging functions (E-VRP-NL). They proposed a mixed integer linear programming formulation and a hybrid metaheuristic that combines simple constraints from the literature and specific constraints for the new problem. The objective function of proposed mathematical model was to minimize the total travel and recharge time. Also, they proposed a set of realistic instances. They demonstrated the importance of better approximating the actual battery charging function through extensive computational experiments.

Shao, Guan, Ran, He, and Bi (2017) proposed a realistic framework that considering the charging and variable travel time of EVs. For this reason, dynamic traffic environment, vehicle capacity, time window, recharging cost, penalty cost, etc. have been dealt with. The model was solved by using genetic algorithm to obtain the routes, the vehicle departure time at the depot, and the charging plan.

Strehler, Merting, and Schwan (2017) developed a mathematical model for finding shortest routes for hybrid and electric vehicles, which is a kind of constrained shortest path problem with convertible resources and charging stations. They studied properties of solutions by classifying several types of cycles that may occur in the optimal route. They stated sufficient conditions to exclude some of these cycle classes and they derived appropriate approximation schemes with provable quality and strict feasibility.

Paz et al. (2018) considered EVRP with time windows, multi-depot and homogeneous fleet and developed a mixed integer programming model with non-linear charging function. It was aimed to make some decisions in the developed model such as; i) the number and location of RSs, ii) the number and location of the depots, iii) the number and routes of the EVs. In addition to RSs, there are also battery swap stations (BSS) where the batteries are exchanged. It was assumed that; the recharging time is always longer than the battery swap time. Also, the vehicle speed is constant, and that the energy consumption is depending on the distance travelled. The model was solved with CPLEX using data sets generated by, Schiffer and Walther (2017).

The identified gaps in literature to clarify the future research opportunities are presented in Table 1.

Table 1. Literature Review

	Fleet		Recharge Type		Recharge Speed		Power Consumption					Problem Scope			Solution Approache		Other
	Homo.	Mixed	Full	Partial	Standart	Slow/Fast	Distance	Road Characteristic	Wheather	Payload	Speed	Routing	Location Selection	Forecasting	Optimization	Simulation	Time Window
Wang vd. (2013)	✓		✓	✓	✓		✓		✓	✓	✓	✓		✓	✓	✓	
Bruglieri vd. (2015)	✓		✓	✓	✓		✓					✓			✓		✓
Goeke ve Schneider (2015)		✓	✓		✓		✓	✓		✓	✓	✓			✓		✓
Yang vd. (2015)	✓		✓		✓	✓	✓			✓		✓			✓		
Yang ve Sun (2015)	✓						✓					✓	✓		✓		
Agrawal vd. (2016)		✓					✓				✓	✓		✓	✓	✓	
Hiermann vd. (2016)		✓	✓		✓		✓					✓			✓		✓
Keskin ve Çatay (2016)	✓		✓	✓	✓		✓					✓			✓		✓
Lin vd. (2016)		✓	✓		✓		✓			✓	✓	✓			✓		
Sun ve Zhou (2016)	✓		✓	✓	✓		✓					✓			✓		
Zeng ve Wang (2016)	✓		-	-	-	-	✓	✓			✓			✓	×	✓	
De Cauwer vd. (2017)	-	-	-	-	-	-	✓	✓	✓	✓	✓			✓	✓		
Genikomsakis ve Mitrentsis (2017)	-	-	-	-	-	-	✓	✓	✓		✓			✓	×	✓	
Hof vd. (2017)	✓		-	-	-	-	✓					✓			✓		
Montoya vd. (2017)	✓		✓	✓		✓	✓					✓			✓		
Schiffer ve Walther (2017)	✓		✓	✓	✓		✓					✓	✓		✓		✓
Shao vd. (2017)	✓		✓		✓	✓	✓				✓	✓			✓		✓
Strehler vd. (2017)	✓		✓	✓	✓		✓	✓			✓	✓		✓	✓		
Paz vd. (2018)	✓		✓	✓	✓		✓					✓	✓		✓		✓

CONCLUSION

In this paper, we reviewed the related studies of electric vehicle routing problem. In this frame, the search was conducted on Web of Science which is one of the major scientific databases. Related publications were published in various journals. Vehicles in the literature are categorized in terms of engine type. Problem variations, such as vehicle routing, vehicle energy consumption forecasting, battery swap station selection, and recharging decisions under a fixed route, are evaluated. Factors on energy consumption are examined. Although most of the studies have assumed that the fleet is homogeneous, considering mix fleet would be more realistic. Almost all papers considered standard recharge speed. The effect of weather on power consumption was considered by only a few papers. A few papers focused on routing and considered location selection problem and forecasting.

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FUZZY COGNITIVE MAP APPROACH FOR SUPPLY CHAIN CONFIGURATION IN AUTOMOTIVE INDUSTRY

Mehtap Dursun[1], Nazli Goker[2], Guray Gumus[3]

Abstract *– Today's competitive market conditions and evolved organizational structure compel firms to design their supply chain more efficiently. Supply chain becomes more important because of growing global competence and effectiveness concepts. Therefore, professionals endeavor to find best supply chain configuration (SCC) for their firms. This paper investigates the detailed evaluation of supply chain management factors by analyzing relationships and strength of them in order to determine the most appropriate reactions to the risks. Fuzzy cognitive map (FCM) methodology is employed to identify the most important factors in SCC. FCM is viable modeling for researchers to reveal and analyze interrelationship among the identified concepts for tracking impacts of factors in the system. FCM methodology is appropriate due to cause-and-effect relationships among factors, positive as well as negative relationships, and the lack of crisp data. The application is conducted in an automobile factory, which is one of the largest manufacturers in Turkey. The results shows that particularly three factors, which are the selection of proper suppliers, agility and cost, are more powerful. On the other hand, it shows that lower responsiveness performance, lean and demand and supply uncertainty concepts, respectively, have a low degree of strength.*

Keywords – Fuzzy cognitive map, fuzzy decision making, supply chain configuration, supply chain management

INTRODUCTION

Today's competitive business world makes supply chain management much more complex and dynamic. Besides this competitive environment, growing uncertainties also impact firms seriously and force them to develop sustainable approaches along supply chain operations. The definition of supply chain involves all process that starting from raw materials to final products and include delivering of them to end consumer by organizational network and reverse logistic (Iansiti & Levien, 2004).

Supply chain management (SCM) is the management of all process of supply chain that has several basic phases like planning, implementing and controlling (Park et al., 2005). Supply chain becomes more important because of growing global competence and "effectiveness" concept. Therefore, professionals endeavor to find best supply chain configuration (SCC) for their firms.

This paper investigates the detailed evaluation of supply chain management factors by analyzing relationships and strength of them in order to determine the most appropriate reactions to the risks. Fuzzy cognitive map (FCM) methodology is used to determine the most important factors in SCC. FCM methodology is appropriate due to cause-and-effect relationships among factors, positive as well as negative relationships, and the lack of crisp data. Two scenarios are analyzed in order to understand the effect of an increase or a decrease of the importance degree of specific concept node(s) on other concept nodes.

The rest of the study is organized as follows. Section 2 analyzes FCM methodology. In Section 3, a case study in automotive sector is illustrated. Scenario analyses are given in Section 4. Finally, Section 5 presents conclusions and future research directions.

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FUZZY COGNITIVE MAP

FCM is viable modeling for researchers to reveal and analyze interrelationship among the identified concepts for tracking impacts of factors in the system. It is a practical method to apply for a large number of variables. Generally, construction of FCM bases on causal human experience, knowledge and historical data. FCM method process all data by using its system, which is combined of fuzzy logic and neural network (Kosko, 1986).

FCM is modeled using graphical representations with feedbacks where concept nodes and weighted edges are the elements. Edges represent relations between the concepts by means of direction of causality: whether the causal relationship is positive, negative or null, and connect the nodes through which causal relationships between concepts are produced (Büyükavcu et al, 2016).

$C=(C_1,C_2,\ldots,C_n)$ is the representation of concepts set that usually represent a state, variable, event, action, goal, target, value or other element of the systems. Edges demonstrate how much effect concept C_j causes concept C_i and are utilized for causal relationships among concepts. The intensity of causality links value in the interval [-1,1] or can be represented with linguistic variables such as "negatively medium", "zero", "positively very strong", etc. Figure 1 indicates the graphical presentation of an FCM.

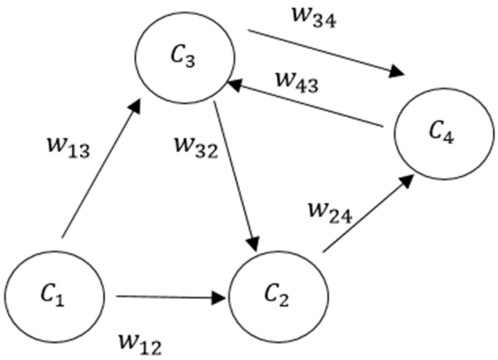

Figure 1. Graphical Representation of FCM

The sign w_{ji} indicates the direction of causal links between concepts. If $w_{ji} > 0$, then there is a positive cause-effect relationship, if $w_{ji} < 0$, then there is a negative cause-effect relationship between concepts C_j and C_i. Besides, if $w_{ji} = 0$, then there is no causality between associated concepts. In addition, the direction of causal links represents if concept C_j causes concept C_i, or vice versa. In order to determine the power of these causal relations, a value has to be assigned to weight w_{ji}. For instance, in Figure 1, concept C_2 causes an increase or a decrease in C_3 with a degree of w_{23}. Each concept's value is computed by considering the influence of the other concepts on the evaluating concept, and by running the iterative formulation as follows:

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j\neq i \\ j=1}}^{N} A_j^{(k)} w_{ji}\right) \qquad (1)$$

where $A_i^{(k)}$ is the value of concept C_i at kth iteration and w_{ji} is the weight (intensity) of the connection from C_j to C_i, and f is a threshold function. The threshold function in FCM provides obtaining the concept values that are belong to the intervals [0,1] or [-1,1]. In this study, hyperbolic tangent function is used, since it generates concept values in the interval [-1,1]. Hence, negative in addition to positive causal relationships between pair of factors are considered.

All concepts activation levels are synchronously updated in FCM, which indicates a discrete time system. Therefore, the system is updated in a simultaneous way. Concept C_i activation level is denoted by A_i^t and t is the time step. The vector $A^t=[A_1^t, A_2^t,\ldots, A_n^t]$ shows the entity of the FCM at time step t, n is the number of concepts. Each concept has an initial and a final vector, which represent a state for the system at the initial and the last time step, respectively. FCM modeling main objective is to identify the final vector that provides decisive value of each concept (Büyükavcu et al, 2016).

CASE STUDY

FCM is very beneficial method when there is only linguistic variable of fuzzy numbers at decision process. It also provides to view negative relationships unlike ANP (Analytic Network Process) and DEMATEL (Decision-Making Trial and Evaluation Laboratory) approaches. When it is difficult or impossible to formulate quantitative mathematical model due to lack of numerical data, knowledge based on cognitive map is successful method to make decision for complex systems (Kosko, 1986).

In this study, FCM approach is applied in order to survey interrelations between SCC criteria. The application is conducted in an automobile manufacturer, which is one of the largest manufacturers in Turkey. FCM methodology is preferred to be applied due to the lack of crisp numbers and consequently the requirement of the use of linguistic variables or fuzzy numbers, and the presence of cause-effect relationships among concepts in performance assessment of business process outsourcing.

The first step to construct SCC is determining concepts. There are various perspective and configurations in the literature. Some of researchers investigate SCI and PC, some of them focus on SCSs and there are lots of papers about supply chain risk factors. We will compose a new configuration that includes SCI, SCSs, PCs and SCRFs altogether. The main goal of this research is designating best configuration of SC to help DMs or systems to control SC dynamically and take an action according to relationship and degree of relationship of parameters.

Our model contains 13 concepts that each of them can be inputs and outputs in our configuration given in Table 1.

Table 1. SCC Criteria

Label	**Concept**
C_1	Supplier Integration
C_2	Internal Integration
C_3	Customer Integration
C_4	Delivery
C_5	Quality
C_6	Flexibility
C_7	Cost
C_8	Lean
C_9	Agile
C_{10}	Demand and supply uncertainty
C_{11}	Lower responsiveness performance
C_{12}	A poor quality or process yield at work
C_{13}	The selection of proper suppliers

The SCC model, which is designated through literature and experts' knowledge is analyzed by three experts who have solid background and deep knowledge about supply chain management. They indicate the effect of one concept on another. Initially, they determine whether there is a causal relationship between each pair of concepts, or not. If there is no relation, they skip the associated pair of concepts, but if there is a causal link, they indicate the direction (sign) of the relation such as positive or negative. Experts then indicate the power of causal relations by using linguistic terms given in Figure 2.

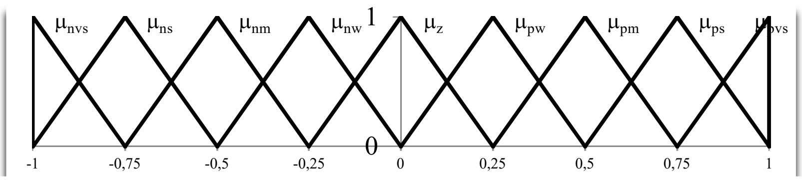

Figure 2. Membership Functions Corresponding to Fuzzy term of Influence (Büyükavcu et al, 2016)

The evaluations given by the experts are transformed into a single fuzzy set via MAX method, which is coded in MATLAB Fuzzy Toolbox. The single fuzzy set, which is obtained from MAX aggregation method, is converted into numerical value, w_{ji}, with the defuzzification method of Center of Gravity (COG), which is coded in MATLAB Fuzzy Toolbox. The formulation of this method is given in the following formulation (Ross, 2010).

$$z^* = \frac{\int \mu_{\tilde{A}}(z) z dz}{\int \mu_{\tilde{A}}(z) dz} \quad (2)$$

The weight matrix for the criteria is generated by employing aggregation and defuzzification processes for every relation between each pair of connected concepts, and it is given in Table 2.

Table 2. Weight Matrix Obtained from the Experts

	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}	C_{11}	C_{12}	C_{13}
C_1	0.00	0.25	0.50	0.50	0.80	0.80	-0.38	0.80	0.38	-0.13	-0.80	-0.75	-0.80
C_2	0.13	0.00	0.25	0.50	0.50	0.25	-0.13	0.38	0.25	0.00	-0.13	-0.40	0.00
C_3	0.40	0.13	0.00	0.49	0.39	0.40	-0.39	0.00	0.37	-0.80	-0.49	-0.25	-0.25
C_4	0.00	0.00	0.00	0.00	0.00	0.00	-0.13	0.00	0.37	0.00	-0.13	0.00	0.00
C_5	0.50	0.00	0.25	0.00	0.00	0.00	0.67	0.25	0.00	0.00	-0.63	-0.63	0.80
C_6	0.00	0.00	0.00	0.13	-0.25	0.00	0.10	-0.51	0.65	-0.63	-0.50	0.63	0.63
C_7	0.00	0.00	0.00	-0.13	0.75	-0.13	0.00	0.00	-0.38	0.63	-0.25	0.00	0.00
C_8	0.50	0.00	0.00	0.00	0.40	-0.65	0.00	0.00	-0.75	-0.25	0.00	-0.50	-0.50
C_9	0.63	0.00	0.00	-0.13	-0.50	0.67	0.25	-0.75	0.00	-0.50	-0.63	0.50	0.50
C_{10}	-0.50	0.00	-0.56	-0.80	0.00	-0.38	0.63	-0.63	0.50	0.00	0.63	0.31	0.25
C_{11}	-0.38	-0.50	-0.63	-0.25	0.00	-0.80	0.25	0.00	-0.80	0.50	0.00	0.00	0.00
C_{12}	-0.50	-0.25	-0.40	-0.25	-0.92	0.00	0.80	0.00	0.00	0.39	0.50	0.00	0.63
C_{13}	-0.75	0.00	0.00	-0.35	-0.63	-0.50	-0.80	-0.38	-0.50	0.13	0.80	0.75	0.00

FCM model that is created with regard to the results of the weight matrix is provided in Figure 3.

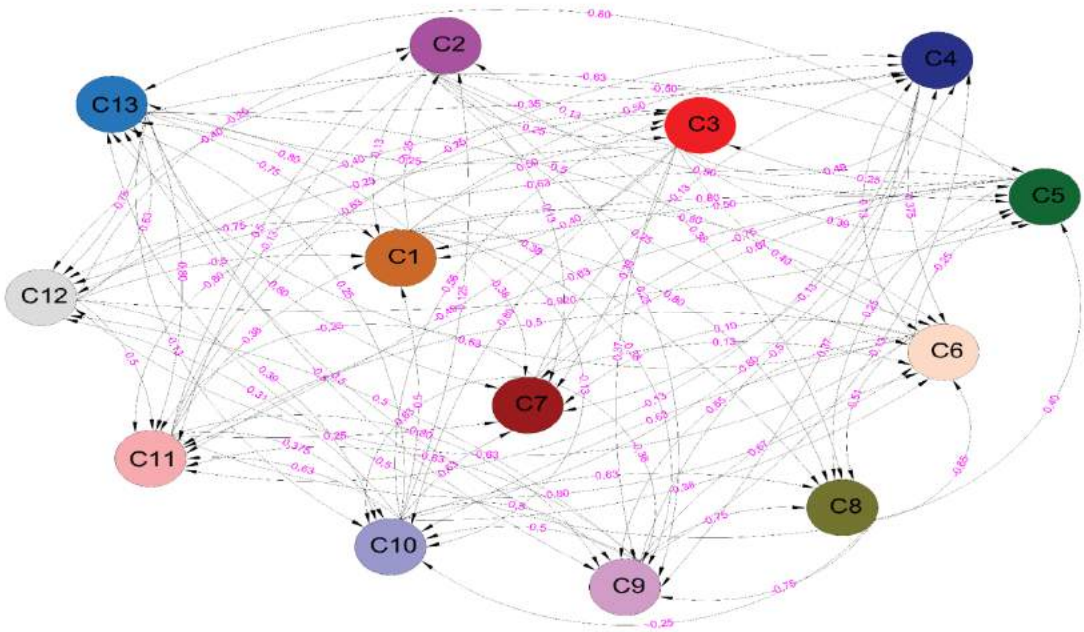

Figure 3. FCM Model for analyzing SCC factors

For obtaining concepts' values, Formulation (1) starts to be activated with the initial vector A^0=[1,1,…,1]. After many iterations, the system reaches the equilibrium and the stabilization is provided. Obtained concepts' values of SCC are listed as in Table 3.

Table 3. Concepts' Values of SCC Criteria

Label	Concepts' Values
C_1	0.67
C_2	0.64
C_3	0.64
C_4	0.64
C_5	0.70
C_6	0.71
C_7	0.74
C_8	0.47
C_9	0.74
C_{10}	0.49
C_{11}	0.31
C_{12}	0.67
C_{13}	0.86

Table 3 indicates that the selection of proper suppliers and a poor quality or process yield at work are powerful risk factors unlike lower responsiveness performance and demand and supply uncertainty, moreover the selection of proper supplier is most powerful factor of SCC.

SCENARIO ANALYSES

Scenario 1:

Flexibility and agility are two key terms to cope with growing expectation and differentiated requirements and uncertainties. When we decrease these concepts value, lean concept increases more than others. A poor quality or process yield is most influenced concepts. Its value decreases as a result of increasing leanness. Besides these significant changes; quality, demand and supply uncertainty, lower responsiveness performance are affected positively unlike the selection of proper suppliers, cost, delivery. For supply chain integration, there are minor positive and negative changes on the concepts' value. Therefore, we can say that decreasing flexibility and agility affect supply chain integration less than other concept groups.

Scenario 2:

Lower responsiveness performance and poor quality or process yield at work are risk factors that can be minimize by operational effectiveness more than others. And if these risk factors values are equal to zero, we can evaluate effects of environmental uncertainties better. All concepts change positively except cost, the selection of proper suppliers, demand and supply uncertainty. Supplier integration, cost, demand and supply uncertainty has significant changes among concepts.

CONCLUSIONS

In addition to increasing and differentiated uncertainties, technological developments, fast changing market condition and of course clients' growing requirements force firms to cope with hard challenges in order to maintain their competitive advantages. Organizations measure their performance generally in two categories such as business performance (return on investment (ROI), market share, return on sale (ROS), etc.) and operational performance (flexibility, cost, delivery, quality, etc.). These are important output to evaluate system effectiveness but operational performance criteria play an important role as an input of business performance criteria. SCM is the strategic component of operations, efficient well-design configuration provide firm many advantages, as well as potential disadvantages.

In this study, SCC criteria were determined both reviewing the literature and using experts' knowledge. Afterwards, 20 RFs were sent to three different experts whose jobs are related to SCM. First, they reduced them into 4 main RFs that effect SCM more frequent and strongly. Lately our SCC model was composed and forwarded to same decision makers again. In this step, experts decided whether there is causality or not. If there is causality between each pair of concepts, then they determine the sign of the relationship. After that the weight of outlined causal links was decided according to specified linguistic variables. These linguistic variables are converted into fuzzy numbers according to the associated membership function and they were aggregated by using MATLAB Fuzzy Toolbox. Finally, aggregated fuzzy numbers were defuzzified by using MAX and center of gravity methods to compose weight matrix. The result of FCMapper reveals particularly three factors more powerful, which are the selection of proper suppliers, agility and cost. On the other hand, it shows that lower responsiveness performance, lean and demand and supply uncertainty concepts, respectively, have a low degree of strength. Finally, two different scenario analyses were employed to understand the influence of an increase or a decrease of the power of specific concept(s) on other concepts. Further researches should focus on different RFs that are changing according to sectors, legal regulation, geography, etc. Besides, increasing expert number can provide more correct result.

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A FUZZY DECISION MAKING APPROACH FOR FUEL PROVIDER SELECTION: A CASE STUDY FOR TURKEY

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Abstract *− Fuel is a material that reacts with other substances in order to release chemical or nuclear energy as heat. The heat energy released by reactions of fuels is converted into mechanical energy via a heat engine. Heat is utilized for warming, cooking, or industrial processes. This work presents a fuzzy decision making approach for fuel provider selection problem. Evaluation criteria are weighted employing fuzzy cognitive map methodology, then the most suitable fuel provider alternative is determined using fuzzy TOPSIS method. Lead time, reliability, sustainability, cost, service quality, location and warranties are taken into consideration. In order to illustrate the application, a numerical example is provided by conducting a case study in Turkey.*

Keywords − Provider selection, fuzzy cognitive map, fuzzy TOPSIS, fuzzy decision making

INTRODUCTION

Energy is fundamental aspect to obtain quality of life and economic wealth in a society. From past to present, heating and cooking are used intensively, and biomass has been used both for cooking and heating. Food is needed by every person to continue their lives. The grand majority of staple foods, approximately 95%, need cooking before they can be eaten, and most people cook 2-3 times per day. 90% of household energy consumption is cooking energy in developing countries. Today, in the some parts of the world which are especially developed countries, electricity and gas are preferred as cooking fuel, biomass and biomass stoves are only used for recreational cooking. In Turkey, a significant number of the households use biomass as a primary cooking fuel. Non-commercial energy forms, stoves and ovens using biomass are the main source of the energy especially in rural areas. They are used both for cooking and heating. The second mainly used fuel is coal. Many different stoves and ovens are used in rural and urban areas, some of them are traditional stoves and some of them are commercial stoves which are made regarding Turkish standards (Isler & Karaosmanoglu, 2008).

The objective of this study is to propose an integrated fuzzy decision making approach for selecting the most appropriate cooking fuel provider that performs in Turkey. Over the last decade, scholars have contributed to the provider selection by proposing several decision making approaches. Wu and Chien (2008) constructed a decision framework to evaluate outsourcing providers and to solve order allocation decision problem. Büyüközkan et al (2009) proposed a 2-additive choquet integral method to fourth party logistics service provider selection problem. They conducted the case study in a logistic firm that performs in Turkey. Kahraman et al (2009) ranked and selected the most appropriate IT service providers for a furniture company in Konya, Turkey. Wan et al. (2015) selected the suitable logistics outsourcing provider by using an intuitionistic fuzzy linear programming method. Govindan et al (2016) identified 3PL provider selection criteria to help managers in automotive industry for obtaining competitive advantage. Wang et al (2016) evaluated and selected contractors in logistics outsourcing. Rajaeian et al (2017) provided a literature review on information technology (IT) outsourcing by observing MCDM, optimization and simulation methods that support IT outsourcing decision process.

The rest of this work is organized as follows. Section 2 explains fuzzy cognitive map methodology. Subsequent section outlines fuzzy TOPSIS technique. Section 4 provides the case study that is conducted in a Turkish company. The final section delineates conclusions and future research directions.

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FUZZY COGNITIVE MAPS

Fuzzy Cognitive Maps (FCMs), helping model complex decision systems, is a causal knowledge-based method which is originated from the combination fuzzy logic and neural networks (Kosko, 1986). Hereafter, Kosko (1992) extended the method and included fuzzy numbers or linguistic variables for revealing the causal relationships among concepts in FCM. These concepts stand for an entity, a state, a variable or a characteristic of a system, a behavior of a knowledge-based system is represented by concepts in FCM. Concept nodes and weighted arcs are the elements of FCM which can be graphically showed with feedback. Arcs are signed to understand the direction of causality: whether the causal relationship is positive, negative or null; and connect the nodes through which causal relationships among concepts are produced (Buyukavcu et al, 2016). The weights of causality links can be represented with linguistic variables such as "negatively weak", "zero", "positively weak", etc. The value of each concept is calculated, considering the effect of the other concepts on the under-evaluation concept, by applying the following iterative formulation.

$$A_i^{(k+1)} = f\left(A_i^{(k)} + \sum_{\substack{j \neq i \\ j=1}}^{N} A_j^{(k)} w_{ji}\right) \tag{1}$$

where $A_i^{(k)}$ is the value of concept C_i at k^{th} iteration, w_{ji} is the weight of the connection from C_j to C_i and f is a threshold function.

FUZZY TOPSIS METHODOLOGY

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is a common method introduced by Hwang and Yoon (1981). This technique is typically used for solving MCDM problems. In TOPSIS method, two solutions are identified, ideal solution and anti-ideal solution. While ideal solution maximizes the benefit criteria and minimizes the cost criteria, anti-ideal solution maximizes the cost criteria and minimizes the benefit criteria. Because of this reason, the principal idea behind TOPSIS is, locating shortest distance to ideal solution and longest distance to anti-ideal solution.

It is a well-known fact that, to express the necessities, preferences and thoughts is not sufficient by using crisp numbers only. Fuzzy set theory was evolved to eliminate this limitation by allowing to model uncertainty of human judgments (Zadeh, 1965). While in classical TOPSIS, the ratings for criteria are known literally, in fuzzy TOPSIS, the ratings for criteria are described in linguistic terms.

PROPOSED INTEGRATED FUZZY DECISION MAKING PROCEDURE

This section outlines the proposed decision making approach for cooking fuel provider selection in Turkish food sector. The application steps are as follows:

Step 1: *Determination of provider selection factors:* In this study, lead time (C_1), reliability (C_2), sustainability (C_3), cost (C_4), service quality (C_5), location (C_6), and warranties (C_7) are determined as provider selection criteria through a literature survey and experts' opinions.

Step 2: *Signing causality links:* The experts determine the direction of causal relationships in three categories: positive, negative, null.

Step 3: *Fuzzification:* Experts decide the degree of causalities by using linguistic variables; subsequently linguistic variables are mapped to fuzzy numbers. In this study, nine linguistic terms are utilized such as negatively very strong (nvs), negatively strong (ns), negatively medium (nm), negatively weak (nw), zero (z), positively weak (pw), positively medium (pm), positively strong (ps), positively very strong (pvs), as shown in Figure 1.

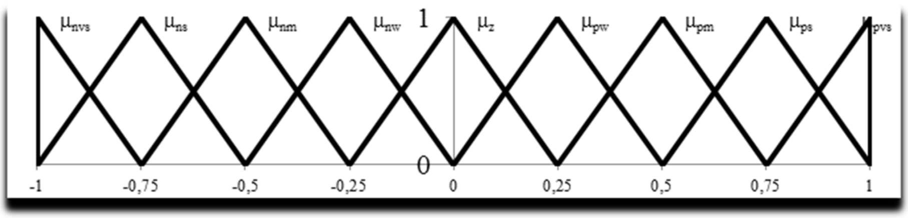

Figure 1. The nine membership functions corresponding to each fuzzy term of effect

Step 4: *Obtaining the result of aggregation:* By means of MAX method, the outputs corresponding to each rule are transformed into a single fuzzy set, hereafter, this fuzzy number belonging to the interval [-1,1] is defuzzified by using Centre of Gravity (COG) method and is converted to a numerical value, w_{ji}.

Step 5: *Copy the matrix:* The process starts with the initial vector.

Step 6: *Check the matrix:* Updating the values of the initial vector is completed by applying formulation (1) and a threshold function. $f(x)= 1/1+e^{-x}$ is an appropriate transform function for restricting the values of $A_i^{(k)}$ in the interval [0,1].

Step 7: *Calculate factors' values:* Each risk indicator's value is computed via formulation (1), by taking the weighted arcs into consideration.

Steps 6-7 are repeated until the concepts reach equilibrium which means that the system has to be stabilized after required iterations.

Step 8: *Normalize concepts' values:* The data are normalized in order to apply fuzzy TOPSIS method. Hence, the values of $\widetilde{w}_j$ are obtained.

Step 9: *Construct the fuzzy decision matrix* ($\widetilde{D}$): The evaluation of alternatives with respect to criteria and the weight matrix of criteria ($\widetilde{W}$) are denoted as

$$\begin{bmatrix} \tilde{x}_{11} & \cdots & \tilde{x}_{1n} \\ \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \cdots & \tilde{x}_{mn} \end{bmatrix} \quad i=1,2,\dots,m;\ j=1,2,\dots,n. \tag{2}$$

$$\widetilde{W}_j = (\widetilde{w}_1, \widetilde{w}_2, \dots, \widetilde{w}_n) \quad j=1,2,\dots,n. \tag{3}$$

where $\tilde{x}_{ij}$ can be represented as $\tilde{x}_{ij} = (x_{ij}^1, x_{ij}^2, x_{ij}^3)$ in triangular fuzzy number format. The linguistic term set is shown in Table 2.

Table 2. Linguistic term set

VL	(0, 0, 0.25)
L	(0, 0.25, 0.5)
M	(0.25, 0.5, 0.75)
H	(0.5, 0.75, 1)
VH	(0.75, 1, 1)

Step 10: Normalize the fuzzy decision matrix:

The normalized fuzzy decision matrix $\tilde{R}$ is constructed as $\tilde{R} = [\tilde{r}_{ij}]$, i=1,2,…,m; j=1,2,…,n,

$$\tilde{r}_{ij} = \left\{\left(\frac{x_{ij}^1}{x_j^*}, \frac{x_{ij}^2}{x_j^*}, \frac{x_{ij}^3}{x_j^*}\right), \ x_j^* = max\, x_{ij}^3, \ \ j\epsilon B_j \tag{4}$$

$$\tilde{r}_{ij} = \left\{\left(\frac{x_{ij}^-}{x_{ij}^3}, \frac{x_{ij}^-}{x_{ij}^2}, \frac{x_{ij}^-}{x_{ij}^1}\right), \ x_j^- = min\, x_{ij}^1, \ \ j\epsilon C_j \tag{5}$$

where B_j represents the set of benefit-related criteria for which the greater the performance value the more its preference, C_j represents the set of cost-related criteria for which the greater the performance value the less its preference.

Step 11: Compute the weighted normalized decision matrix, $\tilde{V} = [\tilde{v}_{ij}]$, as

$$\tilde{v}_{ij} = \tilde{r}_{ij}\widetilde{w}_j \tag{6}$$

Step 12: Define the ideal solution $(A^{*}) = (\tilde{v}_1^{*}, \tilde{v}_2^{*}, \dots, \tilde{v}_n^{*})$, and the anti-ideal solution $(A^{-}) = (\tilde{v}_1^{*}, \tilde{v}_2^{*}, \dots, \tilde{v}_n^{*})$, where $\tilde{v}_j^{*} = (1,1,1)$ and $\tilde{v}_j^{-} = (0,0,0)$ for j = 1,2, …, n.

Step 13: Compute the distances from ideal and anti-ideal solutions (d_i^{*}) and (d_i^{-}), respectively for each alternative A_i as

$$d_i^{*} = d(A_i, A^{*}) = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{*}) \tag{7}$$

where

$$d(\tilde{v}_{ij}, \tilde{v}_j^{*}) = \sqrt{\frac{1}{3}(v_{ij}^{1} - v_j^{*1})^2 + (v_{ij}^{2} - v_j^{*2})^2 + (v_{ij}^{3} - v_j^{*3})^2} \tag{8}$$

and

$$d_i^{-} = d(A_i, A^{-}) = \sum_{j=1}^{n} d(\tilde{v}_{ij}, \tilde{v}_j^{-}) \tag{9}$$

where

$$d(\tilde{v}_{ij}, \tilde{v}_j^{-}) = \sqrt{\frac{1}{3}(v_{ij}^{1} - v_j^{-1})^2 + (v_{ij}^{2} - v_j^{-2})^2 + (v_{ij}^{3} - v_j^{-3})^2} \tag{10}$$

Step 14: Calculate the closeness coefficient (CC_i) of each alternative as follows:

$$CC_i = \frac{d_i^{-}}{d_i^{-} + d_i^{*}}, \; i = 1,2, \dots, m. \tag{11}$$

Step 15: *Rank the alternatives:* The alternatives are ranked according to CC_i values in descending order. Identify the alternative with the highest CC_i as the best alternative.

CASE STUDY

This section illustrates the proposed integrated fuzzy decision making approach for cooking fuel provider selection. The case company performs in Turkish food sector, and wants to provide cooking fuel from a third party provider. Evaluation criteria are determined and assessed by literature survey and opinions of three employees who works in the case company for minimum four years. Criteria weights are obtained by employing FCM methodology by utilizing the data collected from these three experts. They indicated the causal relationships between each pair of factors by using nine linguistic terms mentioned before. The related data are given in Table 1.

Table 1. The related data

	Lead time	Reliability	Sustainability	Cost	Service quality	Location	Warranties
Lead time	(z,z,z)	(nm,ns,nw)	(z,z,z)	(z,z,z)	(nm,nw,ns)	(z,z,z)	(z,z,z)
Reliability	(z,z,z)	(z,z,z)	(z,z,z)	(z,z,z)	(z,z,z)	(z,z,z)	(ps,pm,ps)
Sustainability	(z,z,z)	(pm,pm,pm)	(z,z,z)	(z,z,z)	(z,z,z)	(z,z,z)	(pw,pw,pm)
Cost	(z,z,z)	(pw,pw,pw)	(z,z,z)	(z,z,z)	(z,z,z)	(z,z,z)	(z,z,z)
Service quality	(z,z,z)	(ps,ps,ps)	(z,z,z)	(ps,pm,ps)	(z,z,z)	(z,z,z)	(ps,pm,pm)
Location	(ns,ns,ns)	(z,z,z)	(z,z,z)	(z,z,z)	(nw,nm,nw)	(z,z,z)	(z,z,z)
Warranties	(z,z,z)	(ps,pm,pm)	(z,z,z)	(ps,ps,ps)	(z,z,z)	(z,z,z)	(z,z,z)

Afterwards, these linguistic terms are aggregated by using MAX method and defuzzified by center of gravity method, and weight matrix is obtained as in Table 2.

Table 2. Weight matrix

	Lead time	Reliability	Sustainability	Cost	Service quality	Location	Warranties
Lead time	0	-0.5	0	0	-0.5	0	0
Reliability	0	0	0	0	0	0	0.625
Sustainability	0	0.5	0	0	0	0	0.375
Cost	0	0.25	0	0	0	0	0
Service quality	0	0.75	0	0.625	0	0	0.625
Location	-0.75	0	0	0	-0.375	0	0
Warranties	0	0.625	0	0.75	0	0	0

In order to compute the final values of factors, formulation (1) is run applying sigmoid function as a threshold function, FCMapper software is used, and the resulting values are as follows:

Table 3. Concepts' values

Label	Result
Lead time	0.501905
Reliability	0.892075
Sustainability	0.659046
Cost	0.862452
Service quality	0.500635
Location	0.659046
Warranties	0.880607

The results are normalized to employ fuzzy TOPSIS technique. Criteria weights are delineated in Table 4.

Table 4. Criteria weights

Label	Result
Lead time	0.101277
Reliability	0.180007
Sustainability	0.132986
Cost	0.174030
Service quality	0.101021
Location	0.132986
Warranties	0.177693

In order to select the most appropriate provider alternative, a director who directly works on outsourcing activities determined four possible provider alternatives, and evaluated them according to seven criteria. He used the linguistic scale given in Table 2. The related data are provided in Table 5.

Table 5. Evaluation of alternatives according to the criteria

Alternative	Lead time	Reliability	Sustainability	Cost	Service quality	Location	Warranties
1	M	L	L	H	H	H	M
2	L	VH	H	L	H	L	L
3	L	H	H	VH	M	M	H
4	H	VL	VH	M	L	H	H

Rank order of the alternatives is provided in Table 6.

Table 6. Ranking results of the alternatives

Alternative (i)	d_i^*	d_i^-	CC_i	Rank
1	6.633052	0.619152	0.085374	4
2	6.311808	0.971257	0.133358	2
3	6.286385	1.141058	0.153627	1
4	6.561626	0.699219	0.0963	3

CONCLUSIONS

In this work, an integrated fuzzy decision making approach for cooking fuel provider selection problem, is introduced. Evaluation criteria are weighted employing fuzzy cognitive map methodology, then the most appropriate provider alternative is determined using fuzzy TOPSIS method. Lead time, reliability, sustainability, cost, service quality, location and warranties are considered as evaluation criteria. In order to illustrate the application, a numerical example is provided by conducting a case study in Turkey. According to the ranking results, third alternative is identified as the most suitable provider, which is followed by the alternatives 2, 4, and 1, respectively.

The future research directions may be focus on incorporating hesitant fuzzy linguistic term set into the decision framework.

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RANKING AGILE SUPPLIER ALTERNATIVES EMPLOYING A FUZZY DEA APPROACH

Michele Cedolin[1], Nazli Goker[2], Mehtap Dursun[3]

Abstract *− In competitive markets, companies have to give immediate response to unpredictable changes and uncertainty, and they should construct their supply chain according to dynamic environment. An agile supply chain is flexible, quick, responsive, and competent in increasing global competition. In order to gain supply chain agility, agile supplier selection has become a crucial managerial problem to be solved. This work aims to solve agile supplier selection problem employing a fuzzy data envelopment analysis, which is an extension of data envelopment analysis by incorporating imprecise and qualitative data into the decision framework. The proposed methodology selects the most appropriate agile supplier without requiring subjective assessment of decision makers for determining the importance of evaluation criteria. In order to illustrate the proposed decision approach, a case study is conducted in a dye manufacturer company that performs in Turkey.*

Keywords − Agility, multi-criteria decision making, fuzzy decision making, supplier selection

INTRODUCTION

Agility enables the firms responsiveness in a quick and an effective way to the set of interdependent changes required in design, production, marketing and organization of the companies. Since the supply chain is a comprehensive concept which has direct or indirect effects on production and marketing aspects of the companies, it is crucial for the companies to implement agility concept through the supply chain. Supply chain agility is defined and redefined many times in the literature; Sharp et al. (1999) formed a concept for supply chain agility as the capability for quickly reacting to changes, occurred in business environment and customer requirements, however; Ismail & Sharifi (2006) defined it as the ability of the supply chain and its elements acting as an entire entity for immediately cooperation of the network with the underlying activities in order to respond to fluctuating customer needs.

Although supply chain management, agility and agile manufacturing have been earlier research topics, agile supplier selection is a new paradigm, emerged in the last few years. Thus, the existing literature does not provide a numerous studies for agile supplier selection. Luo et al. (2009) proposed a model that supports a possibility for dealing with the information processing difficulties that occur in examining a large number of candidate pre-selection procedure. The model evaluated candidate suppliers according to multiple criteria based on artificial neural network by using both qualitative and quantitative criteria. Wu and Barnes (2011) conducted a study which includes a dynamic feedback model consisting of four-phases for supplier selection in ASCs that work efficiently in rapidly changing markets. The developed model focused on techniques involving quantitative and qualitative methods namely analytic network process-mixed integer multi-objective programming (ANP-MIMOP), radial basis function artificial neural networks (RBF-ANN), the Dempster-Shafer and optimization theories. Viswanadham and Samvedi (2013) identified the best agile supplier alternative by constructing a fuzzy MCDM framework. Abdollahi et al. (2015) evaluated agile suppliers based on the features related to product and organizational characteristics of them in order to gain competitive advantage in business environment and to increase the level of flexibility against possible fluctuations in supply and demand. ANP was implemented to determine each candidate supplier's criteria weight, data envelopment analysis (DEA) was employed for ranking process. A fuzzy decision making trial and evaluation laboratory (DEMATEL) is utilized in order to resolve the interdependency. Beikkhakhian et al. (2016) weighted agile supplier selection criteria by using fuzzy

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analytic hierarchy process (AHP) methodology, identified the best performing agile supplier alternative by incorporating fuzzy technique for order preference by similarity to ideal solution (TOPSIS) approach.

The aim of this work is to solve agile supplier selection problem employing a fuzzy data envelopment analysis DEA), which is an extension of data envelopment analysis by incorporating imprecise and qualitative data into the decision framework. The rest of the study is organized as follows. Section 2 explains the fuzzy DEA model. The case study with a numerical illustration in dye industry is presented in Section 3. Finally, concluding remarks are delineated in Section 4.

FUZZY DEA MODEL

In this study fuzzy DEA model proposed by Saati et al. (2002) is employed, considering the linguistic evaluation of the experts. The following model classifies the decision making units (DMUs) as efficient and non-efficient.

$$maxE = \overline{y_p}$$

subject to (1)

$$\overline{x_p} = 1$$

$$\overline{y_j} - \overline{x_j} \leq 0$$

$$v(\alpha x_j^m + (1-\alpha)x_j^l) \leq \ \overline{x_j} \leq v(\alpha x_j^m + (1-\alpha)x_j^u) \qquad \forall j,$$

$$u(\alpha y_j^m + (1-\alpha)y_j^l) \leq \ \overline{y_j} \leq v(\alpha y_j^m + (1-\alpha)y_j^u) \qquad \forall j,$$

$$u, v \geq 0$$

Where x and y stands for inputs and outputs, respectively. Similarly, u is the weight vector of the inputs and v is the weight vector of the outputs. This model is equivalent to a parametric programming, while $\alpha \in (0,1]$ is a parameter. It is noted that for each , we have an optimal solution. Thus, we can provide the decision maker a solution table with different in $\alpha \in (0,1]$.

The following model enables to give a ranking for efficient DMUs.

$$minz = \theta$$

subject to (2)

$$\theta(\alpha x_p^m + (1-\alpha)x_p^l) \geq \sum_{j=1}^{n} \lambda_j \left(\alpha x_j^m + (1-\alpha)x_j^u\right)$$

$$\theta(\alpha y_{rp}^m + (1-\alpha)y_{rp}^u) \leq \sum_{j=1}^{n} \lambda_j \left(\alpha y_{rj}^m + (1-\alpha)y_{rj}^u\right) \qquad \forall r,$$

$$\lambda_j \geq 0, \qquad \forall j$$

CASE STUDY

Increasing competition leads companies to keep up with rapid changes for surviving in such competitive environment therefore agile supplier selection becomes a crucial managerial decision problem in supply chain management. In order to illustrate the application of the proposed decision making approach for agile supplier selection, a case study conducted in a dye manufacturer that performs Istanbul, Turkey, is introduced. Evaluation criteria are determined and assessed by literature survey and opinions of the employees who works in the case company for minimum five years. The related data are given in Table 1.

Table 1. Data Related to Agile Supplier Selection Problem

	DMU1			DMU2			DMU3			DMU4			DMU5			DMU6		
Cost	0.75	1	1	0.75	1	1	0.5	0.75	1	0	0.25	0.5	0	0.25	0.5	0.75	1	1
Delivery time	0.75	1	1	0.5	0.75	1	0.5	0.75	1	0.25	0.5	0.75	0	0.25	0.5	0.5	0.75	1
Delivery speed	0.75	1	1	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.5	0.75	1	0	0.25	0.5
Delivery flexibility	0.5	0.75	1	0.5	0.75	1	0.5	0.75	1	0.75	1	1	0.75	1	1	0.5	0.75	1
Agile customer responsiveness	0.5	0.75	1	0.5	0.75	1	0	0.25	0.5	0.5	0.75	1	0.75	1	1	0	0.25	0.5

The results of the formulation (1) is obtained as in the following table.

Table 2. Results of the Formulation (1)

alpha	0	0.2	0.4	0.6	0.8	1
DMU1	1	1	1	0.796	0.632	0.5
DMU2	1	1	1	1	0.762	0.571
DMU3	1	1	1	0.872	0.662	0.5
DMU4	1	1	1	1	1	1
DMU5	1	1	1	1	1	1
DMU6	1	1	0.81	0.63	0.488	0.375

As can be observed from the tables, in the first model all the DMUs have efficiency score of "1" for alfa equal to 0 and 0.2, while increasing this parameter we noticed that the efficiency scores decrease, and firstly the DMU6 , than DMU1 and DMU3 become inefficient. Shortly, only DMU4 and DMU5 remain as efficient units. Thus, it is not possible to rank these DMUs. The objective of supplier evaluation and selection processes is to obtain a comparison among the units, so that the same score for more than one unit is not desirable.

For further investigations, the ranking model given in formulation (2) is applied to the same data set, a ranking scheme between alternatives is obtained as in Table 2. The ultimate results are not really changed and DMU 4 and DMU5 showed the best performance, while DMU6 showed the worst performance in each case.

Table 2. Results of the Formulation (2)

alpha	0	0.2	0.4	0.6	0.8	1
DMU1	1.6	1.264	1.002	0.796	0.632	0.5
DMU2	2.4	1.791	1.345	1.012	0.762	0.571
DMU3	2	1.511	1.47	0.872	0.662	0.5
DMU4	13.8	13	5.241	2.785	1.636	1
DMU5	13.8	13	5.241	2.785	1.636	1
DMU6	1.333	1.039	0.81	0.63	0.488	0.375

CONCLUSIONS

The competition of the market have become extremely challenging and the structure of the business environment is considerably complex recently. In this competitive and complex environment, acquiring competitive power with responding the rapidly fluctuating situations of the environment. In order to achieve this enhancement agility concept creates a great opportunity to adapt firms to give quick responses to market changes.

This work aims to solve agile supplier selection problem employing a fuzzy data envelopment analysis, which is an extension of data envelopment analysis by incorporating imprecise and qualitative data into the decision framework. The proposed methodology selects the most appropriate agile supplier without requiring subjective assessment of decision makers for determining the importance of evaluation criteria. In order to illustrate the proposed decision approach, a case study is conducted in a dye manufacturer company that performs in Turkey.

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DETERMINING THE APPROPRIATE OPEN INNOVATION MODEL FOR LOGISTICS FIRMS USING AN INTEGRATED FUZZY AHP-VIKOR APPROACH

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Abstract *– Innovation activities in the global economies have become more interrelated and open in their nature. So, firms want to increasingly enter into collaborative relationships with their environments to exploit innovation. This trend shapes a new approach called as Open Innovation. It involves making collaborative relationships with other organizations as the basis for achieving competitive advantage through the development of new or improved products and services. Open innovation has an effect the logistics firms because these firms have many services and products and also various relationships with their shareholders. The main purpose of this study is to determine the appropriate open innovation model of logistics firms. The application process is performed by a Multi Criteria Decision Making model. This model includes both alternatives (inbound, outbound and coupled open innovation models) and criteria (control, focus, innovation process, knowledge, cost, capacity, market, utilization, policy, motivation). It determines the weights of the criteria by fuzzy AHP and ranks the alternatives by VIKOR. According to results, the most important three criteria are innovation process, motivation, and market respectively. Outbound is the appropriate open innovation model for logistics firms.*

Keywords – AHP, Fuzzy, Logistics, Open Innovation, VIKOR.

INTRODUCTION

In the modern global marketplace, organizations must constantly look for innovative strategies to improve their competitiveness (Chapman et al., 2003). Therefore, innovation has the vital role in firms' strategy for each sector. Innovation brings with many new approaches. Openness as one of these approaches has increasingly become a trend in innovation management (Lopes and Carvalho, 2018). Innovation activities in the global economies have become more interrelated and open in their nature. So, firms want to increasingly enter into collaborative relationships with their environments to exploit innovation. This trend shapes a new approach called as Open Innovation (OI). OI involves making collaborative relationships with other organizations as the basis for achieving competitive advantage through the development of new or improved products and services

OI is a complex phenomenon because it has multiple aspects (Randhawa et al., 2016). Thus, identifying the key variables and factors affecting open innovation is still a research challenge (Lopes and Carvalho, 2018). Elmquist et al. (2009) identified the areas of interest where open innovation is focused. Similarly, Bigliardi et al. (2012) aims to answer the research question by a multiple case study namely: "Which open innovation approach is adopted by the companies belonging to the ICTs industry?". Casprini et al. (2017) aims to shed light on how family firms execute OI strategies by managing internal and external knowledge flows with an exploratory case study on an Italian family firm. Hsieh et al. (2016) identified which conditions cause firms to choose between outbound open innovation (hierarchy governance) and inbound open innovation (market governance).

Multiple environmental trends (sophisticated services, customer expectations, competitive pressure) have recently increased logistics firms' need to be more innovative (Busse and Wallenburg, 2011). Thus, innovation activities have an important role in these firms. Acknowledging the major changes in the economy and the advent of the new business paradigm, many authors (Hellström and Nilsson, 2011; Su et al., 2011; Wirtz, 2011; De Martino et al., 2013; Anderson and Forslund, 2018) have identified logistics which provides innovative

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solutions. Furthermore, many researchers focused on the relationship between innovation and logistics (Germain, 1996; Richey et al., 2005; Shen et al., 2009; Grawe, 2009; Busse, 2010; Daugherty et al., 2011; Busse and Wallenburg, 2011; Rossi et al., 2013; Pedrosa et al., 2015; Shou et al., 2017; Björklund and Forslund, 2018). Innovation has become a topic high on the international research agenda as well as in practice (Su et al., 2011).

Hossain and Anees-ur-Rehman (2016) stated that studies on OI are limited to several industries according to results of their extensive literature review. In this point, this study concentrates on the logistics sector as a new aspect in OI literature. Many researchers (Chapman et al., 2003; Flint et al., 2008; Wagner, 2008; Wagner and Franklin, 2008; Wagner and Sutter, 2012) indicated that innovation activities have a very important role in logistics capability. Grawe (2009) stated that innovation in the logistics context have also impacted practitioners in marketing, sales, finance, and even end consumers.

Although the study of the effects of OI activities on innovation and firm performance has become increasingly popular in the literature (Hochleitner et al., 2017), the appropriate innovation model for the firms has not confronted in the related literature yet. Furthermore, OI research on logistics firms is very limited. For these reasons, the aim of this study is to determine the appropriate OI model for logistics firms.

The remainder of the paper is organized as follows. First, we describe our method. Thereafter, we present our proposed model including the alternatives and criteria. Analysis and results are depicted and discussed, before the paper concludes with discussion and suggestions on a future research agenda.

METHOD

This study proposes a Multi Criteria Decision Making (MCDM) approach includes AHP and VIKOR. Fuzzy logic is also integrated with this approach, referred to as Fuzzy AHP-VIKOR. Theoretical steps of this proposed methodology are detailed in Appendix.

Fuzzy Analytical Hierarchical Process (FAHP) method uses a range of values; from this range decision makers can select a value based on their preferences. Since the comparison procedure has a fuzzy nature, it seems more reliable to decision makers for making interval judgments (Kahraman et al., 2003). After the study of van Laarhoven and Pedrycz (1983), the first study Fuzzy AHP proposed, another method for Fuzzy AHP is carried out by Buckley (1985) by using trapezoidal fuzzy numbers. Then, the extent analysis method is introduced by Chang (1996), which is a new approach that uses triangular fuzzy numbers in the comparison process. In this study, the FAHP method of Chang is used to calculate the fuzzy weights as Appendix 1.

Fuzzy VIKOR method bases on the principle of positive and negative ideal solving approach in the MCDM process, developed by Opricovic (1998) (Chu et al., 2006). The steps of Fuzzy VIKOR, based on the Opricovic and Tzeng (2004; 2007) and Opricovic (2011), are Appendix 2.

THE PROPOSED MODEL

The aim of this study is to determine the appropriate OI model for logistics firms. For this purpose, an integrated MCDM approach based Fuzzy AHP and VIKOR is proposed. The decision makers should firstly determine the model includes alternatives and related criteria.

Alternatives

Alternatives of this study include the OI models. Although there are a lot of researches about OI models, these models can be grouped as *inbound* and *outbound* generally. Many researchers (Naqshbandi and Kaur, 2014; Cheng and Shiu, 2015; Burcharth et al., 2017; Usman and Vanhaverbeke, 2017) used this two OI models. In addition to these two OI models, some researchers (Mazzolo et al., 2012; Piller and West, 2014; Canık et al., 2017; Battistella et al., 2017) have mentioned a third model, which is the *coupled.*

Inbound OI refers to innovative ideas and technological knowledge that flow into the firm's innovation system. In this model, firm can access external innovative knowledge and internal ideas to complement its business model. Outbound OI refers to ideas or technological knowledge that flow out of the firm's innovation system (Chou et al., 2016). Coupled OI model combines both the inbound and outbound OI model with the goal of commercializing innovation via alliances, cooperation and joint ventures (Enkel et al., 2009; Chou et al., 2016). Theoretical framework of these three OI models can be shown in Figure 1.

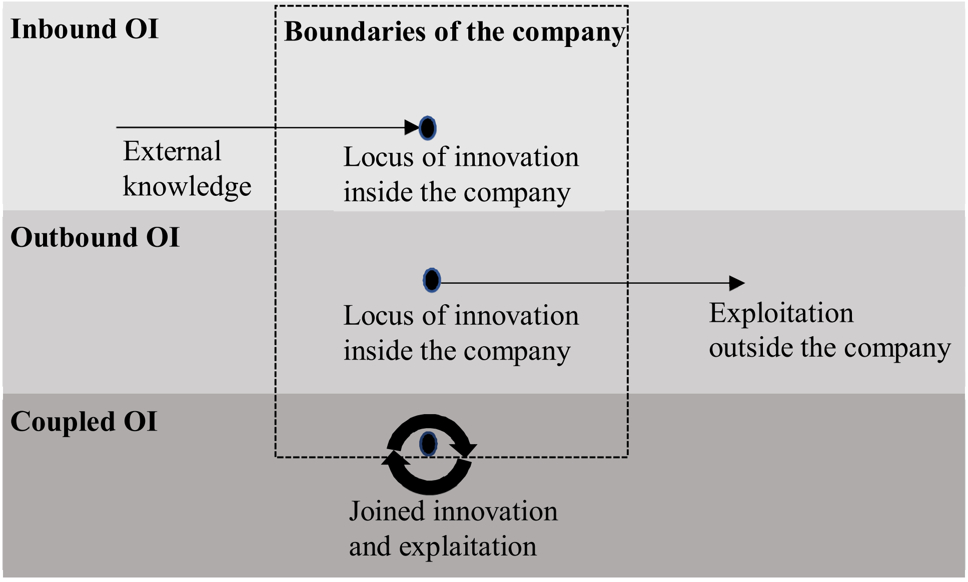

Figure 1. Three OI Models (adapted from Gassmann and Enkel, 2004).

Criteria

In a MCDM problem, choosing the criteria are very important in evaluating the alternatives. So, authors reviewed the related literature. Dahlander and Gann (2010) identified referred to four main types of openness as revealing, selling, sourcing and acquiring. Rangus et al. (2016) conceptualized the tendency for open innovation of a firm, which relates to the firm's predisposition to perform inbound and outbound open innovation activities. According to it, specific dimensions of open innovation are inward IP licensing and external participation, outsourcing R&D and external networking, customer involvement, employee involvement, venturing and outward IP licensing. Hsieh et al. (2016) defined the main factors that influence start-ups' open innovation activitites as dedicated asset specificity, human asset specificity, environmental uncertainty, behavioral uncertainty, transaction frequency and number of parties. Lopes and Carvalho (2018) identified the OI antecedents in two groups as openess (business model, human aspects, innovativeness, number of partners, strategy) and main players (competitors, consultants, customers, government, network partners, suppliers, universities and research institutes).

van de Vrande et al. (2009) determined the motivation factors to adopt OI practices as *control, focus, innovation process, knowledge, cost, capacity, market, utilization, policy, motivation* and *other*. They also specified the hampering factors when adopting open innovation practices as administration, finance, knowledge, marketing, organization/culture, resources, IPR, quality of partners, adaption, demand, competences, commitment, idea management and other. The analyzed the effects of these motivation and hampering factors on technology exploitation and exploration.

This study proposes the ten criteria (Table 1) based on factors by van de Vrande et al. (2009) except for *other*. There are two main reasons of this selection. Firstly, van de Vrande et al. (2009) analyzed these factors in terms of firm inside and outside. Thus, this factors have an impact role both inbound and outbound OI. Furthermore, these factors include both organisational and behavioural aspects. These two aspects are very important to measure a firm's potential for open innovation (Rangus et al., 2016).

Table 1. Criteria (van de Vrande et al., 2009)

Criteria	Examples
Control *(C_1)*	Increased control over activities, better organization of complex processes
Focus *(C_2)*	Fit with core competencies, clear focus of firm activities
Innovation Process *(C_3)*	Improved product development, process/market innovation, integration of new technologies
Knowledge *(C_4)*	Gain knowledge, bring expertise to the firm
Costs *(C_5)*	Cost management, profitability, efficiency
Capacity *(C_6)*	Can not do it alone, counterbalance lack of capacity
Market *(C_7)*	Keep up with current market developments, customers, increase growth and/or market share
Utilization *(C_8)*	Optimal use of talents, knowledge, qualities, and initiatives of employees
Policy *(C_9)*	Organization principles, management conviction that involvement of employees is desirable
Motivation *(C_{10})*	Involvement of employees in the innovation process increases their motivation and commitment

ANALYSIS AND RESULTS

The proposed model was analyzed for logistics firms. Relevant information such as weights, evaluation criteria and corresponding values of each criterion against the OI models were gathered from the decision makers. The weights of the ceriteria and the values of OI models were obtained using fuzzy numbers from the decision makers. They are 2 academicians specializing in open innovation, 3 academicians specializing in logistics, and 2 vice general managers in two logistics firms.

After receiving the decision makers' opinions, fuzzy AHP was applied to compute the relative weightings of the individul criteria, as shown in Table 2. The results indicate that consistency rate is lower than 0.1. According to it, innovation process (*C_3)* is the most important criterion, with a weighting of 0.171, followed by motivation (C_{10}), with a weighting of 0.169.

Table 2. Weights of the criteria

Criteria	C_1	C_2	C_3	C_4	C_5	C_6	C_7	C_8	C_9	C_{10}
Weight	0.073	0.095	0.171	0.074	0.006	0.001	0.142	0.133	0.135	0.169
Rank	8	6	1	7	9	10	3	5	4	2

Following the criteria weights from fuzzy AHP, VIKOR was applied to evaluate the three OI models. According to VIKOR methodology, Table 3 presents the ranking of the three OI models with v being equal to 0.5. As shown in Table 3, outbound OI model is the appropriate OI model for logistics firms.

Table 3. Rankings of the alternatives

Alternative	***Si***	***Ri***	***Qi***	***Rank***
Inbound OI	0.7505	1.0000	0.8752	3
Outbound OI	0.1014	0.5789	0.3401	1
Coupled OI	0.6374	1.0000	0.8187	2

DISCUSSION AND CONCLUSION

Firms make collaborative relationships with other organizations as the basis for achieving competitive advantage because they want to increasingly enter into collaborative relationships with their environments to exploit innovation. So, OI is a hot topic subject both academicians and practitioners. However, the appropriate innovation model for the firms has not confronted in the related literature yet. Furthermore, OI research on logistics firms is very limited. For these reasons, the aim of this study is to determine the appropriate OI model for logistics firms. For this purpose, an integrated MCDM approach based fuzzy AHP and VIKOR is proposed. In this study, the proposed model for logistics sector differs from the other sectors. So, it should be noted that it is practible model for each sector in some modifications.

The proposed MCDM model includes three alternatives (inbound OI, outbound OI, and coupled OI) and ten criteria (control, focus, innovation process, knowledge, cost, capacity, market, utilization, policy, and motivation). According to fuzzy AHP results, innovation process is the most important criterion in determining the appropriate OI model. This process includes the application of product development, process/market innovation, and integration of new technologies. So, it can be affect the OI selection decision.

The results of the VIKOR method indicate the outbound OI as the appropriate OI model for logistics firms. It means that outflow of ideas or knowledge more suitable for logistics firms. These firms should also focus on external exploitation of internal knowledge because they can make profits by bringing ideas to the market. Firms should also sell licenses such as copyrights or trademarks to other firms to better benefit from their innovation efforts. It should be noted that logistics firms want to implement to this model should transform the whole their business process with the help of the outbound OI approach.

This study used fuzzy AHP-VIKOR method to solve the decision problem with qualitative criteria. Methods such as ELECTRE and PROMETHEE comparatively in a fuzzy environment is used in the future studies. Further studies can also apply both qualitative and quantitative criteria.

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APPENDIX 1 (*FUZZY AHP*)

Let A ($a_1, a_2, \ldots, a_n$) be an object set and B ($b_1, b_2, \ldots, b_m$) be a goal set. M extent analysis values for each object can be obtained as $M_{bi}^1, M_{bi}^2, \ldots\ldots, M_{bi}^m, i = 1, 2, \ldots, n$.

1. The values of fuzzy extensions for the i_{th} object are given in Equations 1 and 2.

$$S_i = \sum_{j=1}^{m} M_{bi}^j * \left[\sum_{i=1}^{n} \sum_{i=1}^{m} M_{bi}^j\right]^{-1} \quad (1)$$

$$\sum_{j=1}^{m} M_{bi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j\right) \quad (2)$$

2. While M_1 and M_2 are triangular fuzzy numbers the degree of possibility for is defined as:

$$V(M_2 \geq M_1) = sup_{y \geq x}\left[\min(\mu_{M_1}(x), \mu_{M_2}(y)\right] = hgt\,(M_2 \cap M_1)\mu\ M_2(d) \quad (3)$$

Where d is the ordinate of the highest intersection point D between μM1 and μM2. It can be represented in the following manner by Equation (4)

$$= \begin{cases} 1, & if \quad m_2 \geq m_1 \\ 0, & if \quad l_1 \geq u_2 \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)}, & otherwise \end{cases} \quad (4)$$

To compare μM_1 and μM_2, values of both, $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$ are needed.

3. The degree of possibility for a convex fuzzy number to be greater than k convex numbers Mi (i=1,2,...,k) can be defined by Equation (5)

$$V(M \geq M_1, M_2, \ldots, M_K) = V[(M \geq M_1), (M \geq M_2), \ldots, (M \geq M_K)] = \min V(M \geq M_i), \ (i = 1,2,3, \ldots, k) \quad (5)$$

Assume that Equation (6) is;

$$d^1(X_i) = minV(S_i \geq S_k), for\ k = 1,2, \ldots, n; k \neq i \quad (6)$$

So the weight vector is obtained by Equation (7):

$$W = (d^1(X_1), d^1(X_2), \ldots\ldots, d^1(X_n))^T\ where\ X_i\ (i = 1,2, \ldots, n) consist\ of\ n\ elements. \quad (7)$$

4. Through normalization the weight vectors are reduces to Equation (8).

$$W = (d(X_1), d(X_2), \dots\dots.., d(X_n))^T \text{ where } W \text{ represents absolute number.} \quad (8)$$

APPENDIX 2 (*FUZZY VIKOR*)

1. Determine alternatives, criteria and decision makers. (M alternative, k criteria, and n decision maker).

2. Define linguistic variables and corresponding triangular fuzzy numbers.

3. Decision makers' preferences and views are combined. The arithmetic mean of the sum of the N number of decision makers' evaluations for each criterion is taken.

$$W_j = \frac{1}{n}\left[\sum_{e=1}^{n} m_j^e\right], j = 1,2, \dots\dots.., k \quad (9)$$

For the criterion of number j, the preference of each decision criterion with respect to the weight of each criterion and the ratio of each option to the number of alternatives (i) is calculated as equation (10) and a normalized fuzzy decision matrix is constructed.

$$X_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n} x_{ji}^e\right], j = 1,2, \dots\dots.., m \quad (10)$$

4. For each criterion, the fuzzy best value and the fuzzy worst value are determined from the alternatives.

$$f_j^* = max_i x_{ij} \quad , f_j^- = min_i x_{ij} \quad (11)$$

5. Calculate the value of $W_j(f^*\text{-}X_{ij})/f_j^* - f_j^-), S_i, R_i$

$$S = \frac{\sum_{j=1}^{k} w_j\left(f_j^* - X_{ij}\right)}{f_j^* - f_j^-} \quad (12)$$

$$R = \frac{max_j w_j\left(f_j^* - X_{ij}\right)}{f_j^* - f_j^-} \quad (13)$$

6. Calculate the value of S^*, S^-, R^*, R^-, Q_i

$$S^* = min_i S_i, S^* = max_i S_i \quad (14)$$

$$R^* = min_i R_i, R^* = min_i R_i, R^- \quad (15)$$

$$Q_t = \frac{v(S_i - S^*)}{S^- - S^*} + (1 - v)(R_i - R^*)/(R^- - R^*) \quad (16)$$

7. In this step, the averages of the fuzzy numbers are taken and the Q_i, S_i, R_i index values are calculated. The resulting values are sorted from small to large and the smallest value is considered to be the best solution.

8. The validity of the result is dependent on testing two conditions.

Condition acceptable advantage: This includes proving that there is a clear difference between the best and the closest option. The 'A' value represents the first alternative in the order and the second-best alternative in the A" order.

Q(A") - Q(A') ≥ DQ (m=1/m-1; m is the number of alternatives).

Acceptable Stability: If Q (A") - Q (A') ≥ DQ, then A" and A' are the same concurrency solution. If the second condition is not accepted, there is an inconsistency in decision making, although it has the advantage. Hence the A 'and A' 'conciliatory solutions are the same. The choice of the best alternative with the minimum Q value is made.

THE INTEGRATION OF THE BLOCKCHAIN TECHNOLOGY IN THE SUPPLY CHAIN MANAGEMENT

Saoussane Srhir[1], Ozalp Vayvay[2]

Abstract- *Supply chains and operations are becoming more and more dynamic and complex. The companies have a vast environment with large product variants and multiple parties. Maintaining a competitive advantage in the global market and innovation are the goals of any leading company and the supply chain management is the key to success. After digitalization and computerized systems, the blockchain is the new revolution that will change the supply chain and the logistics industry by increasing the transparency, security and visibility of the operations. This paper will cover the benefits of the blockchain technology and how the companies would integrate this revolution in their supply chain management process. The objective of the study is to show how the blockchain will play a role of a remedy to the fragmented infrastructure of the firm and improve its management. Also, through this paper, the results of the blockchain application will be shown. This study will be based on an extended literature review.*

Keywords: Blockchain technology, computerized systems, digitalization Supply chain, logistics, supply chain management.

INTRODUCTION

Nowadays, the supply chains became more complex because of the changes in manufacturing and distribution, namely, the globalization and outsourcing (Melin, 2013).

We can talk about the Modern supply chain that is characterized by being global, multi-echelon, disconnected and geographically wide (Braun, nd). The companies now are looking for competitive advantages at all levels of the value chain in order to deliver performance, and at the same time, they are called to stay updated about the whole process of the production, starting from the acquisition of the raw material to the delivery of the final product. The consumers became more vigilant about what they are consuming and how the products have been produced. Therefore, a supply chain manager should be aware that the products that will be delivered have in fact the characteristics promised, and this is what makes the supply chain management more and more complex (Hatishar, 2018). A product that goes through different countries, cultures, and different governmental policies and human behavior are certainly passing from a critical process that may disrupt the whole supply chain.

Today, the supply chain is characterized by a large data, however, it has shortcomings in term of trust between the organizations. Thus, the blockchain may be the new revolution that will allow the companies to overcome the problems and ensure a good logistics management in term of:

- traceability, transparency,
- Reducing and eliminating the frauds and risks,
- Improving inventory management,
- Reducing the delays,
- Fast identification of the problems (Nakasumi, 2017).

→ The objective of the study

The objective is to show how the blockchain as a new revolutionary technology will change the supply chain management of the companies and solve the problems that may be faced in term of securing the data, making the transaction faster, tracking the products, and soon, making payments without going through the financial institutions.

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And the study will be based on an extended literature review and the results of this study will be shown through some current examples about some of the biggest companies in the world that started using the blockchain in their businesses.

The following sections of this article are structured as follows: The first part explains the principles of the blockchain and the second part discusses the integration of the blockchain in the supply chain.

ABOUT THE BLOCKCHAIN TECHNOLOGY

Two innovations changed the way how the word "Trust" is perceived: the cryptography and the distributed computing system.

Firstly, it started in 1976 when Whitfield Diffie and Martin Hellman introduced the notion of the dual receiver cryptosystem with the goal of protecting the confidentiality of the data between two parties, using an encryption key that is public and a decryption key, which is kept secret. At the same time, the distributed computing system appeared as well, and now, it is being associated with the dual receiver cryptosystem to create the innovation of the blockchain (Dubertret, nd).

The term blockchain appeared in 2009 in the book "Bitcoine: a peer-to-peer electronic cash system" written by Satoshi Nakamoto. With this book, the cryptocurrency era was born. The blockchain is basically a mathematical structure to store the data and the use of it is changing over time (Nakamoto, nd). It started with the era of the bitcoin digital currency and now, the companies are using it to make a trustful and secure transaction, impossible to fake (Orcutt, 2018).

In a company's supply chain, a blockchain plays a role of the storage and the transmission of all the transaction information with the advantage of traceability, privacy, security, transparency and allowing everyone to check the validity of the chain (Cui, 2017).

The blockchain is composed of an ordered data block in the system. It uses automated script code to program and manage the data and uses the encrypted chain block structure to validate and store data (Nakamoto, nd).

The blockchain is characterized by being decentralized which means that the blockchain data has a distributed system structure through which the data is getting processed. This characteristic makes the blockchain trustful, since the nodes (Any electronic device connected to the internet and has an IP address) are linked and manage the data blocks in the system (WCI, nd).

THE BLOCKCHAIN GUARANTEES THE INVIOLABILITY OF THE INFORMATION

Two mechanisms are the base of the blockchain. The cryptography and the distributed computing system (BizEd, 2018). How it works?

Let's imagine a blockchain as a multitude of blocks linked between one another, if one drops the other will not exist. The code of every block is built after the one before in the block chain at a specific time, knowing that the modification of the blocks is impossible which guarantee the transparency and the originality of the information. Also, during a Bitcoin transaction, we mention about the time-stamping that justify to the possessor the time of owing a cryptocurrency. The whole documents will be saved and validated in the blockchain during that specific time T, and cannot be modified later on (Dréan, 2016).

Additional to that, the blockchain has the characteristic of being a secure and safe network to store the confidential documents of different transactions in different domains. It has what we call "Nodes of the blockchain", that are considered as a list of every single transaction that has happened on a blockchain. Even that the nodes are characterized by having an open access to everybody, it is highly unlikely that a government, hackers or terrorists to threaten the integrity of the blockchain (Holotescu, 2018).

Behind this process, three main functions interact; the digital signatures, the hashes and the miners (BizEd, 2018). It starts from the digital signatures that is defined simply as the user identification, it is an encryption key that follows the users through all the openings of any transaction. Once a transaction is initiated on a blockchain, a block is built and converted into a data algorithm named a "hash" (Dréan, 2016). The information is added to the hashes and are permanent and visible across the blockchain users, whenever an unusual action is attempted, the whole system is alarmed. The hackers need a lot of computing power more than is available in the world to crack the blocks. In other side, the miners are doing their job, once they receive the transaction, these entities use computer software to solve the puzzle that allows the transaction to take place (BizEd, 2018).

The blockchain would be a certain driver to efficiency in many industries, it is fully automated and promise an easy and speedy flow of the transactions.

THE IMPLEMENTATION OF THE BLOCKCHAIN IN THE SUPPLYCHAIN

The sectors for which the blockchain is concerned are numerous. This technology is being adopted to solve the issues of supply chain traceability and the management risks.

The stakeholders among the supply chain register every step of the production process on the blockchain, what makes this technology transparent, timestamping and distributed to all the participants in the supply chain (Nakasumi, 2017). All the detailed information is being registered such as the documents of the products, location, temperature, degree of humidity etc., Thus, giving to the stakeholders a full insight about the situation of the product at every stage of the process, from the production to the distribution (Korzeniowski, 2018).

Intel invented a prototype of traceability using the blockchain technology to track the products. It has been experienced in the fishing industry, once the fish are caught, a connected sensor in the fish batch transmits the data about the location, temperature, humidity, movements, to be saved in the blockchain (Intel, nd).

In case of fraud, food poisoning or any other problem, the players in the industry can therefore, detect in real time where and when they have been committed (David G.Mamunts, 2018). The consumer can also have access to some of the information once he buys the product through the QR code in the packaging.

One of the major actors that have implemented this revolution in their supply chains, Walmart, Alibaba, and Carrefour.

Walmart started to follow the Chinese pork import in 2017, and now they started the project by following the movement of Mangoes to the United States (Protais, 2017). Alibaba in the other side, started in 2017 to improve the traceability of the food products commercialized in the platform using the blockchain (Kaplan, 2018).

RESULTS AND CONCLUSION

Nowadays, logistics chains are still using paper documents that are sources of inefficiencies and encourage fraud. Soon, they are considered to be fully based on the digital technologies.

What points do diamonds, medicines, meat or milk have in common? Logistics chains with many stakeholders. The blockchain may constitute the dominant infrastructure of digital supply chains. Among the benefits of the implementation of this technology in the supply chain is an improved traceability, reduction of fraud or counterfeiting, easier and smoother management of property transfers by limiting intermediaries.

Through this article, we understood how the blockchain is working and how it is relevant in the supply chain because it is a platform where different actors that do not have the same interests must collaborate together. It gives the opportunity to these collaborators to do their work by registering their transactions without necessarily intervening between each other. It is a decentralize database where all the stakeholders will share the same database to make transactions without a need of intermediaries in a trustful digital environment. It provides also a very good traceability of the products to the firm, and to the customer as well.

Beyond all the good aspects shown during this study, it is conceivable that the blockchain will also allow the firms to make its supply chain a source of innovation and improvement in term of marketing, customer relationship, finance, management etc.

The technology blockchain seems promising, but this field still wide open to be studied and tested.

The conclusion made while getting this article done, is that the companies must stay updated about what the technology is giving. As this article shows, this technology is so easy to understand, and after learning more about it and discovering it, its use would bring a huge value to the companies by facilitating the management, reducing the risks and improving the customer relationship management. And this is not an assumption, it has been proven since big companies such as Walmart, Carrefour and many others have been applying the blockchain, and found it useful solving problems that couldn’t be managed before.

However, the matter of trust still suspect and the possibility of making payments through the blockchain has not been proven yet by the governments and the financial institutions.

LIMITATIONS AND FURTHER RESEARCH

This article studies a new topic that is still at an early stage. The blockchain presents many opportunities for the supply chain sector. It facilitates the management of the warehouses, the payments, the orders, etc., and enhances the visibility and the transparency of the transactions. However, this technology still has to undergo a wave of improvements to stick to the use of the supply chain, because they just started implementing this technology, thus they still have to experience how successful this technology can be and the problems that may occur. Also, a lot of challenges are still facing this technology such as:

- The complexity: the interest in new technologies for the manufacturing firms is low.

- The volume of data and the scalability issues: the numbers of the data in one block are limited.
- The legal regulation issues: the fact that saving data without a possibility of deleting it, may be illegal.

Moreover, it will be hard to get the results of the companies since they do not want to share their studies and experiences using the block chain in order to build a competitive advantage.

As further research possibilities, studies with a complete research that resumes the experience of a company's supply chain with the blockchain would be beneficial to understand the process and identify the risks and the consequences of this technology, because even if it is considered as being promising, it is not fully mature and not without risks.

Moreover, how can the companies and individuals make payments through the blockchain could be a future research topic as well.

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ASSESSING CONTRACT LOGISTICS FACILITIES: RESULTS FROM A SURVEY IN ITALY

Martina Baglio[1], Fabrizio Dallari[2], Elisabetta Garagiola[3], Sara Perotti[4]

Abstract *– E-commerce and retailing companies have been recently experiencing a rise in their revenues. This has led to the search for new logistics facilities compliant with their needs. Such research of new spaces and top quality facilities has driven the logistics real estate industry to an unexpected rebirth after the slowdown caused by the last economic crisis. Some example of assessment models for industrial buildings are reported in literature, but they mainly evaluate warehouses from a sustainability perspective. Conversely, the measurement of quality and functionality has been scarcely addressed so far. The paper aims to fill this gap by describing the state of art of contract logistics warehousing in Italy using an original model to assess logistics buildings. The model allows to identify, structure and rate the most relevant features for two main types of logistics buildings, namely warehouses and cross-docking platforms. The proposed model builds on previous literature and integrates the practitioners' perspective. It is structured into four sections, each representing the most important features for logistics building evaluation: location, external spaces, building technical characteristics, and internal areas. Each sub-section contains multiple-choice questions. The significance of each section is given by specific percentage weights defined by the experts involved during multiple semi-structured interviews. Finally, the rating model was validated by pilot tests. The model was applied extensively on 65 contract logistics facilities located in Italy, ranging from 2,000 to 150,000 square metres.*

Keywords – Benchmarking, building performance and sustainability, warehousing, logistics real estate, rating system.

INTRODUCTION

The rebirth of logistics real estate has been supported by industries such as e-commerce (Mangiaracina et al, 2016) and retailing, looking for facilities compliant with their logistics or global supply chain needs (Dablanc et al., 2012). Logistics facilities are also sought by logistics service providers (LSP) involved in the distribution of goods for these industries. They are looking for top-class buildings able to satisfy their operating needs and also the quality requests imposed by their customers (Raut et al, 2018). In recent years, the research of new spaces has led to a 40% reduction of warehouse vacancy rate and an increase of more than 50% in new constructions in terms of floor area compared to 2015.

Nowadays, companies searching for logistics buildings essentially focus their evaluation on its size (e.g. in terms of floor area) and few other aspects, without referring to a shared holistic procedure and without a structured model of classification and evaluation of the quality of the facility. The lack of a reference model for qualitative assessment represents a significant limitation, since logistics building quality is defined by several different elements which are essential to perform a logistics activity, and cannot be simplified focusing only on size (Mattarocci et al, 2017). Therefore, in order to identify the top-class logistics buildings, the need has emerged for measuring both the quality (e.g. architectural and equipment features) and functionality (i.e. compliancy with logistics requirements) of warehouses.

The literature reports a number of assessment models for industrial buildings, especially from a sustainability perspective, such as LEED and BREEAM certifications (Mattoni et al, 2018; Berardi, 2012). However, the measurement of their functionality and overall quality has been scarcely addressed so far.

To fulfil this gap, the present paper develops an original model to assess logistics buildings identifying, structuring and rating the most relevant features of a warehouse. Moreover, it illustrates the results of the application of the model developed on a sample of contract logistics facilities located in Italy.

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The remainder is organized as follows: Section 2 reports the analysis of the existing literature related to logistics real estate. Section 3 describes the objectives and research questions, whereas Section 4 illustrates the methodology adopted. Section 5 describes the proposed model and Section 6 presents the findings related to its implementation on the examined sample of logistics facilities. Finally, the last section discusses the main conclusions and identifies the future research opportunities in this field.

LITERATURE

Rating systems have always been adopted in the real estate industry to evaluate the marketability of different types of buildings or properties, i.e. apartments, offices, industrial buildings, and others (Mattarocci et al, 2017).

In the real estate value chain, the evaluation is performed by different players, such as real estate agents, appraisers, assessors, mortgage lenders, brokers, property developers, investors and fund managers, lenders, market researchers and analysts, tenants (Pagourtzi et al, 2003). The presence of all these players justifies the need of a deep understanding of the asset, since the product under assessment is a durable long-term asset, with a great economic value, characterised by a high differentiation and located in a specific site (Wyman et al, 2011).

Regarding industrial building, the real estate literature reports several evaluation models, which mainly focus on sustainability and safety aspects, such as limitation of gas emissions, energy consumption, application of green regulation during the activities of design and construction (Ding, 2008). Indeed, due to the institutional pressures on building sustainability performance, considerable attention has been paid to the environmental assessment. Even the logistics field has been affected by sustainability issues, and leading to multiple studies about best-in-class policies to reduce gas emission during logistics activities (Colicchia et al., 2016).

Looking at sustainability, a number of models have been also developed – i.e. the so-called Green Building Rating Systems (GBRS) – to assess the degree of sustainability in the real estate industry. The most significant are also recognised as international standards, such as LEED, BREEAM, Green Star, Green Globes, SB Tool, and national versions such as CASBEE for Japan, DNGB for Germany, ITACA for Italy (Mattoni et al., 2018). These models have been generally designed for industrial buildings. Some adjustments have been made to fit the logistics context, but the attention is merely on the environmental assessment of the building.

Focussing on the logistics real estate industry, little attention has been given so far to the development of assessment models that consider the quality of logistics buildings from a multi-dimensional perspective. As above-stated, the existing literature mainly focus on sustainability aspects, as well as quantitative issues related to facility location and site selection, often neglecting other elements related to the building structure. Still, this latter aspect is progressively becoming more of concern, given the growth of the contracts logistics industry (Marchet et al., 2017), and the need of Logistics Service Providers' (LSPs) customers to inspect and evaluate the buildings in order to ensure a good quality of the service (Marchet et al, 2017).

Besides sustainability aspects, other features in the literature have been found as important (Baglio et al., 2018): location, technical/construction characteristics, external and internal spaces, utilities and "green" systems.

The location is considered as one of the most important features in real estate according to Diziain et al. (2014). Regarding the specificity of a logistics building, location is one a key feature for an efficient goods distribution network (Dablanc et al., 2012). Location's aspects have been described in literature. As an example, availability of transport services and infrastructures in the surroundings, such as motorways, railway stations, ports or airports servicing the area, or location in a logistics centre or freight village (Lipińska-Słota et al, 2018). In this case, the location can increase the value of a logistics building in case it supports or facilitates logistics activities (Woudsma, 2008). For instance, a warehouse near a motorway can help deliver goods faster than a farer facility. However, the value given to the location depends on the function played by the building. Indeed, central warehouses or last mile cross-docking facilities have different location needs (Mattarocci et al., 2017).

Other significant aspects, such as technical and construction characteristics, internal and external spaces, utilities and "green" systems, have been pointed out. Technical and construction characteristics refer to the building features such as structural mesh, pavement, and roof structure (Ciaramella, 2010). Internal and external spaces refer to areas (e.g. truck parking lots, offices, recharge areas for material handling equipment, technical rooms, and restrooms) or devices and facilities (e.g. docks, refrigeration rooms, safety systems). Utilities and "green" systems refer to those appliances such as fire-detecting and fire-fighting systems, lighting systems, electric systems, heating/air-conditioning systems, photovoltaic systems.

All the above-mentioned aspects can be evaluate differently depending on the purpose of usage (i.e. "functionality") of a logistic building (Mattarocci et al., 2017). However, it has been underestimated by scholars since generally the value of a facility is generally not assessed considering its functionality (Baglio et al., 2018).

In literature, logistics buildings have been recognised to play different roles. The most common one is inventory holding, i.e. conventional stock warehouses where goods are stored in racks for a long period, depending on the timing of inbound and outbound flows, and customer orders are consolidated before delivery. A second role is cross-docking, i.e. warehouses where goods are moved directly from receiving to the shipping area, rapidly sorted and loaded to their final destinations (Higgins et al., 2012). Cross-docking facilities are commonly used as transit point by transportation companies to optimize long linehaul with last mile delivery. According to Baker et al. (2009), other roles for logistics facilities may include value added services (e.g. secondary packaging activities), or production postponement, returned good (for reverse logistics) and other activities, such as service and repair.

OBJECTIVE AND RESEARCH QUESTIONS

The literature review has identified a gap in terms of evaluation models specifically developed for logistics buildings focusing on their quality and functionality (Baglio et al., 2018). Quality has to be intended as a set of elements (e.g. site location, external spaces, building technical characteristics, internal areas, utilities and "green systems") affecting the overall building evaluation, and not only as a combination of architectural characteristics and equipment features. Functionality refers to the level of compliance of a logistics building to host a certain type of logistics activities (e.g. storage, picking and sorting). To fil this gap, the objective of the present paper is to describe the state of art of the contract logistics warehousing in Italy by applying an original model developed by the authors and presented in Baglio et al. (2018) to assess logistics buildings quality and functionality. Such original model allows to identify, structure and rate the most relevant features of a warehouse, considering also the purpose of usage, in line with Mattarocci et al. (2017). Specifically, the model is applied to evaluate 65 contract logistics facilities located in Italy. The aim is twofold: to enrich the factors that supply chain and logistics managers use in their location decision, and to help policy makers identify factors that may be critical to promote local and industrial development.

According to the intended objective of the research, the following research questions have been identified:

- RQ1: Based on the application of the model developed (Baglio et al., 2018), which is the state of art in terms of quality among contract logistics facilities in Italy, and which are the main features?
- RQ2: How do these main features contribute to the quality and functionality evaluation of the logistics facilities?

METHODOLOGY

The research methodology consisted in different phases. First, a literature review was performed in order to identify the main types of logistics buildings, the significant features to be considered to assess a warehouse or a cross-docking facility, and the rating systems available and adopted in the logistics real estate industry. The literature review results allowed collecting a first set of information to develop the model. Second, six semi-structured interviews with experts of the logistics real estate industry (e.g. logistics real estate managers, structural engineers, and facilities managers) were developed to define the types of logistics buildings (i.e. confirmed as stock warehouses vs cross-docking facilities) and the list of features characterising. They were selected since they operate in the logistics real estate market and have a deep understanding of the industry.

A five-star rating system was then developed to assess the quality of logistics buildings. The five-star rating assessment system was selected since it is easily identified and understood, thanks to its widely deployment in different fields, such as finance, hotels, online customer reviews, safety systems, and sustainability performance in real estate (Berardi, 2012; Sparling et al., 2011). The model was validated by pilot tests on 15 existing warehouses. This phase allowed a fine-tuning of the model, adjusting wording, weights and scores.

To test the model on different types of facilities, either stock warehouses or cross-docking facilities, with different features and quality levels authors decided to implement the model on contract logistics building. To understand the quality of the contract logistics facilities located in Italy (RQ1), and the main features that contribute (RQ2) intended focus was on LSPs' facilities. Therefore, the buildings assessed were stand-alone facilities, and factory warehouses (e.g. logistics buildings with direct access to the manufactory plant) were excluded from the analysis.

To identify the most relevant companies in the industry, authors used the database of the Contract Logistics Observatory (as per Marchet et al., 2018), a permanent research initiative launched by Politecnico di Milano

School of Management since 2011 on the themes of logistics outsourcing. Thanks to the contact database of the Observatory it was possible to reach up to 150 LSPs with the survey including the questions related to the model.

Starting from the database of the response obtained from the survey, a subset of 65 warehouse was achieved. From the initial database, data were cleaned from warehouse with impropriate characteristics, such as more than 30 years old and a size less than 2,000 m^2. Focusing on buildings with more than 30 years old is due to remove obsolete facilities, which typically do not meet safety standards. Instead, overlooking small buildings allows to pay attention on large facilities where LSP's concentrate goods of more clients (multi-client warehouses).

MODEL DEVELOPMENT

The detailed developing of the rating model has already discussed in by Baglio et al. (2018). In this paragraph we present the main issues of the model we developed. In particular, the model is structured into four sections. Each section is divided into sub-sections:

- Section 1: "Location and relationship with the context" divided into two sub-sections: "1.1 Context" and "1.2 Proximity to transport infrastructure";
- Section 2: "External spaces" divided into two sub-sections: "2.1 External yard" and "2.2 Loading/unloading bays";
- Section 3: "Building technical characteristics" divided into three sub-sections: "3.1 Warehouse size", "3.2 Structure" and "3.3 Flooring";
- Section 4: "Internal area, utilities and green systems" divided into two sub-sections: "4.1 Offices and other spaces", and "4.2 Utilities and green systems".

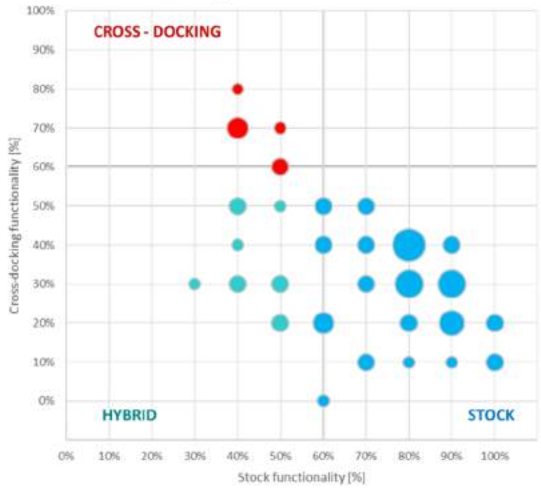
Each subsection includes single-response questions (i.e. items). To evaluate quality and functionality, as highlighted in the methodology section, a pool of expert was involved to define the features to be included in the model and their importance. The weight of each section and sub-section for the quality evaluation was discussed with the pool of experts, while for the items the weights were validated and discussed with practitioners of the field, in order to give higher weights to the most important questions. During the phase of weight allocation, the experts gave their opinion also paying attention to the building functionality. As a result, two patterns of weights emerged: one for the stock warehouses and one for cross-docking facilities. Thus, quality score is computed as the sum of all the scores obtained for each question of the model. The percentage rate of quality is then converted in a score using a five-star rating system. Indeed, five different ranges were set, using intervals of different size, in line with the Green Star certification for sustainability (Mattoni et al., 2018).

Regarding functionality, structured interviews were used to define which features were fundamental to distinguish between stock warehouses and cross-docking facilities. A score has been assigned to each feature, and the sum provides the final functionality rate. When the functionality rate, expressed as a percentage from 0 to 100%, is equal or higher than 60% the warehouse belongs to the stock or cross-docking facilities type. In case the rate is below the level set, the warehouse assessed is considered "hybrid" since it has some of both features of stock and cross-docking facilities.

MODEL RESULTS

This section reports the model application on 65 warehouses located in Italy and used by LSPs. For each logistics facility under assessment, Figure 1 reports the relationship between stock functionality and cross-docking functionality rates. The graph pinpoints three groups of facilities: the one on the top left (red points) includes the cross-docking facilities, the one on the bottom right identifies the stocking warehouses (blue points), while the green group identifies the "hybrid" buildings. These latter facilities do not have the typical characteristics of "stock" and "cross-docking" warehouses (i.e. with both functionality rates under the thresholds of 60%), and are reported in the bottom left quadrant. Finally, no warehouse has been found with a functionality greater than 60% for both “stock” and “cross-docking” types. This is the reason why the area on the top right is empty, since there are not any warehouse with both strong functionality.

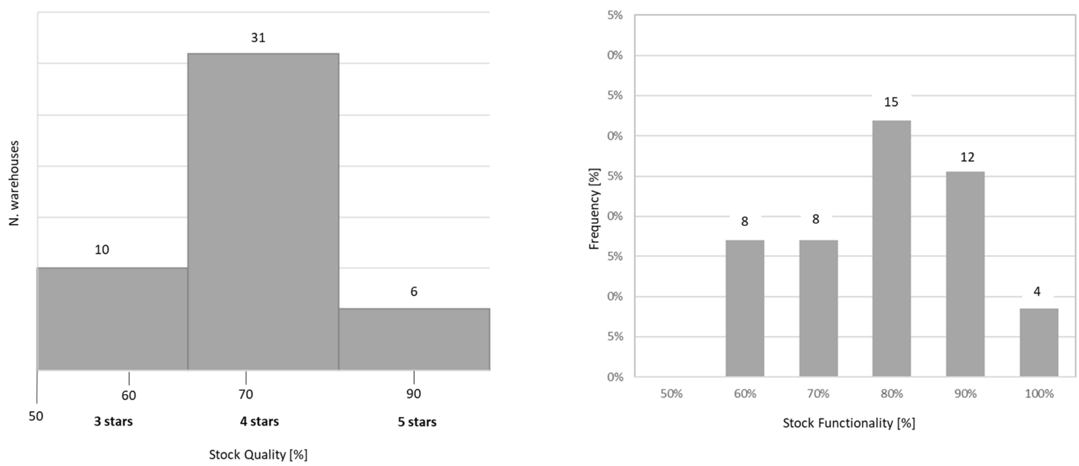
Figure 1: Comparison between functionality rates (stock warehouses vs. cross-docking facilities)



The majority of the observations are reported in the “stock” quadrant (i.e. 47 facilities with stock functionality rate equal or greater that 60%), since most of the logistics service providers interviewed mainly used such facilities to stock, pick and sort the goods of their clients. For this reason, in order to allow homogeneous comparisons in the further analysis, we decided to focus on the subset of stock warehouses only (i.e. warehouses with a stock functionality equal or greater than 60%).

Looking to the subset of stock warehouses, quality and functionality rates are reported in Figure 2. The overall quality mean is equal to 70%, which corresponds to 4 stars in the five-star rating system adopted. Overall, it emerges that the examined warehouse in Italian contract logistics industry have high standard of quality. Regarding functionality, 62% of the observations have rates greater than 80%, meaning that contract logistics warehouses are strongly related to storage activities. The graph reports above each column the number of warehouses.

Figure 2: Stock quality and functionality for the examined subset (47 warehouses)



The quality related only to location features is always greater than 80% in the examined subset. Indeed, location is an important critical success factor for LSPs since all the warehouses are located near transport services and infrastructures (in particular motorways, ports or airports servicing the area), and in the surrounding of metropolitan cities or logistics centres. Regarding railway stations, since the transport is performed mainly by road vehicle in Italy, only 10 facilities have access to this service because they are located in logistics centres. Looking at the other three subsection of the model, quality rate is critical for Section 4 (“Internal area, utilities and green systems”). In fact, there is a lack of investments in warehouse equipment for sustainability improvements because the attention is primarily given to CO_2 emissions in transport. A detailed description of the main features of these subsections is described hereafter.

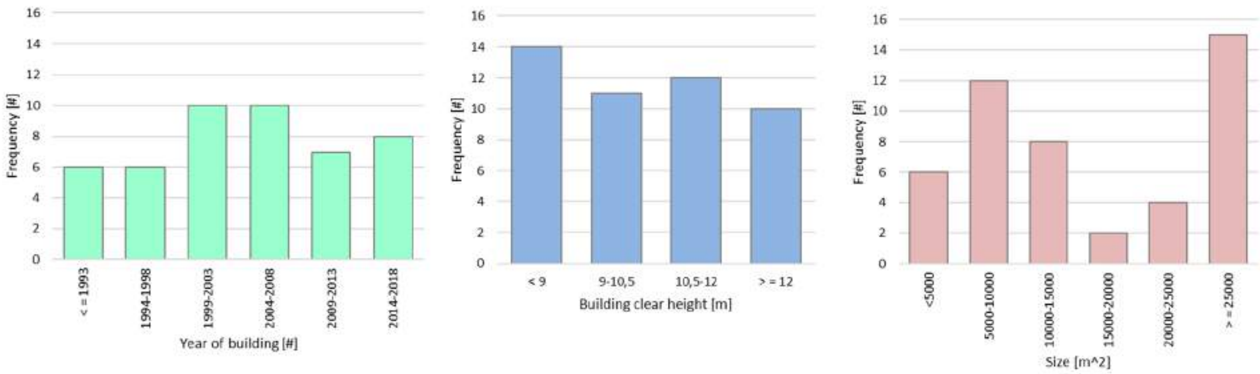
The subset includes different types of warehouses, in terms of year of construction, size and building clear height (Figure 3). Size is defined as the floor space measured is squared metres, while height is the building clear height measured in metres.

Most of the observed buildings have less than 10 years, while only two facilities have more than 30 years. Indeed, most of the warehouses assessed are rented as stated by facilities managers interviewed, making LSPs flexible to the demand and able to move to the newest and most suitable building when necessary. Figure 3 reports in the top-left graph the number of warehouse analysed in a range of five years.

Regarding the building clear height, the sample presents a very wide range of values: from 4.5 m to 14 m. In two cases the clear building height is equal to 29 m since those facilities have automated storage and retrieval systems (AS/RS) in place, that justifies such a huge building clear height. However, these cases are out of scope for the current analysis, since we consider only the height of the concrete building. Excluding those two particular cases, in Figure 3 the top-right graph reports the number of warehouse within a specific range of height. The ranges are formed using 1,5 m as the standard height between two beams of a pallet rack.

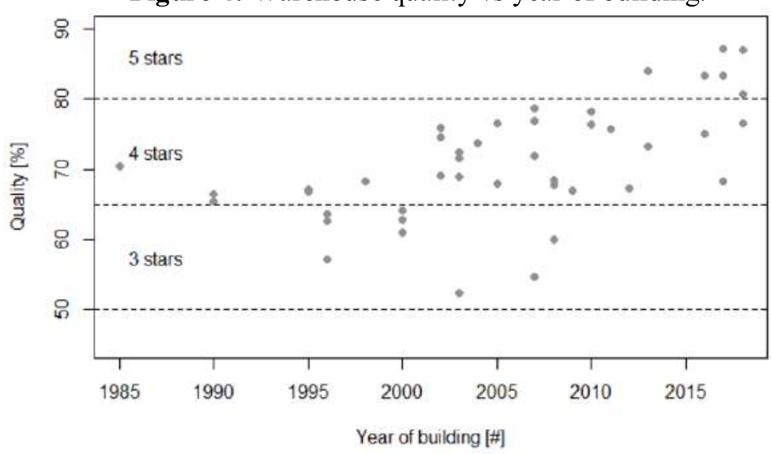
Looking at the size, 60% of the logistics buildings examined have a floor space lower than 20,000 m^2. The sample includes mostly small (less than a standard pattern of 5,000 m^2) or medium-sized warehouses, with an outlier having a size of approximately 140,000 m^2. These features are specific of the Italian context, since in other countries size, year of buildings and building clear height for LSP's facilities could give different results.

Figure 3: Sample characteristics: year of building, building clear height and size.



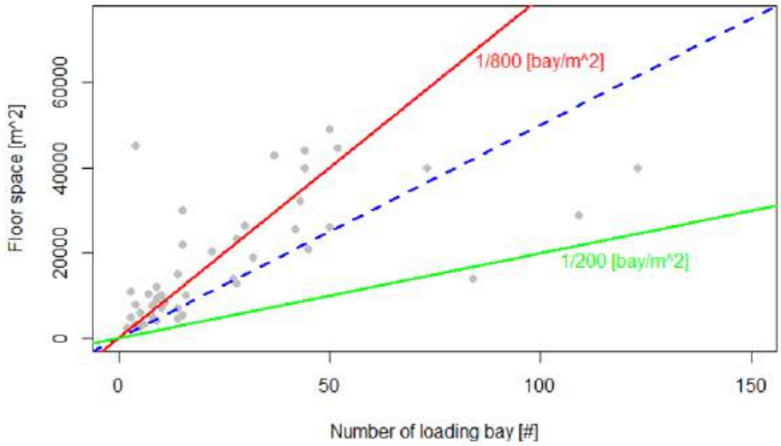
Year of building and quality rate are two variables related one another: it emerged that new warehouses have greater quality score. It is due to the use of innovative building techniques that are compliant with the new requirements of the logistics industry. Warehouses built after 2008 have a quality equal or over 4 stars (more than 65% of quality rate), while facilities built before 2000 have lower value of quality and belong mainly to the 3 stars class.

Figure 4: Warehouse quality vs year of building.



Looking at other variables such as the number of loading bays, it is possible to identify other relationships. Specifically, the relation between size (floor space) and the number of loading bay is one of the key elements used by logistics real estate actors to distinguish a stock warehouse from a cross-docking facility. The general rule inferred from data for stocking warehouse to design the loading bays follows this relation is to have one loading bay for more than 500 m^2 of floor space (blue dashed line). This rule is followed by the majority of the analysed warehouses. A ratio lower than 1/800 is for building completely dedicated to storage activities, such as document storage and management. Conversely, it emerges that logistics buildings with less than one loading bay for 200 m^2 floor space show the typical characteristics of a cross-docking facility.

Figure 5: Size (floor space) vs number of loading bays.



CONCLUSIONS

The objective of the present paper is to describe the state of art of the contract logistics warehousing in Italy by applying an original model developed by the authors and presented in Baglio et al. (2018) to assess logistics buildings quality and functionality. Specifically, the model is applied to 65 contract logistics warehouses located in Italy to determine the characteristics of these specific facilities.

The present work has both practical and academic implications. From an academic perspective, the model addresses an identified gap in the existing warehousing literature, which merely focuses on facility location and site selection problems, and sustainability topics. Moreover, the implementation of the model on contract logistics buildings gives new insights into contract logistics industry in Italy.

From a practical viewpoint, it offers significant implications for the real estate industry. Indeed, the proposed tool can be used by all the actor of real estate value chain to identify the right purpose of usage and, therefore, to better qualify the logistics building under-assessment. It may also be useful to improve quality of an existing logistics building, by identifying its weakest elements and evaluating the potential technical improvements. Ultimately, the model can be also used, as showed in the present work, to map warehouses in a specific industry or within specific geographical areas, with the aim of creating a database of logistics buildings classified by the level of functionality and quality. From this viewpoint, the availability of data for a large number of warehouses would also make it possible to update the distinguishing features of the logistics building types identified in the model, as well as the related weights and scores.

The implementation of the model presents some limitation, given by the characteristics of the database analysed and the model used. The database should be enrich increasing the number of observation in order to provide a complete analysis also on cross-docking and hybrid facilities, thus extending the insights on the contract logistics industry. Even this first version of the model presents some limitations highlighted by the findings of the present work. First, response items and weights have been essentially defined by referring to the Italian context. Therefore, a comparison between facilities in different countries/context to extend the knowledge in contract logistics warehousing requires some adjustments to the model. Second, functionality has been restricted to two types of logistics building only (i.e. stock warehouses and cross-docking facilities). No other differential characteristics, such as product categories, have been considered so far. Third, from a methodological perspective, a higher number of pilot tests should be recommended to improve the fine-tuning of the model.

However, this research offers interesting streams for future investigation. For instance: (1) enlarge the data on contract logistics industry in order to complete the analysis on cross-docking and hybrid facilities, (2) improve the model by including the tenants' perspective, e.g. by looking at the characteristics of the products to be stored in the logistics building in order to analyse the characteristics of warehouse in other industries; (2) extend the model to European context, assessing the difference between Italian and European logistics real estate industry.

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WAREHOUSE SUPPLY CHAIN MANAGEMENT IN HEALTHCARE

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Abstract *– In Turkey, pharmaceutical industry has an economic and strategic importance in healthcare since it provides and protects public health. Pharmaceutical industry with active production is an economic gain; not only it creates employment, value, investment and export opportunities but also has a strategic benefit in unusual situations like embargo, war, epidemic and pandemic diseases. Turkish pharmaceutical market grew by 16.5% in 2016 and sales reached 20.7 billion TL, with 7.6 % CAGR during 2011-2016. The real growth in the industry has been 5.5% CAGR in the past six years, reaching 2.23 billion of boxes by the end of 2016. Global pharma giants have been present in Turkey, engaging in both manufacturing and R&D. Also, direct and contract manufacturing by multinationals are developing which creates a competitive structure in healthcare industry of Turkey. For manufacturing pharmaceutical companies with aggressive sales targets, it is vital to synchronize with suppliers of raw materials from chemical industry. In this study, for a pharmaceutical company's warehouse, the future period sales forecasts are provided via analyzing previous sales data, which will be used in controlling inventory levels of warehouse and raw material supply chain management.*

Keywords – Forecasting, Healthcare, Inventory Management, Pharmaceutical Industry, Time-Series

INTRODUCTION

In today's challenging economic conditions, it is very difficult for companies to decide on issues such as production decision, human resource, capacity management, stock keeping decision, quota determination for the next term. In addition to economic difficulties, seasonal effects and competitive-based trend changes also make it difficult to forecast in the future. In such an environment, decision support systems gain importance in order to be able to make decisions in the future and to act in accordance with the competition conditions. Thanks to these systems, future estimations can be made with acceptable error rates and with these estimates, strategic decisions such as raw material purchasing, human resource management, and infrastructure investment decisions can be made.

In Turkey, pharmaceutical industry has an economic and strategic importance in healthcare since it provides and protects public health. Global pharma giants have been present in Turkey, engaging in both manufacturing and R&D. Also, direct and contract manufacturing by multinationals are developing which creates a competitive structure in healthcare industry of Turkey. For manufacturing pharmaceutical companies with aggressive sales targets, it is vital to synchronize with suppliers of raw materials from chemical industry. As a decision support system, time series analysis is widely used for pharmaceutical industry forecasting. In the last years, Kim et al. used interrupted time series to evaluate changes in patterns of single and combination therapy, brand name drug prescriptions, cost and hospital admission after the introduction of reimbursement restriction in diabetes in Korea (Kim et al., 2018). Larance et al. used interrupted time series analysis of opioid sales data and multiple routinely collected health dataset for the examination of the impact of a new opioid formulation in Australia (Larance et al., 2018). Naunton et al. used time series analysis to examine the trend of reported proton pump inhibitor appropriate use across the international studies (Naunton et al., 2018). He et al. used interrupted time series analysis with three segments divided by two intervention points to evaluate the impact of the pharmaceutical reform in China (He et al., 2018). Kheirandish et al. used interrupted time series to assess the effect of economic sanctions on drugs for diabetes, asthma, cancer and multiple sclerosis in Iran (Kheirandish et al., 2018). Serhiyenko et al. used multivariate count time series in their three-stage analysis to model temporal patterns in prescription counts with marketing data from a multinational pharmaceutical firm (Serhiyenko et al., 2018). Mazerolle et al. used a quasi-experimental time series approach for pharmaceutical sales of

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pseudoephedrine to assess the impact of electronic tracking systems on methamphetamine crime incidents (Mazerolle et al., 2017). Garcia-Molina et al. used interrupted time series to analyze the effectiveness of a computerized pharmaceutical intervention to reduce reconciliation errors at discharge in Spain (Saez et al., 2016).

Decision support systems need data and this data needs to be provided regularly to the decision support system. Reliability of this data is also important for the decision support system to produce accurate results. In this paper, pharmaceutical companies exposed to the mentioned difficulties will be examined and a decision support system will be established which is fed with accurate data. The correct data requirement arises from the fact that the data used in the current system is based on warehouse sales rather than pharmacy sales. In this application, future sales forecasts will be made taking into account pharmacy sales and administrative decisions such as raw material purchasing, personnel resource management / training, promotion activities, determination of future periods' quota targets can be taken in line with these estimations.

TIME SERIES ANALYSIS

Time series are sets of ordered observations taken at points in time (Montgomery & Runger, 2010). Time series analysis is a statistical model, which is generally used in forecasting. The initial point of forecasting is the analysis of available data and its graphical representation. General properties of time series as trends, seasonality etc. can be observed from their graphs. The graphical display of time series is called time series plot as shown in Figure 1.

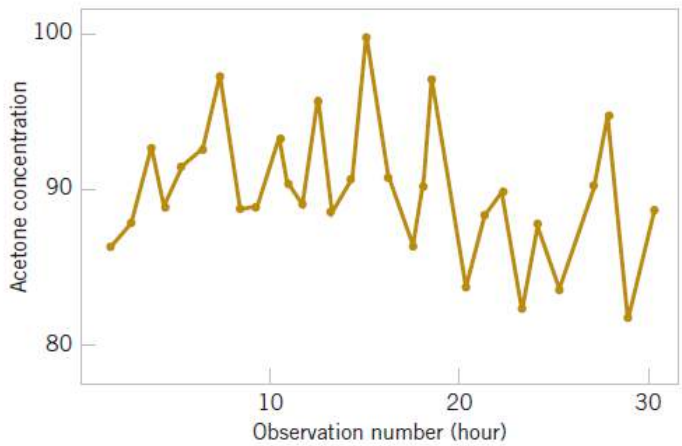

Figure 1. An example of time series plot (Montgomery & Runger, 2010)

Conventional measures of descriptive statistics are not very useful in time series because they do not consider the observations' order in time. Observations of a variable in different times, is under the influence of some fluctuations. They can be defined as components of the time series: trend (T), seasonal variations (S), cyclical variations (C) and irregular component/random variations (E) (Saraçoğlu, 1990).

Trend (T): General difference in the grade of the data in the long term. It can be linear, quadratic, exponential etc.

Seasonal Variations (S): These variations are standard wavelike vacillations of consistent length, repeating themselves inside a time of no longer than a year.

Cyclical Variations (C): These variations are wavelike movements, quasi-regular fluctuations around the long-term trend, lasting longer than a year.

Irregular Component (E): These are the deviations of the observed time series and can be interpreted as errors.

Moving averages can be used to isolate a trend and remove it from the original data, as could more sophisticated regression methods, these techniques might be appropriate when the trend is not a straight line over the history of the time series (Montgomery et al., 2015). Moving averages are a statistical approach applied to the time series to find the general trend of the series by removing time series from error rates, seasonal and cyclical influences. In the time series, a range is defined such that the starting point is the first value, including k observations. The average of the values specified in this range is calculated.

There are different models in time series. Additive model has the form:

$$Z_t = T_t + M_t + C_t + E_t \quad (1)$$

Multiplicative model has the form:

$$Z_t = T_t \times M_t \times C_t \times E_t \quad (2)$$

NUMERICAL APPLICATION IN PHARMACEUTICAL INDUSTRY OF TURKEY

Turkish pharmaceutical market grew by 16.5% in 2016 and sales reached 20.7 billion TL , with 7.6 % CAGR during 2011-2016. The real growth in the industry has been 5.5% CAGR in the past six years, reaching 2.23 billion of boxes by the end of 2016. This growth in the pharmaceutical industry is expected to accelerate the research effort and desire. The formation of qualified and talented staff within the industry will also revitalize the existing universities and other research potential institutions in the country and will allow the development of the country's industry parallel to the expectations of the future of the world.

In Turkey's pharmaceutical industry, there exist nearly 300 companies and 69 of them have 74 production facilities. 15 of the 56 companies with foreign capital produce in their own facilities. Today, the pharmaceutical companies work in compliance with World Health Organization rules in very few countries. Turkey's pharmaceutical industry reached the technological level to produce all kind of products apart from the products that require very special production technology (biotechnology etc.). As in other European countries, international norms and standards are applied in Turkey as well. Technology and quality standards are an essential and necessary precondition for internationalization and this has been fulfilled. In particular, the intensity of EU relations puts the conditions and rules of the pharmaceutical industry above expectations.

All 10 of the world's largest pharmaceutical manufacturers are selling to Turkey's market. Top 3 ranks Pfizer, Novartis and Sanofi also have manufacturing facilities in Turkey. In addition, Turkey is the regional headquarters for the production and / or sales of some international pharmaceutical companies. In Figure 2, 6 pharmaceutical companies, which are in ISO 500, are shown.

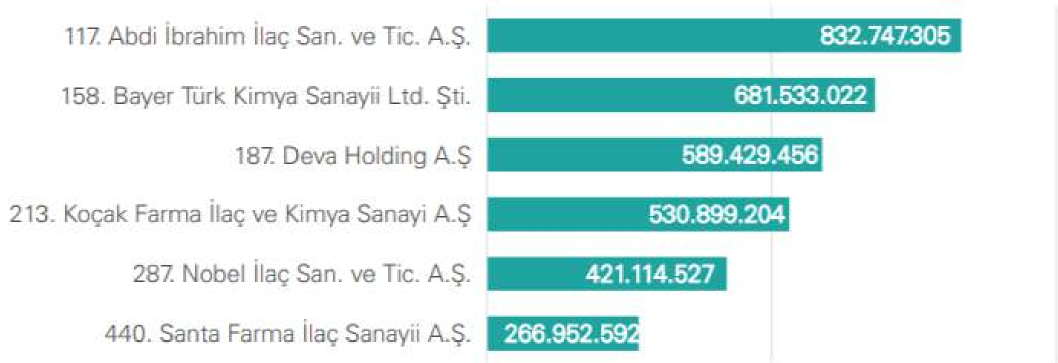

Figure 2. 6 Pharmaceutical companies in ISO 500 (KPMG, 2018)
https://assets.kpmg.com/content/dam/kpmg/tr/pdf/2018/01/sektorel-bakis-2018-ilac.pdf

While the production facilities in our country are routinely under the supervision of the Ministry of Health, the facilities of exporting companies are also inspected by international authorities. Most of the industry is concentrated in the Marmara and Trakya provinces, especially in Istanbul due to factors such as the more suitable infrastructure, closeness of the material and technical personnel, transportation and communication opportunities, and the concentration of health institutions in the Marmara Region.

As numerical application, a forecast will be calculated according to the sales data of the first two years of a drug group of one of these six companies. Sales forecasts for the year 2017 will be made using sales data for the years 2015 and 2016, and the performance will be observed using the actual sales for the year 2017.

In Table 1, pharmacy sales amounts (in boxes) of a drug group is given for the years 2015 and 2016, and the graph of 24 months is given in Figure 3.

Table 1. 2015 and 2016 pharmacy sales

Months	Pharmacy Sales	Months	Pharmacy Sales
1	2 426 962	13	2 124 254
2	2 071 698	14	2 011 172
3	2 441 832	15	2 438 893
4	2 326 770	16	2 286 259
5	2 484 371	17	2 896 581
6	2 429 552	18	2 323 549
7	2 055 064	19	2 230 356
8	2 085 603	20	2 089 925
9	2 768 921	21	2 655 596
10	2 013 153	22	2 039 292
11	2 301 996	23	2 702 520
12	2 618 492	24	2 225 855

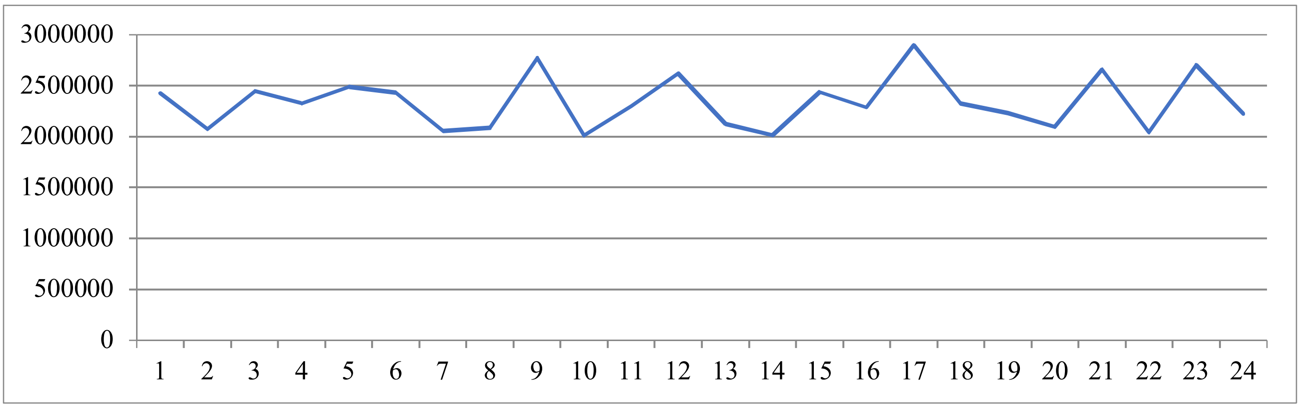

Figure 3. 24 months sales graph

The time series show releases as an additive model with 12-month period. In order to find the regression coefficients, 12-month moving averages are calculated. Y, Y^2, X, X^2 and XY values for the regression formula is shown in Table 2.

Table 2. 2015 and 2016 pharmacy sales

Y	X	X^2	Y^2	XY
2322755.00	7	49	5395190790025.00	16259285.00
2307620.25	8	64	5325111218210.06	18460962.00
2304975.88	9	81	5312913784332.02	20744782.88
2303165.46	10	100	5304571128459.79	23031654.58
2318652.92	11	121	5376151347966.84	25505182.08
2331411.54	12	144	5435479776616.54	27976938.50
2334298.58	13	169	5448949876152.01	30345881.58
2341782.50	14	196	5483945277306.25	32784955.00
2337240.71	15	225	5462694128690.50	35058610.63
2333607.96	16	256	5445726103196.67	37337727.33
2351385.58	17	289	5529014161507.84	39973554.92
2351714.21	18	324	5530559717676.88	42330855.75

Using linear regression formula, assuming $Y=b_0+b_1X$, the slope b_1 and the constant b_0 is calculated. Linear regression line is estimated as:

$$Y=2277714.23+4040.27.X \quad (3)$$

Using (3), the estimates of the first 24 months is calculated as shown in Table 3.

Table 3. 2015 and 2016 regression estimates

Months	Pharmacy Sales Estimates	Months	Pharmacy Sales Estimates
1	2 281 754.496	13	2 330 237.681
2	2 285 794.761	14	2 334 277.947
3	2 289 835.027	15	2 338 318.212
4	2 293 875.292	16	2 342 358.478
5	2 297 915.558	17	2 346 398.743
6	2 301 955.823	18	2 350 439.009
7	2 305 996.089	19	2 354 479.274
8	2 310 036.354	20	2 358 519.539
9	2 314 076.620	21	2 366 600.070
10	2 318 116.885	22	2 366 600.070
11	2 322 157.150	23	2 370 640.336
12	2 326 197.416	24	2 374 680.601

Deviations from real sales amounts are calculated and shown in Table 4.

Table 4. Deviations from real sales amounts

Months	Deviations	Months	Deviations
1	145207.504	13	-205983.6813
2	-214096.7615	14	-323105.9468
3	151996.9731	15	100574.7878
4	32894.70765	16	-56099.47766
5	186455.4422	17	550182.2569
6	127596.1768	18	-26890.00855
7	-250932.0887	19	-124123.274
8	-224433.3541	20	-268594.5394
9	454844.3804	21	288995.9297
10	-304963.885	22	-327308.0703
11	-20161.15045	23	331879.6642
12	292294.5841	24	-148825.6012

Average deviation of each month for 12 months are calculated and standardized as shown in Table 5.

Table 5. Deviations for months

Months	Average Deviation	Standardized
1	-30388.08868	-37363.279004
2	-268601.3541	-275576.544447
3	126285.8804	119310.690110
4	-11602.385	-18577.575333
5	368318.8496	361343.659224
6	50353.08411	43377.893782
7	-187527.6813	-194502.871661
8	-246513.9468	-253489.137104
9	371920.1551	364944.964731
10	-316135.9777	-323111.167990
11	155859.2569	148884.066567
12	71734.49145	64759.301124

Estimates of 2017 is calculated using (3) and adjusted with standardized deviations as shown in Table 6.

Table 6. 2017 Regression Estimates

Months	Estimates	Adjusted Estimates
25	2378720.87	2341357.59
26	2382761.13	2107184.59
27	2386801.40	2506112.09
28	2390841.66	2372264.09
29	2394881.93	2756225.59
30	2398922.19	2442300.09
31	2402962.46	2208459.59
32	2407002.72	2153513.59
33	2411042.99	2775987.95
34	2415083.26	2091972.09
35	2419123.52	2568007.59
36	2423163.79	2487923.09

To observe the forecast performance, comparisons are made between the estimates and the real sales amounts of the year 2017 as shown in Table 7.

Table 7. Real sales amounts of 2017 and forecast deviations

Months	2017 Sales Amounts	Absolut Difference	Absolut Percent Error
25	2 384 404	43046.4123	1.8053
26	1 967 981	139203.5876	7.0734
27	2 262 949	243163.0876	10.7454
28	2 745 975	373710.9124	13.6094
29	2 367 953	388272.5876	16.3969
30	2 282 521	159779.0876	7.0001
31	2 380 741	172281.4124	7.2364
32	2 291 435	137921.4124	6.0189
33	2 681 365	94622.95492	3.5289
34	2 334 422	242449.9124	10.3858
35	2 508 025	59982.5876	2.3916
36	2 571 692	83768.91236	3.2573

Mean absolute deviation (MAD) is calculated as 178 183.6. Tracking signal is calculated as 0.178. Mean average percent error (MAPE) is calculated as 7.45%.

CONCLUSIONS

Decision support systems can be designed to help decision-making by different units of business. In this paper, the aim was to obtain sales estimates for the next period in order to find answers to how inventory levels should be controlled in the pharmaceutical sector. The results obtained will not only be used for the marketing activities but also assist in taking decisions on production, human resources management and stock keeping. With the help of the forecasts, the future production quantity can be predicted and the production band can be used more effectively on this scale. Cost effective storage can be achieved in an efficient manner.

Time series with additive model is used in this application. The reason for this is that the time series shows a steady oscillation of the sales data according to the month. This release in the time series may be because of promotional activities, purchasing habits, quarter targets. Moving averages are applied on a monthly basis to minimize the error parameter before the addition method is applied. The reduction of the error parameter to a minimum has been effective in bringing the estimate closer to reality. Performance indicators reveal that this decision support system can be useful in pharmaceutical industry.

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DESIGN OF JOB ASSIGNMENT AND ROUTING POLICIES IN SERVICE LOGISTICS

Zehra Duzgit[1], Ayhan Ozgur Toy[2]

Abstract *– In this study, we consider to improve efficiency of an after-sales technical service in home appliances industry, through newly proposed job assignment and routing policies for technicians. The objective of this study is to minimize total working hours spent in a day in the after-sales service. A mixed integer programming model is proposed which assigns technicians to jobs and determines the routing for each technician so as to minimize total time (man-hour) spent in a day. The model takes the technician competencies and customer locations into account and gives job assignments, routes of jobs (in other words, customers' visiting sequence) for each technician, start and completion time of jobs, waiting time of technicians before starting a job and the jobs which are left for the next day. This model solves the problem in a static way at the beginning of each work day, based on the expected job durations according to past data. However, planned and actual job durations may be different. Therefore, a dynamic algorithm is developed which can be implemented based on the outputs of the mathematical model by considering realizations at the customers. During a day, in case of observing a difference between the actual and the predicted time of a job, the dynamic algorithm is applicable at the completion time of each job, to check whether to continue with the planned program or not. Due to the dynamic nature of the problem and deviations from the planned output, the dynamic algorithm may yield a different plan than the mathematical model and a new program may be constructed. The proposed solution methodology is validated through hypothetical case studies.*

Keywords – job assignment, job routing, mathematical modelling, mixed integer programming, dynamic programming algorithm

INTRODUCTION

We consider the problem of a company in durable consumer goods sector. The product range of the company includes white goods (refrigerator, washing machine, dishwasher, etc.), electronic devices (television, notebook etc.), heating and cooling systems (air conditioner, boiler etc.), small house appliances (iron, kitchenware etc.). The company also provides after-sales service through their authorized technical services (ATS). Each technician in those ATS's must be expert at least in one of the product segments to provide the related product service.

ATS mainly offers shipment of products from store to the house of customer, installation of products, giving information, repair (in case of failure of product), replacement (if repair is not possible). Also, they offer discovery to customers who want to learn if the physical conditions are available for the product before buy it. In addition to these services, they sell additional warranty. Providing a satisfactory after-sales service requires a well-planned business operation. A successful day in a technical service could be summarized as follows: assigning the right amount of jobs to right technicians, ensuring that the technicians are equipped correctly – right spare parts with the right amounts– following the most time-efficient route between technical service and customers, minimizing overtime and reducing the delays in completion of jobs.

There are three ways for customers to reach the technical service: *i*) calling call-center, *ii*) calling technical service directly, *iii*) visiting technical services' offices by themselves. If customer calls the call center, the representative first decides whether the request is help for failure or installation. If the request is for failure, before directly sending the customer to ATS, the representative tries to solve the problem by applying First Line

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Support (FLS) process. In this process, the representative asks some questions to customer and according to the answers, he/she tries to direct the customer to fix the problem. If the problem can be solved via FLS process, no other operation is required. Otherwise, the representative assigns the customer call to proper ATS, regarding product type and the customer's place of residence, creates a notification for ATS to call the customer. If the customer's request is installation, the representative directly assigns this customer call to proper ATS and creates a notification for ATS to call the customer. If the customer directly calls the ATS or the customer prefers to come to ATS, similar procedures are followed.

Before arriving to the customer, the technician calls the customer to make sure if they are available for visit. If the customer is available, he goes to that customer. If the service type is failure, the technician first diagnoses the failure. After then, he checks whether any spare part is needed or not. If there is a need, the technician checks if he has that spare part with him. If he has it, the technician repairs the machine and the failure receipt is closed. However, if the spare part is not on hand with the technician, the technician must check the availability of that spare part in ATS's inventory. If there is an inventory for that spare part in ATS, the technician directs the customer to ATS to schedule a new appointment, to come back with the necessary spare part. If there is no inventory for the spare part needed, the technician informs the responsible of ATS who gives orders for spare parts and then, the technician directs the customer to ATS to schedule a new appointment. If the technician is not able to fix the problem, the machine is sent to the workshop. If the service type is installation, they start installation process as soon as they arrive the customer's house.

Sometimes the customers might not be available, or they might forget their appointment. In this situation, technician checks the requested time interval by customer for the day according to his availability. If he is available, he includes that job again into the shift, reroute the jobs again and calls the next customer to check his/her availability. If the schedule pf the technician is not available, he directs the customer to ATS's call center for a new appointment. At the end of the day, technicians come back to the ATS and give reports about completed and not completed jobs.

To observe the daily working policy of ATS's, a pilot ATS is selected and visited. The processes such as appointment system and routing policy, competencies, spare part stock management operations and authorized service organization structure were observed in detail. After observations at ATS visits, a fishbone diagram (Figure 1) is constructed to represent the subproblems leading to the main problem: the delays in completion of jobs, which is the motivation for this study.

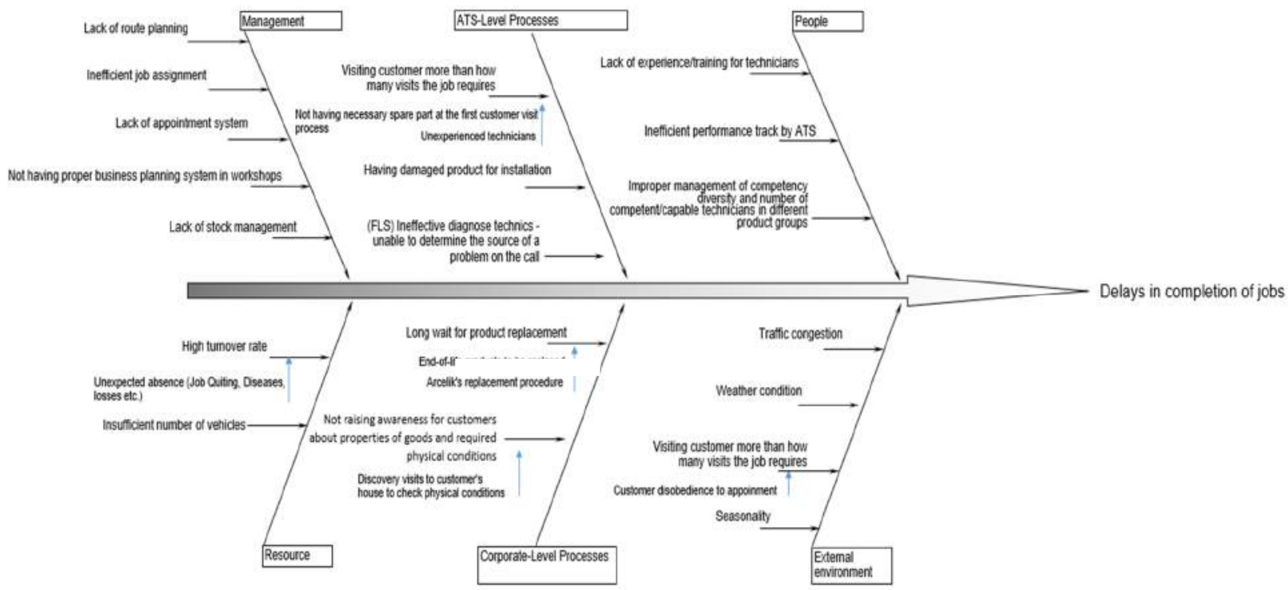

Figure 1. Fishbone diagram for investigation of reasons of delays in completion of jobs

As mentioned in the fishbone diagram, delays in completion of jobs have 6 different subcategories:

1) Management perspective:

- *Lack of route planning:* There is no proper routing management and it is up to the technician's himself to decide the order of customer visits.
- *Inefficient job assignment:* Job assignments are just done based on sub-regions assigned to the technicians and their competencies. Their capacities and experiences are not considered while assigning jobs and there is not a systematic method to find out the optimal number of job assignments for each technician.
- *Lack of appointment system:* ATS's tend to make an appointment for their customer based on customer requests. Although the company wants appointments to be scheduled based on 2-hour time intervals, generally the appointments are planned as before afternoon and after afternoon. This situation decreases the probability of catching the customer at the house which may cause delays in completion of jobs.
- *Not having proper business planning system in workshops:* ATS has just one workshop and products that are not suitable to be repaired at customer's house, are taken to the workshop to get repaired. Sometimes workshops may be overloaded because of seasonality, disorganization of the workshop, lack of employee etc.
- *Lack of stock management:* Although there is a huge amount of spare parts in stock, the greater portion of their stocks contains spare parts for old products. When they need a spare part, they usually order it from the company and it takes 1-2 days to be delivered.

2) ATS level processes:

- *Visiting customer more than how many visits the job requires:* Because of not having necessary spare part at the first customer visit, technicians may have to visit the same customer again after getting needed spare part. Also, technicians may bring wrong spare parts with them. Not enough experienced technicians may also work slowly and may not diagnose the product's break accurately.
- *Having damaged product for installation:* Technicians do not pay much attention for checking whether the new product is damaged or not. When the product is damaged and unable for installation, another visit is required with another new product.
- *(First Line Support) Ineffective diagnose technics:* Call centers in ATSs are sometimes unable to diagnose the problem on the call. Sometimes, customers also cannot explain the problem accurately.

3) People:

- *Lack of experience/training for technicians:* Experience of technician affects the duration of solving the problem at the first customer visit. Sometimes, technicians cannot solve the problem due to the lack of experience and take the products to the workshop.
- *Inefficient performance track by ATS:* To evaluate technicians, there is only one system where the customer evaluates the technician between 0-9 points.
- *Improper management of competency diversity and number of competent/capable technicians in different product groups:* Since the demand fluctuates based on product group and seasonality, this may have a negative effect on assigned jobs for technicians and may cause delays in completion of jobs.

4) Resource:

- *High turnover rate:* Some experienced technicians quit the job to run their own businesses. ATS needs to hire new technicians with less experience and lack of technician experience can cause longer time to solve the problem.
- *Insufficient number of vehicles:* Due to the cases of car accidents or breakdowns, jobs may be delayed. Also, especially for installations, because the vehicle capacity is limited for a number of products. This situation leads to rescheduling of jobs.

5) Corporate-level processes:

- *Long wait for product replacement:* For the end-of-life products, it may take long time to find a similar product instead of the product that will be replaced. The replacement procedure takes too long time since the replacement decision requires some approvals.
- *Not raising awareness for customers about properties of goods and required physical conditions:* Some products require discovery visits due to their dimensions and specifications. But generally, the store does not

offer discovery survey before installation and if the product is not suitable for installation, the second visit is planned again.

6) External environment:

- *Traffic congestion:* Traffic conditions especially rush hours throughout the day affect the customer visit hour for the day and if the customer is not available for that time, the job may be rescheduled for another day.
- *Weather condition:* Weather (especially snow) and extreme events (floods) caused by weather conditions may affect the planned visiting hour and if the customer is not available for that time, the job may be rescheduled for another day.
- *Customer disobedience to appointment:* When the customer is not available at the planned visiting hour, the job may be rescheduled for another day.
- *Seasonality:* Due to the seasonality, the assigned jobs per team per day may increase and this situation lead to delays in jobs. For instance, a campaign that offers taking back the old product and giving a brand-new product with a discount or buying refrigerator and deep-freezer more around Feast of Sacrifice, may be examples of seasonality.

In this study, we focus on “management perspective” and “people”.

PROBLEM DEFINITION

Based on observations during ATS field visits, it is seen that the customer representatives in authorized technical services do not take the location of the customer into consideration when he/she assigns the jobs to technicians. Representatives reach out technicians to assign an additional job with no consideration of their current locations, but only based on their competencies. Technicians have the initiative to choose whether to accept an additional new arriving job within a day or not. Although the representatives are responsible for assigning jobs and giving an appointment to the customer, the technicians sometimes take the charge of representatives’ work by communicating with the customer, who was visited before, by themselves. The routing plan of the daily jobs are not set systematically but it is done by technicians without taking into consideration of distance, the details of jobs such as duration of jobs, the required tool for those jobs etc. All these findings cause delays in completion of jobs and decreases the number of jobs completed in a day.

According to all those observations, the objective of our study is to minimize the total working hour spent in a day while covering all the jobs assigned through a mathematical model which creates optimal route plan for each technician and optimal job assignment which is consistent with the appointment time of the customer, technicians’ competencies, customer location, job durations and appointed time intervals.

LITERATURE REVIEW

Following the problem definition, we find studies in literature within our frame of problem definition. Technician routing and scheduling problem is a variant of the well-known vehicle routing problem with time windows. A study is conducted by Kovacs et al. (2011). The study is motivated by the problem faced by maintenance or infrastructure providers. The maintenance providers usually try to accomplish a given number of jobs requiring a particular set of competencies in a working day. The resources through which they finalize the jobs are a given number of technicians having different kind of competencies. One of the obstacles to get over in such a problem is that the jobs to be serviced are located in different addresses. Another is that each job has a time window at which the job could be intervened only. The objective of their study is to minimize the sum of total technician routing and outsourcing cost with the help of adaptive large neighborhood search algorithm.

Binart et al. (2016) determine service routes with a 2-stage approach, which are planning and execution stage, to serve mandatory and optional customers under stochastic travel and service times. Mathlouti et al. (2018) study technician routing and scheduling problem with multiple time windows, a spare part inventory for each technician and solve by tabu search and adaptive memory methodology. Cordeau et al. (2010) study the technician and task scheduling problem by considering outsourcing and precedence constraints. A two-phase constructive heuristic is proposed where teams are constructed in the first phase and tasks are assigned in the second phase. Additionally, an adaptive large neighborhood search heuristic is proposed for the same problem. Chen et al. (2016) examine and propose a model for the technician routing and scheduling problem subject to workforce heterogeneity and experience-based learning of technicians, to minimize the makespan in a day. The duration of a service time depends on the technician's experience.

Damm et al. (2016) propose constructive heuristics and a genetic algorithm-based meta-heuristic for the field technician scheduling problem to maximize the total priority value of daily service tasks. An experimental study is conducted to evaluate the performance of the proposed solutions. Chen at al. (2017) consider service technician and task scheduling problem with experimental learning and stochastic tasks. An approximate dynamic programming algorithm is developed to minimize the sum of expected daily service durations for a multi-period planning horizon.

Mathlouthi et al. (2018) construct a mixed integer linear programming model for the technician routing and scheduling problem to maximize the difference between total gains based on served customers and the operating costs, by considering availability of spare and special parts, time windows and postponement of tasks. The model is solved for small size instances. Paraskevopoulos et al. (2017) introduce a taxonomy regarding renewable resource-constrained routing and scheduling, including technicians' problems. Pillac et al. (2013) propose a matheuristic to solve technician routing and scheduling problem. The proposed approach is composed of three components: a constructive heuristic, a parallel adaptive large neighborhood search, a post-optimization mechanism. Xu and Chiu (2001) analyze field technician scheduling problem for telecommunication sector and propose a greedy heuristic, a local search algorithm, and a greedy randomized adaptive search procedure to solve the problem. All these studies are beneficial in terms of technician routing, time windows and related issues.

MATHEMATICAL MODEL

We propose a mathematical model to solve the aforementioned problem. We consider a particular ATS to demonstrate the proposed solution methodology. There are 13 technicians in that ATS. The assumptions, sets, parameters, decision variables and the model are presented below:

Assumptions:

1. ATS1 is considered as the initial node for each technician in a day and accepted as the first job.
2. ATS2 is considered as the final node for each technician in a day and accepted as the last job.
3. Since ATS1 and ATS2 are physically the same places, the distance between them is 0.
4. Hypothetically, if a technician is not assigned to any job in a day, he will start the day at ATS1, cover the virtual route from ATS1 to ATS2 and finish the day at ATS2.
5. Jobs arriving during the day are not taken into consideration.
6. There is no time planned for lunch break.
7. A regular working day is planned to be 10 hours (600 minutes), but overtime is allowed.
8. A job requires only one competency.

Sets:

Set for jobs

$I = \{ATS1, 1, 2, \dots, m, ATS2\},\ i \in I$

Set for technicians

$J = \{1, 2, 3, \dots, n\},\ j \in J$

Set for jobs (identical with *I*)

$K = \{ATS1, 1, 2, \dots, m, ATS2\},\ k \in K$

Set for competencies

$Y = \{1, 2, 3, \dots, l\},\ y \in Y$

Subsets:

$I' = \{ATS1, 1, \dots, m\}$

$I'' = \{1, \dots, m, ATS2\}$

$I_{\prime}'' = \{1, \dots, m\}$

$K' = \{ATS1, 1, \dots, m\}$

$K'' = \{1, \dots, m, ATS2\}$

$K_{\prime}'' = \{1, \dots, m\}$

Parameters:

$H_{i,y} = \begin{cases} 1, & if\ job\ i\ requires\ competency\ y \\ 0, & otherwise \end{cases}$

$C_{j,y} = \begin{cases} 1, & if\ technician\ j\ has\ competency\ y \\ 0, & otherwise \end{cases}$

$D_i = The\ duration\ for\ completing\ job\ i$ (in minutes)

$T_{i,k} = The\ travelling\ time\ from\ job\ i\ to\ job\ k$ (in minutes)

$S = The\ regular\ working\ hours\ in\ a\ day$ (=600 minutes)

$E_i = The\ earliest\ time\ at\ which\ job\ i\ could\ be\ started$

$L_i = The\ latest\ time\ at\ which\ job\ i\ could\ be\ started$ (=E_i + 120 minutes)

$p = Penalty\ coefficient$ (Since the overtime working is allowed but not wanted, we define a penalty coefficient for overtime working as p)

$w = Afterday\ coefficient$ (Also, the jobs which are not completed in a day reveal an unwanted situation and this situation requires a penalty, too and here we define that penalty coefficient as w)

$H_{i,y}$ is a binary matrix which denotes *Job – Competency Requirement.* Jobs are stated in rows and required competencies are stated in columns. Whenever a job arrives, the required competency is known in advance. A sample matrix is shown in Table 2.

Table 2. Job - Competency Requirement

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
J1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
J3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
J4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
J6	0	0	0	0	0	0	0	0	1	0	0	0	0	0
J7	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J9	0	0	0	1	0	0	0	0	0	0	0	0	0	0
J10	1	0	0	0	0	0	0	0	0	0	0	0	0	0

$C_{j,y}$ is a binary matrix which shows *Technician – Competency.* We have different technicians in rows (*j*=T1, T2, …, T13) and different competencies (*y*=A, B, …, N) in columns. For instance, A represents the capability to install a dishwasher whereas H represents the ability to repair a refrigerator. A technician may have more than one competency. For each possessed competency, we assign 1 for the corresponding entry, as shown in Table 3.

Table 3. Technician – Competency

	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**	**J**	**K**	**L**	**M**	**N**
T1	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T2	0	0	0	1	0	0	1	0	0	0	0	0	1	0
T3	0	0	0	0	0	0	0	0	0	1	0	0	0	0
T4	0	0	0	0	0	1	0	0	0	1	0	0	0	0
T5	1	1	1	1	1	0	1	0	0	0	0	0	0	0
T6	0	0	0	0	0	0	0	0	0	0	1	1	0	1
T7	1	1	1	1	1	1	0	0	0	0	0	0	0	0
T8	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T9	0	0	0	0	0	0	1	0	0	0	1	1	0	1
T10	1	1	1	1	1	0	1	0	0	0	0	0	0	0
T11	0	0	0	0	0	1	0	0	0	0	0	0	0	0
T12	0	0	0	0	0	0	1	0	0	0	0	0	0	0
T13	0	0	0	0	0	0	0	1	0	0	0	0	0	0

Decision Variables:

$X_{i,j} = \begin{cases} 1, & if\ technician\ j\ is\ assigned\ to\ job\ i \\ 0, & otherwise \end{cases}$

$B_{i,k,j} = \begin{cases} 1, & if\ technician\ j\ covers\ the\ route\ from\ node\ i\ to\ node\ k \\ 0, & otherwise \end{cases}$

$V_j = The\ amount\ of\ overtime\ that\ technician\ j\ works$

$F_{i,j} = The\ starting\ time\ of\ job\ i\ by\ technician\ j$

$R_i = \begin{cases} 1, & if\ job\ i\ is\ left\ to\ the\ following\ day \\ 0, & otherwise \end{cases}$

$N_{i,j} = The\ finishing\ time\ of\ job\ i\ by\ technician\ j$

$WT_{i,k,j} = The\ waiting\ time\ between\ job\ i\ and\ job\ k\ by\ technician\ j$

The Model:

$$\min z = \sum_{j=1}^{n} \sum_{i=ATS1}^{m} \sum_{k=1}^{ATS2} B_{i,k,j} T_{i,k} + \sum_{j=1}^{n} \sum_{i=ATS1}^{ATS2} D_i X_{i,j} + \sum_{i=ATS1}^{ATS2} \sum_{k=ATS1}^{ATS2} \sum_{j=1}^{n} WT_{i,k,j} + \sum_{j=1}^{n} V_j p + \sum_{i=1}^{m} R_i w \quad (1)$$

subject to;

Assignment constraints:

$\sum_{i=ATS1}^{ATS2} X_{i,j} \geq 2; \quad \forall j$ (2)

$X_{i,j} - \sum_{y=1}^{l} C_{j,y} H_{i,y} \leq 0; \quad \forall j, \forall i \in I,''$ (3)

$\sum_{j=1}^{n} X_{i,j} + R_i = 1; \quad \forall i \in I,''$ (4)

$X_{ATS1,j} = 1; \quad \forall j$ (5)

$X_{ATS2,j} = 1; \quad \forall j$ (6)

Routing constraints:

$\sum_{k=1}^{ATS2} B_{ATS1,k,j} = 1; \quad \forall j$ (7)

$\sum_{i=1}^{ATS2} B_{i,ATS1,j} = 0; \quad \forall j$ (8)

$\sum_{i=ATS1}^{m} B_{i,ATS2,j} = 1; \quad \forall j$ (9)

$\sum_{k=ATS1}^{m} B_{ATS2,k,j} = 0; \quad \forall j$ (10)

$\sum_{i=ATS1}^{m} B_{i,k,j} - \sum_{i=1}^{ATS2} B_{k,i,j} = 0; \quad \forall j, \forall k \in K,'' \quad (i \neq k)$ (11)

Assignment-Routing constraints:

$\sum_{i=1}^{ATS2} B_{k,i,j} - X_{k,j} = 0; \quad \forall j, \forall k \in K,'' \quad (i \neq k)$ (12)

$B_{k,i,j} + B_{i,k,j} \leq 1; \quad \forall j, \forall i \in I', \forall k \in K''$ (13)

$\sum_{i=ATS1}^{m} B_{i,k,j} - X_{k,j} = 0; \quad \forall j, \forall k \in K,'' \quad (i \neq k)$ (14)

$X_{i,j} + B_{ATS1,ATS2,j} \leq 1; \quad \forall j, \forall i \in I,''$ (15)

Overtime constraints:

$V_j - N_{ATS2,j} + S \geq 0; \quad \forall j$ (16)

Appointment constraints:

$F_{i,j} - E_i X_{i,j} \geq 0; \quad \forall j, \forall i \in I,''$ (17)

$F_{i,j} - L_i X_{i,j} \leq 0; \quad \forall j, \forall i \in I,''$ (18)

$F_{ATS1,j} = 0; \quad \forall j$ (19)

Arriving-Leaving-Waiting constraints:

$F_{i,j} + D_i X_{i,j} + T_{i,k} - M(1 - B_{i,k,j}) - F_{k,j} \leq 0; \quad \forall i, \forall k, \forall j$ (20)

$N_{i,j} - F_{i,j} - D_i X_{i,j} = 0; \quad \forall j, \forall i$ (21)

$F_{k,j} - N_{i,j} - B_{i,k,j} T_{i,k} - M(1 - B_{i,k,j}) - WT_{i,k,j} \leq 0; \quad \forall i, \forall k, \forall j \quad (i \neq k)$ (22)

Sign restrictions:

$V_j \geq 0 \quad \forall j$ (23)

$F_{i,j}, N_{i,j} \geq 0 \quad \forall i, \forall j$ (24)

$WT_{i,k,j} \geq 0 \quad \forall i, \forall k, \forall j$ (25)

$R_i \in \{0,1\} \quad \forall i$ (26)

$X_{i,j} \in \{0,1\} \quad \forall i, \forall j$ (27)

$B_{i,k,j} \in \{0,1\} \quad \forall i, \forall k, \forall j$ (28)

By the way of objective function (1), we want to minimize total time spent in a day and the penalties due to overtime working and assigning jobs after that day. Since overtime working and planning jobs for the other day are not desired situations, the model will force to minimize them while minimizing the total time spent for the completed jobs in a day. Total time spent by completed jobs includes three components: transportation time, job duration time and waiting time for technicians (due to appointment windows).

Technicians must be assigned to jobs. While constraint (2) assigns at least 2 jobs to each technician, constraint (5) and constraint (6) ensure that those 2 jobs are ATS1 and ATS2. Based on constraints (5) and (6), ATS1 and ATS2 are both assigned to each technician, because technicians need to start their daily job schedules at ATS1 and finish it at ATS2. Constraint (3) checks if technician j has necessary competency y to be assigned to job i. By the help of constraint (4), we satisfy the condition that a job i must be assigned only one of the technician j's in daily schedule or the job i is left for the following day.

In terms of routing, we need to satisfy that ATS1 is the starting point (job) for each technician and ATS2 is the ending point (job) for each technician. Constraint (7) ensures that each technician j starts from ATS1 before visiting a node (customer), and constraint (8) bans visiting ATS1 after a node (customer) visit. Similarly, constraint (9) guarantees that each technician j must visit a customer before he visits ATS2 while constraint (10) bans a visit to a customer for each technician j after technician visits ATS2. We have a flow balance equation, that is constraint (11) by which we make sure that a technician j who visits the route between node i to node k must visit any other route from that node k to any other node, except node i.

There must be constraints by which route between node i to node k ($B_{i,k,j}$) are linked to job assignment ($X_{i,j}$). Therefore, we introduce constraints (12) and (13) where (12) assigns technician j to job k if technician j is assigned to the route from node k to node i. Likewise, constraint (14) assigns technician j to job k if technician j is assigned to the route from node i to node k. Constraint (13) serves the purpose of eliminating backward movement of each technician. Namely, if technician j visits the route from node i to node k, technician j cannot visit the route from node k to node i. Constraint (15) ensures that if there is a technician j assigned for a job i, that technician j cannot be assigned to the route from ATS1 to ATS2 directly.

We want to minimize overtime hours in a day, by introducing constraints (16) and (23). Through these constraints, it is ensured that overtime related decision variable (V_j) is set to be 0 for a technician j if the total time the technician j spends in a day is less than or equal to the daily regular working time, else (V_j) gets the value by subtracting the daily regular working time from the total time the technician j spends in a day.

Constraints (17) and (18) are the constraints by which we use time windows for appointments. While constraint (17) ensures that earliest starting time of a job i by a technician j is satisfied, constraint (18) ensures that the job i's latest time to start by a technician j is satisfied. We set decision variable ($F_{i,j}$) to 0 for ($i = ATS1$) via constraint (19) since each technician must start his job in ATS1 at time zero.

Constraint (20) sets up the relation between starting time of job i and job k as the following job as follows: if a technician j is assigned to job i and job k as the next job, then starting time of job k is calculated by adding up starting time of job i, the time spent at job i and the travelling time between job i and job k. Constraint (21) defines the finishing time of job i assigned to technician j by adding up the duration of job i to starting time of job i. Waiting time for a technician j before he starts job k is calculated by summing up the finishing time of previous job i and the travelling time between job i and job k and subtracting the value from starting time of the job k if waiting time occurs by constraint (22). The remaining constraints are sign restrictions.

EXPERIMENTAL STUDY

We aim to design various business scenarios by changing the inputs for the model to monitor how the output changes in relation with reorganization of inputs. Reorganizing inputs and running the model for different business scenarios leads a decision maker to reallocate their resources and to make managerial decisions. These managerial decisions can be listed such that number of technicians to be employed, the competency training for the technicians, and the extent of time interval to serve the customers. We initially observe the changes in objective function value caused by the scenarios below:

1. ATS having 3 technicians with random competency match experiences 20 jobs with random competency requirements with 120-minute time slots given to serve the customer. The starting time for service is decided randomly by customers.
2. ATS having 3 technicians with random competency match experiences 20 jobs with random competency requirements with 240-minute time slots given to serve the customer. The starting time for service is decided randomly by customers.

3. ATS having 3 technicians with full competency match experiences 20 jobs with random competency requirements with 120-minute time slots given to serve the customer. The starting time for service is decided randomly by customers. Full competency match means that each of 3 technicians is educated for all competencies.

4. ATS having 3 technicians with full competency match experiences 20 jobs with random competency requirements with 120-minute time slots given to serve the customer. The starting time for service is decided randomly by customers. Full competency match means that each of 3 technicians is educated for all competencies.

The inputs are summarized in Table 3. The results for the relevant business scenarios listed above are presented in Table 4.

Table 4. Input Tables for Scenario Analysis

D(i)	
ATS1	60
J1	18
J2	18
J3	15
J4	19
J5	39
J6	24
J7	17
J8	12
J9	11
J10	13
J11	11
J12	17
J13	12
J14	18
J15	15
J16	17
J17	19
J18	13
J19	19
J20	16
ATS2	30

C(j,y)														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
T1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
T2	1	1	1	1	1	1	1	1	1	1	1	1	1	1
T3	1	1	1	1	1	1	1	1	1	1	1	1	1	1

H(i,y)														
	A	B	C	D	E	F	G	H	I	J	K	L	M	N
J1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J2	0	0	0	1	0	0	0	0	0	0	0	0	0	0
J3	0	0	1	0	0	0	0	0	0	0	0	0	0	0
J4	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J5	0	0	0	0	0	0	0	1	0	0	0	0	0	0
J6	0	0	0	0	0	0	0	0	1	0	0	0	0	0
J7	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J8	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J9	0	0	0	1	0	0	0	0	0	0	0	0	0	0
J10	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J11	0	0	1	0	0	0	0	0	0	0	0	0	0	0
J12	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J13	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J14	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J15	0	1	0	0	0	0	0	0	0	0	0	0	0	0
J16	0	0	1	0	0	0	0	0	0	0	0	0	0	0
J17	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J18	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J19	1	0	0	0	0	0	0	0	0	0	0	0	0	0
J20	1	0	0	0	0	0	0	0	0	0	0	0	0	0

E(i)	
J1	60
J2	120
J3	180
J4	120
J5	240
J6	560
J7	360
J8	420
J9	120
J10	240
J11	180
J12	120
J13	60
J14	240
J15	180
J16	300
J17	60
J18	420
J19	360
J20	300

L(i)	
J1	180
J2	240
J3	300
J4	240
J5	360
J6	680
J7	480
J8	540
J9	240
J10	360
J11	300
J12	240
J13	180
J14	360
J15	300
J16	420
J17	180
J18	540
J19	480
J20	420

T(i,k)																						
	ATS1	J1	J2	J3	J4	J5	J6	J7	J8	J9	J10	J11	J12	J13	J14	J15	J16	J17	J18	J19	J20	ATS2
ATS1	0.0	4.7	3.5	3.0	5.0	4.6	1.3	0.4	3.9	4.5	1.5	3.2	3.6	4.8	5.4	1.4	4.0	0.9	0.1	3.2	1.5	0.0
J1	4.7	0.0	**2.2**	**1.8**	**2.9**	**1.1**	**3.8**	**5.0**	**2.8**	**0.2**	**5.5**	**3.3**	1.4	0.9	2.8	3.4	3.6	5.0	4.7	1.6	3.3	4.7
J2	3.5	2.2	**0.0**	**1.3**	**1.6**	1.4	2.3	3.7	0.8	2.0	3.8	1.1	2.3	1.7	1.9	2.1	1.5	3.4	3.5	2.1	2.7	3.5
J3	3.0	1.8	**1.3**	0.0	**2.8**	1.7	2.1	3.3	2.0	1.5	3.7	2.0	1.2	1.8	2.9	**1.7**	2.7	3.2	3.0	0.9	1.7	3.0
J4	5.0	2.9	1.6	2.8	0.0	1.8	3.7	5.2	1.2	2.9	5.0	1.9	3.6	2.1	0.5	**3.7**	1.4	4.8	5.0	3.5	4.3	5.0
J5	4.6	1.1	1.4	1.7	1.8	0.0	3.5	4.9	1.9	1.1	5.1	2.5	2.0	0.3	1.7	**3.2**	2.6	4.7	4.6	2.1	3.4	4.6
J6	1.3	3.8	2.3	2.1	3.7	3.5	0.0	1.5	2.6	3.6	1.7	1.9	3.0	3.7	4.1	**0.5**	2.7	1.2	1.3	2.6	1.5	1.3
J7	0.4	5.0	3.7	3.3	5.2	4.9	1.5	0.0	4.0	4.8	1.2	3.3	3.9	5.0	5.5	**1.6**	4.1	0.7	0.3	3.6	1.9	0.4
J8	3.9	2.8	0.8	2.0	1.2	1.9	2.6	4.0	0.0	2.7	3.9	0.8	3.0	2.2	1.5	**2.6**	0.8	3.6	3.9	2.9	3.3	3.9
J9	4.5	0.2	2.0	1.5	2.9	1.1	3.6	4.8	2.7	0.0	5.3	3.1	1.2	0.9	2.7	**3.2**	3.4	4.7	4.5	1.4	3.0	4.5
J10	1.5	5.5	3.8	3.7	5.0	5.1	1.7	1.2	3.9	5.3	0.0	3.1	4.6	5.4	5.4	**2.1**	3.7	0.6	1.4	4.3	2.8	1.5
J11	3.2	3.3	1.1	2.0	1.9	2.5	1.9	3.3	0.8	3.1	3.1	0.0	3.1	2.7	2.4	**2.0**	0.9	2.9	3.2	2.9	2.8	3.2
J12	3.6	1.4	2.3	1.2	3.6	2.0	3.0	3.9	3.0	1.2	4.6	3.1	0.0	2.0	3.6	**2.5**	3.8	4.0	3.6	0.4	2.0	3.6
J13	4.8	0.9	1.7	1.8	2.1	0.3	3.7	5.0	2.2	0.9	5.4	2.7	2.0	0.0	1.9	**3.4**	2.9	4.9	4.8	2.1	3.5	4.8
J14	5.4	2.8	1.9	2.9	0.5	1.7	4.1	5.5	1.5	2.7	5.4	2.4	3.6	1.9	0.0	**4.0**	1.9	5.2	5.4	3.6	4.5	5.4
J15	1.4	3.4	2.1	1.7	3.7	3.2	0.5	1.6	2.6	3.2	2.1	2.0	2.5	3.4	4.0	0.0	2.8	1.6	1.4	2.2	1.0	1.4
J16	4.0	3.6	1.5	2.7	1.4	2.6	2.7	4.1	0.8	3.4	3.7	0.9	3.8	2.9	1.9	2.8	0.0	3.6	4.0	3.6	3.7	4.0
J17	0.9	5.0	3.4	3.2	4.8	4.7	1.2	0.7	3.6	4.7	0.6	2.9	4.0	4.9	5.2	1.6	3.6	0.0	0.8	3.7	2.2	0.9
J18	0.1	4.7	3.5	3.0	5.0	4.6	1.3	0.3	3.9	4.5	1.4	3.2	3.6	4.8	5.4	1.4	4.0	0.8	0.0	3.3	1.6	0.1
J19	3.2	1.6	2.1	0.9	3.5	2.1	2.6	3.6	2.9	1.4	4.3	2.9	0.4	2.1	3.6	2.2	3.6	3.7	3.3	0.0	1.7	3.2
J20	1.5	3.3	2.7	1.7	4.3	3.4	1.5	1.9	3.3	3.0	2.8	2.8	2.0	3.5	4.5	1.0	3.7	2.2	1.6	1.7	0.0	1.5
ATS2	0.0	4.7	3.5	3.0	5.0	4.6	1.3	0.4	3.9	4.5	1.5	3.2	3.6	4.8	5.4	1.4	4.0	0.9	0.1	3.2	1.5	0.0

Table 4. Outputs of Scenarios

Scenario	Parameters	Output	Value			Total
	# of daily jobs:20,		T1	T2	T3	
	Technicians have each	Number of Jobs Completed by Technician	0	0	20	**20**
	competency, Customers	Number of Jobs Planned the Day After		0		**0**
	have 120 minutes of	Time Spent by Technician	90	90	600	**780**
S1	appointment interval,	Overtime of Technician	0	0	15	**15**
	each technician works	Total Waiting Time of Technician	0	0	145	**145**
	for 600 minutes,	Objective Function		1102		**1102**
	Overtime is allowed.	Total Completion Time of Jobs (Total Spent Man-Hour)		795		**795**
	# of daily jobs:20,		T1	T2	T3	
	Technicians have limited	Number of Jobs Completed by Technician	10	5	5	**20**
	competency, Customers	Number of Jobs Planned the Day After		0		**0**
	have 120 minutes of	Time Spent from Available Work Time by Technician	600	351	407	**1358**
S2	appointment interval,	Total Waiting Time of Technician	335	145	217	**698**
	each technician works	Overtime of Technician	15	0	0	**15**
	for 600 minutes,	Objective Function		1680		**1680**
	Overtime is allowed.	Total Completion Time of Jobs (Total Spent Man-Hour)		1373		**1373**
	# of daily jobs:20,		T1	T2	T3	
	Technicians have each	Number of Jobs Completed by Technician	20	0	0	**20**
	competency, Customers	Number of Jobs Planned the Day After		0		**0**
	have 240 minutes of	Time Spent from Available Work Time by Technician	568	90	90	**748**
S3	appointment interval,	Total Waiting Time of Technician	101	0	0	**101**
	each technician works	Overtime of Technician	0	0	0	**0**
	for 600 minutes,	Objective Function		748		**748**
	Overtime is allowed.	Total Completion Time of Jobs (Total Spent Man-Hour)		748		**748**
	# of daily jobs:20,		T1	T2	T3	
	Technicians have limited	Number of Jobs Completed by Technician	10	5	5	**20**
	competency, Customers	Number of Jobs Planned the Day After		0		**0**
	have 240 minutes of	Time Spent from Available Work Time by Technician	555	291	347	**1193**
S4	appointment interval,	Total Waiting Time of Technician	269	89	157	**516**
	each technician works	Overtime of Technician	0	0	0	**0**
	for 600 minutes,	Objective Function		1194		**1194**
	Overtime is allowed.	Total Completion Time of Jobs (Total Spent Man-Hour)		1194		**1194**

We just reorganize 2 of the inputs for all 4 scenarios above which are extent of time slots and competency distribution to the technicians. When we evaluate the results in terms of the objective function and its corresponding total completion time of jobs value, that is the ending value which penalties are subtracted from objective function, we come up with a best-case scenario which is scenario 3. In scenario 3, All 3 technicians are educated for all type of competencies therefore the model can assign any type of job to any technician, and customers can choose a 4-hour time slot to accept a technician to start the job. From the perspective of customer satisfaction, scenario 3 looks a bit problematic since 4-hour is too much time to claim that a technician arrive the customer location at any moment in between the time slot. Majority of customers is surely not into that much waiting at home for a service. That is why its applicability in business might be arguable for a decision maker. However, we have a more customer friendly case than scenario 3. The total completion time of jobs in scenario 1 is very close to the value in scenario 3, moreover technicians are educated for all competencies and the time slot provided to customers is 2 hours. Yet, competency education for technicians might require an investment, but it is still a case to consider massively because it possible yields a high customer satisfaction. Scenario 2 and scenario 4 are the scenarios in which technicians do not have all the competencies but it is distributed randomly. These scenarios result in a total completion time of jobs value that is dramatically higher than that scenario 1 and scenario 3 result in. The consequences of the study above reveal that a managerial decision about competency education for technicians and service policy is possible to be made.

Another study we conducted consists of 3 different scenarios. The constant inputs in all 3 are the number of jobs and the competencies the jobs require and number of technicians working. Only changing input in scenario is competencies. We run the model for the identical jobs and the different competency distributions for technicians. We expect to detect the competency distribution for technicians that better-off the objective function value. The scenarios are listed below:

1. The number of daily jobs is 111 and the number of technicians is 13. Technicians have competencies which they currently have in the considered ATS.
2. The number of daily jobs is 111 and the number of technicians is 13. Each technician has all competencies.
3. The number of daily jobs is 111 and the number of technicians is 13. Each technician has 2 competencies. However, we apply a condition that any technician cannot have such 2 competencies that are mostly demanded in a day.

We come up with a result that such a competency distribution plan has no significant effect on the objective function value. It is just worth to indicate that the best-case scenario is the one in which each technician has all competencies. The detailed results are shown in Table 5.

Table 5. Results of Scenarios

Scenario	Parameters	Output	Value													Total
			T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	**600**
S1	# of daily jobs:111, Technicians have current competency, Each technician works for 600 minutes, Overtime is allowed.	Number of Jobs Completed by Technician	0	1	0	0	33	0	32	7	4	32	0	0	2	**111**
		Time Spent from Available Work Time by Technician	90	136	90	90	600	90	597	324	394	595	90	90	194	**3381**
		Overtime of Technician	0	0	0	0	0	0	0	0	0	0	0	0	0	**0.00**
		Objective Function							3381							**3381**
		Total Completion Time of Jobs (Total Spent Man-Hour)							3381							**3381**
			T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	**600**
S2	# of daily jobs:111, Technicians have each competency, Each technician works for 600 minutes, Overtime is allowed.	Number of Jobs Completed by Technician	0	0	21	26	20	0	0	0	0	0	22	22	0	**111**
		Time Spent from Available Work Time by Technician	90	90	421	563	518	90	90	90	90	90	571	562	90	**3355**
		Overtime of Technician	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Objective Function							3355							**3355**
		Total Completion Time of Jobs (Total Spent Man-Hour)							3355							**3355**
			T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11	T12	T13	**600**
S3	# of daily jobs:111, Technicians have two competencies, Two competencies which are the most demanded cannot be given to a technician, Each technician works for 600 minutes, Overtime is allowed. There are just 2 technicians who has just one competency.	Number of Jobs Completed by Technician	18	6	30	0	0	5	0	7	13	0	0	29	3	**111**
		Time Spent from Available Work Time by Technician	428	181	588	90	90	211	90	391	361	90	90	600	193	**3404**
		Overtime of Technician	0	0	0	0	0	0	0	0	0	0	0	0	0	**0**
		Objective Function							3381							**3381**
		Total Completion Time of Jobs (Total Spent Man-Hour)							3375							**3375**

To sum up, we conducted 2 different experimental studies for managerial purposes. We aimed to lead decision makers to find their ways for improving their business. The mathematical model we developed allows us to carry out such analysis. Thus, the kind of studies could be varied for specific business cases via making changes on inputs and observing the change in the objective function value.

DYNAMIC PROGRAMMING ALGORITHM

Jobs are assigned to technicians at the beginning of each day according to the proposed mathematical model and the model gives a solution by using the predicted times of transportation and duration. However, these times of transportation and duration might change in an actual case. It will be more realistic if the model could change the route of technicians dynamically. For this reason, a new algorithm that makes the model dynamic is proposed as a pseudo code. Firstly, the mathematical model is solved with GAMS by using input from predicted data and a solution is generated. Secondly, for each technician, jobs are taken from GAMS solution and put into jobs list. Then, the first job in the list is taken out and checked if the predicted and actual time of this job is equal. If it is not, remaining jobs are put into GAMS and the model gives a new solution for them. This process continues until the jobs list is empty. When all jobs are considered, algorithm goes through other technicians until all the technicians are processed. At the end, the algorithm returns the actual route of each technician with completion time as an output.

Pseudocode for dynamic programming algorithm:

Step 1: Predicted and actual time of jobs are received from input file.
Step 2: Model is run with the predicted time of all jobs.
Step 3: For each technician:
Step 3.1: Jobs assigned by the model are put into the jobs list.
Step 3.2: Until the jobs list is empty:
Step 3.2.1: The first job which is in the jobs list is taken out.
Step 3.2.2: The taken out job is put into done jobs list and is never considered again.
Step 3.2.3: The predicted and actual time value of that job is compared. If the predicted time value is not equal to the actual time value, the model is run again for the remaining jobs. If not, the next job is considered.
Step 3.3: The next technician is processed according to the same steps until all the technicians are processed.
Output: This algorithm gives us how much time the technicians spend in a day with an actual job order.

CONCLUSION

By the help of this study, ATSs would serve customers with an optimal route planning and job assignment system which results in decreasing delays in completion of jobs. This improvement in the service would increase the customer satisfaction and the customers would become more loyal to the brand. They would opt more products of the brand and they would need more after sales services from the ATSs. ATSs would keep providing better service with a proper planning provided by the proposed model.

Additionally, the total time spent is reduced with a proper route planning, so that the amount of fossil fuel the technicians use during transportation also decreases. This situation decreases the spending for fuel, which is one of the biggest cost factors of ATSs, and makes their earnings remain more. These reductions in the time spent on the road and reduction in fossil fuel consumption cut down the amount of CO_2 emission to the environment which decreases the greenhouse gas (GHG) effect in the atmosphere. As a result, since the GHG is the most effective factor for the climate change, this GHG reduction provides a better environmental condition for us and prevents climate change become worse.

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A STOCHASTIC MODEL FOR WEEE RECOVERY LOGISTICS AND OPERATIONS PLANNING

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Abstract *− Due to legislations, reusing or recycling the end-of-life products has become compulsory. Especially, the waste of the electrical-electronic products (WEEE) requires that harmful materials are disposed of properly, and waste metal, plastic components are recycled and remanufactured in specialized facilities. However, there are uncertainties in the amount of material that can be recovered from WEEE related to the quality of the product returned. Moreover, some uncertainties exist in scrap prices of materials that are obtained out of the waste products. To perform logistics and operations planning of WEEE recovery, we modeled this problem as a two-stage stochastic programming model, by considering the above-mentioned uncertainties. Since waste recovery is performed due to environmental legislations, and these reverse logistics activities are costly, the objective of the model is the minimization of the net total cost. In the objective, the revenue earned by sales of the material recovered is also considered. Safe recovery of the harmful oil and gas substances are forced within the constraints. Besides, the collection target percentage defined by the legislation is also taken into account within the constraints.*

Keywords − Reverse logistics, Wastes of the electrical-electronic products, Waste recovery

INTRODUCTION

Increase in the usage of hazardous products will end up with hazardous wastes that cause pollution and endanger livings life. With informing the public by government channels and civil society organizations, attention has been taken to waste management of these hazardous materials.

Reverse logistics (RL) is generally considered as reverse of forward logistics and they are similar, however reverse logistics is much more complex since it includes complicated returned product collection and recovery processes with uncertain parameters. However, it's hard to implement structure, companies especially that are large-scale, prefer to construct RL supply chain because of the driven forces of RL that are economic benefit, forcing legislations and environmental concerns.

Nature of the supply chain is uncertain, when it comes to reverse supply chain it comprehends more uncertainty than traditional supply chain because of its more dynamic nature. Parameters such as demand, return amount of products, cost and prices of materials are considered as uncertain in some papers in literature to give a better understanding and exact results. However some parameters should have also evaluated as uncertain; delivery time, lead time, transportation time, waste generation, environmental issues, risk factors and different weights.

Single and multi-parameter sensitivity analysis is the first approach to tackle the uncertainties. However, it is not as flexible as a stochastic programming approach (Listes, 2007). In stochastic RL problems, two-stage or robust optimization techniques are used. Stochastic modeling is a more developed area since it gives accurate results in OR however requirements of historical data and complexity of modeling making it impractical. In literature, uncertainty in the RL generally is not taking into account because of these necessities. While considering uncertainties stochastic modeling is not the only approach to cope with uncertainties; for larger problems heuristic and metaheuristics are appropriate too (Tabu Search, Simulated Annealing, Genetic algorithm and Ant Colony Search).

In stochastic optimization approach, historical data and known distribution used. Scenarios are created and all scenarios solved to evaluate the strategic decisions in stochastic optimization. The two-stage stochastic

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optimization approach is considered in two level and long-term (strategical decisions) and short-term (tactical decisions) made. Strategic decisions should be made firstly. Since amount of demand and supplies are not known, first stage decisions made and then when these uncertain parameters become known second stage decision can be made. First stage strategic decisions about facility capacities, number of workers and machines required are determined. In the second stage operational decisions are analyzed such as production, inventory and disposal rates (Kaya et al, 2014).

First stage variables must be defined at the beginning of the planning horizon and cannot be set independently of the uncertainty in future scenarios. On the other hand, the second stage variables have different values according to the scenario. Decision makers can choose the appropriate one of these values to carry out according to the emergence of scenarios.

In the literature, several studies are performed considering uncertainties in reverse logistics. Pishvaee et al. (2009) proposed a stochastic MILP model for single period, single product, multi-stage closed loop logistics network design and used scenario-approach to solve. First, they modeled the system as deterministic and adding uncertain variables they turned model into a stochastic model with 3 uncertainties; quantity and quality of returned products and demand for this product.

In Ramezani et al. (2013)'s model different parameters such as price, production costs, operating costs, collection costs, disposal costs, demands and return rates are assumed to be uncertain. The ε-constraint method used to generate a set of Pareto-optimal solutions. The model aims to maximize the total profit and the customer service level and minimize the defected products that are provided by suppliers.

Amin & Zhang (2013) proposed a closed loop facility location model in supply chain network with multiple facilities and multiple products. This mixed-integer linear programming model is solved with weighted sums and e-constraint methods and show that e-constraint method gives more efficient solutions. After uncertainties in demand and returns taken into account, it is solved with stochastic programming (scenario-based).

Ayvaz et al (2015) proposed a stochastic model under the return quantity, sorting ratio (quality), and transportation cost uncertainties. In the first stage cost of opening centers and in second stage transportation, processing, recycling and disposing costs are determined. In her master's thesis, Can (2017) proposed a multi-objective mathematical model for the operations planning of a reverse logistics facility, solved the model for a real recovery facility, and performed sensitivity analysis to account for the uncertainties in the model parameters.

Ma & Li (2018) modeled multi-echelon network including both forward and reverse flows taking demands and returns randomly. Parallel enumeration method and genetic algorithm solution approaches are used to solve this two-stage stochastic model for hazardous product problem. Maximum acceptable risk (defined by the governments) and reward-penalty intensity are selected parameters to conduct the sensitivity analyses.

PROPOSED MATHEMATICAL MODEL

Generally, RL activity is not very preferred due to its cost. However, the companies carry out their RL activities to ensure that they are recovered from legal punishment by recycling as much as the state requires. In this model, a company whose legal collection amount has been determined by the state is handled. It is intended for the firm to make decisions about where to collect end-of-life products, where to evaluate the products they collect, and where to ship the products they decide to remanufacture.

The reverse logistics system can be formulated as a mixed-integer linear programming model. Sets, parameters, and decision variables are defined as follows:

Indices:

i: $Product\ index\ (i \in I)(i = 1,2)$
b: $Geographical\ regions\ \ index\ (b \in B)(b = 1,..,7)$
k: $Sorting\ center\ index\ (k \in K)$
r: $Remanufacture\ center\ index\ (r \in R)$
t: $Periods\ index(Years)\ (t \in T)(t = 1,..,12)$
j: Module index $(\mathrm{j} \in \mathrm{J})(\mathrm{j} = 1,..,9)$
m: Machine index $(m \in M)(m = 1,..6)$
s: $Set\ of\ senarios\ (s \in S)$
c: Type of cycling method required$(\mathrm{c} \in \mathrm{C})(\mathrm{c} = \mathrm{Rec, Rem, Dis})$
$Lifetime$: $1..L$

Decision Variables:

$Y_k = \begin{cases} 1, & if\ sorting\ center - k\ is\ constructed \\ 0, & otherwise \end{cases}$

$Y_r = \begin{cases} 1, & if\ remanufacturing\ center\ - r\ is\ constructed \\ 0, & otherwise \end{cases}$

X_{itkbs}: $Number\ of\ product - i\ collected\ from - b\ transferred\ to\ sorting\ center - k\ in\ period - t, in\ scenario\ s.$

Z^s_{jtkr}: $Number\ of\ from\ module - j\ transported\ from\ k\ to\ remanufacuring\ center - r\ in\ period - t, in\ scenario\ s.$

Q^s_{jtk}: $Number\ of\ module\ j\ for\ recycle\ at\ sorting\ center\ k\ \ in\ period\ t, in\ scenario\ s.$

D^s_{jtk}: $Number\ of\ module\ j\ disposed\ at\ sorting\ center - k\ in\ period\ t, in\ scenario\ s.$

L_{tk}: $Labor\ source\ that\ is\ required\ in\ sorting\ center - k, in\ period\ t\ (man * hour)$

L_{tr}: $Labor\ source\ that\ is\ required\ in\ remanufacturing\ center - r, in\ period\ t\ (man * hour)$

Parameters and Variables:

LC_t: $Labor\ cost\ per\ worker\ in\ period\ t.$

F_b: $Fixed\ cost\ of\ working\ with\ a\ 3rd\ party\ provider\ to\ collect\ product - waste\ from\ region\ b.$

G_{ic}: $Operational\ time\ per\ one\ piece\ of\ product - i. for\ cycle\ type\ c.$

Dis_{bk}: $Distance\ between\ center\ of\ the\ region - b\ from\ the\ sorting\ center - k.$

Dis_{kr}: $Distance\ between\ sorting\ center - k\ from\ remanufacturing\ center - r.$

R^s_j: $Revenue\ that\ is\ gained\ by\ sales\ of\ material\ j\ per\ kg, according\ to\ scenario - s.$

d^s_{ibt}: $Amount\ of\ product\ i\ that\ can\ be\ collected\ from\ region\ b\ in\ period\ t\ for\ senario\ s\ .$

Mij: $Ratio\ of\ Material - j\ obtained\ from\ one\ piece\ of\ product - i\ (\%)$

w_i: $Weight\ of\ product\ type\ i\ (kg)$

$\alpha_{\ il} = Percentage\ of\ the\ i\ th\ product\ is\ sent\ to\ sorting\ facility\ after\ l\ year\ used.$

$\beta^s_{cl} =\ Percentage\ of\ c^{th}\ \ cycling\ type\ of\ product\ that\ lifetime\ is\ l\ for\ senario\ s.$

Co_{ic}: $Cost\ of\ processing\ ith\ product\ if\ it\ is\ considered\ as\ type\ c.$

Pr_{ic}: $Profit\ from\ processing\ ith\ product\ to\ be\ cycled\ type\ c.$

Q^s_{ict}: $Amount\ of\ processed\ \ product\ i\ by\ c\ cycle\ type\ \ of\ product\ for\ senario\ s\ in\ period\ t.$

π^s: $probability\ of\ scenario\ s$

F_k: $Fixed\ cost\ of\ sorting\ center\ k(or\ dealing\ with\ 3rd\ party\ to\ carry)$

F_r: $Fixed\ cost\ of\ remanufacturing\ center\ r(or\ dealing\ with\ 3rd\ party\ to\ carry)$

F_b: $Fixed\ cost\ of\ collecting\ from\ region\ b(or\ dealing\ with\ 3rd\ party\ to\ carry)$

Scalars:

FTL: $Full\ truck - load\ (kg)$

$Legco$: $Targeted\ collection\ amount\ according\ to\ legislation.$

TC: $Unit\ transportation\ cost\ per\ km\ for\ one\ full - truckload.$

FCT: $Fixed\ cost\ of\ a\ truck$

$FiCost$: $Annually\ fixed\ cost\ of\ the\ facility(maintanance, office, management..)$

Objectives:

Objective (Cost minimization)

$$minz = \sum_{k\in K} F_k * Y_k + \sum_{r\in R} F_r * Y_r + \sum_{b\in B} F_b * Y_b + \sum_{s\in S} p^s \Big(\sum_{t\in T}\sum_{k\in K} L^s_{tk} LC_t + \sum_{t\in T}\sum_r L^s_{tr} LC_t + \sum_{k\in K}\sum_{b\in B}\sum_{t\in T}\sum_{i\in I} \frac{x^s_{itbk}}{FTL} * (TC * Dis_{bk} + FCT) * w_i + \sum_{r\in R}\sum_{j\in J}\sum_{t\in T}\sum_{k\in K} \frac{Z^s_{jtkr}}{FTL} * Mij * (TC * Dis_{kr} + FCT) - \sum_{t\in T}\sum_{j\in J}\sum_{k\in K} R^s_j\, Q^s_{jtk} - \sum_{t\in T}\sum_{r\in R}\sum_{j\in J}\sum_k R^s_j\, Z^s_{jtkr} + \sum_{t\in T}\sum_{j\in J}\sum_{k\in K} D^s_{jtk} R^s_j \Big) \quad (1)$$

Constraints:

$$\sum_b \sum_j M_{ij} x^s_{itbk} = \sum_j \left(\sum_{r\in R} Z^s_{jtkr} + D^s_{jtk} + Q^s_{jtk} \right) ;(\forall s \in S), (\forall i \in I), (\forall k \in K), (\forall t \in T) \quad (2)$$

Legislation target constraint

$\sum_b \sum_t x_{ibtk}^s \geq \sum_t d_{ibt}^s \times Legco_t; (\forall i \in I)\ (\forall s \in S)$ (3)

Collection constraint

$x_{ibtk}^s \leq d_{ibt}^s * Y_k; (\forall i \in I)\ (\forall b \in B)(\forall t \in T)(\forall s \in S)$ (4)

$\sum_{k \in K} Z_{jtkr}^s \leq M * Y_r; (\forall j \in J)\ (\forall r \in R)(\forall t \in T)\ (\forall s \in S)$ (5)

Capacity constraints

$\sum_{i \in I} \sum_{b \in B} x_{itbk}^s G_{ij} = L_{tk}^s; (\forall t \in T)\ \ (\forall s \in S)\ \ (\forall k \in K)$ (6)

$\sum_{K \in K} \sum_{j \in J} z_{jtkr}^s \beta_j = L_{tr}^s; (\forall t \in T)\ \ (\forall s \in S)\ \ (\forall r \in R)$ (7)

Truck constraints

$\sum_i w_i * x_{itbk}^s \leq FTL\ (\forall b \in B)(\forall t \in T)(\forall k \in K)$ (8)

Sign Constraints:

$x_{itbk}^s, z_{jtkr}^s, q_{jtk}^s, d_{jtkr}^s \in Z^+;\ \ \forall i \in I;\ \forall t \in T;\forall b \in B$ (9)

$Y_k, Y_r \in \{0,1\};\ \forall k, r \in K, R$ (10)

Equation 5.1 minimizes the total cost consisting of opening costs of sorting and remanufacturing centers and collection cost of regions, labor and transportation cost minus revenue that is gained from the materials. Equation 5.2 satisfies total product amount is equal to total module (each part of the product) amount in these products. Total collected product amount should be equal to or greater than the legislated amount in that period is given in Equation 5.3. In Equation 5.4 collected product amount in a sorting center is directly related with the opening decision of that sorting center. Equation 5.5 ensures that modules that should be remanufactured are transferred to the remanufacturing center from different sorting centers. In Equation 5.6, available products that are not collected for different reasons are accepted as inventory. Required labor source in recycling and sorting centers are provided by Equations 5.6 and 5.7. Equation 5.8 provides the full truckload for transportation. Equations 5.9 and 5.10 used as sign constraints.

In fact, if reusing the products are possible, it is profitable to sell them. Therefore, if there is a chance to re-evaluate the product or its parts, this should be performed first. This also meets the need for product and parts as the end-of-life products are included in the cycle again and the damage to the environment is reduced. In our model, all products come to sorting center and if they are proper for remanufacturing they are directed to remanufacturing center. Hazardous materials are sent to the licensed firms to dispose properly. Otherwise, they are recycled and sold as scrap materials.

CONCLUSION

Reverse Logistics is a popular subject, which includes all of the operations related with returned products collection, inspection and gaining value from them. In our model product collection region, sorting and recycling center locations are decided.

In this study, a multi-product multi-level stochastic model was established. As a result of scenario-based evaluations, more realistic results can be obtained by using the stochastic modeling to handle the uncertainties. Probabilities are associated with scenarios and a solution is sought against all possible scenarios. Opening and closing a plant is both expensive and time-consuming, so it is impossible to change the plant in the short-term. As a fist stage, opening decisions and as second stage operational decisions are made. We cannot say that the optimal result has been reached for every scenario.

So far, the model has not been solved for any instance. In future studies, based on real or hypothetical data sets, the proposed model will be tested, and the results will be interpreted.

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A DECISION SUPPORT SYSTEM PROPOSAL BASED ON INTERNET OF THINGS FOR RECYCLABLE WASTE COLLECTION

Nadide Çağlayan[1], Şule Itır Satoğlu[2], Emine Nisa Kapukaya[3]

Abstract *− Waste management is the whole of process including the collection, transportation, storage, recycling, disposal and control of these for all of the waste types. The process of collection and transportation are covered for recyclable waste in this study. A decision support system has been proposed to plan waste collection according to real-time data in this study. Currently, all containers are visited in fixed frequency. In the proposed system, it is desirable to establish a smart and dynamic waste collection system to prevent the unnecessary use of resources and to collect the wastes on time by knowing fullness of the containers in advance. By using internet of things (IoT), the occupancy rates of the containers are known and the collection plan is prepared according to these rates. Vehicles do not visit the containers until they reach the specified fullness. Thanks to the IoT system, real-time data can be gathered so that waste in containers can be collected at the right time. In the proposed model, it is aimed to reduce the route length and total time traveled. The current and proposed system are compared with a simulation study. Systems have been compared in terms of total time they traveled and as a result of the study, it is seen that there is a significant difference in terms of the total time between the proposed system and the current system.*

Keywords − internet of things, real time data, recyclable wastes, simulation

INTRODUCTION

The world is undergoing a transformation. This transformation is reflected in our life together with technology. One product of this transformation is also the smart cities. Smart city systems are a system that comes with the use of different information technologies together. Smart City applications can be implemented in every area of the city management such as infrastructure, transportation, traffic system, waste management, building management. With smart city applications, the quality of life of residents and the efficiency of urban infrastructures are increased (Cicirelli et al., 2017). The most important of the purposes of smart city design is to optimize the use of resources in monitored systems, continuously. "Internet of things" which appeared as a radio frequency based system by Kevin Ashton in 1999 is a concept that has the ability of sensing and communicating objects. The internet of things (IoT) provides to monitor, manage, control and emerge new information in real time (Kim et al., 2017). So it creates smart systems. IoT creates a smarter environment by saving time and energy. IoT consists of connected devices that can transfer data to optimize their performance (Mahdavinejad, et. al., 2018). The basic structures required for smart cities based on IoT are identification, sensing, communication, computation, services, and security (Khan, 2017). A smart city system design is possible with the construction of these bases. There are numerous IoT based system that can be included such as traffic, logistics, health, agriculture, smart metering, retail, monitoring, automation, etc. (Čolakovića & Hadžialić, 2018). In this study, it is focused waste management based IoT.

Waste management is an important part of the smart city system. Rapidly growing technology have accelerated the rate of urbanization and population growth, the increase in community living standards, and the rate of waste generation in developing countries. Waste management is a comprehensive process and critical issue. It covers many processes such as collection, separation, transport, conversion and disposal of waste etc. By utilizing information and communication technologies, each stage of waste management can be tracked as real-time. The use of information technology in waste management provides both economic and environmental

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efficiency as it is in other smart city applications. To provide the connections of the system components, "Internet of Things (IoT)" can be utilized. The use of IoT will provide many advantages for waste management in smart cities (Anagnostopoulos, 2015). The main objective is to use the resources efficiently. In this context, by optimizing the utilization of resources, economic advantages, collection of wastes on the time and the use of less energy can also provide environmental advantages.

Faccio et al. (2011) simulated multiple vehicle routing for solid wastes. Economic analyzes were also included in the study by using the stocastic data. Anghinolfi et al. (2013) proposed a GIS based dynamic optimization model in order to minimize the collection and transportation costs. Islam et al. (2014) has proposed a system that recognizes the amount and type of waste in the waste box with image processing technique. With this system, waste estimations and system decisions can be made. Mes et al. (2014) study with sensors. They proposed a heuristic approach to the reverse inventory routing problem. Medvedev et al. (2015) has proposed a cloud-based decision support system that includes all system elements for dynamic routing. Elia et al. (2016) has studied the IOT-PSS based hybrid vehicle modeling with dynamic routing for e-waste. Lozano et al., (2018) simulated capacity constrained vehicle routing using data obtained from wireless sensor network. The model proposed in the study provides savings in the distance covered by the static model. In addition, wireless sensor network (Longhi et al., 2012; Narendra et al., 2014; Lozana et al., 2018), IoT and wireless sensor network (Lata et al.; Mustafa & Azir, 2017; Rajkumar et al., 2017; Saranya et al., 2017), GSM sensor technologies (Zavare et al., 2017), Radio Frequancy Identification (RFID) (Hong et al., 2014) are the information system structures used in studies that proposes the decision support systems for waste collection.

The aim of the study is to suggest an IoT based decision support system for the collection of recyclable wastes, where the waste accumulation rate varies according to the regions. In this study, the collection of waste containers has been studied according to the real-time data by utilizing IoT. With this decision support system, vehicle circulation is done according to the occupancy information of the containers and it is aimed to complete the route with the shortest traveled time of the vehicle. The current and the proposed system are simulated and the difference between them is evaluated in terms of total traveled time. In the later part of the study, problem description, proposed system structure, simulation study and results are presented.

PROBLEM DESCRIPTION AND PROPOSED SYSTEM STRUCTURE

Cities are now designed with smart systems. Smart designs made with environmental and ecological expectations are being offered to the community. This study focuses on the collection of recyclable household waste, where recyclable waste accumulates in a relatively more irregular manner. Because the rate of accumulation of recyclable wastes is affected by many demographic characteristics such as the population in the region, the education level of the region, and consumption habits. This means that waste accumulation can occur at different rates even within the same region. Waste accumulates more slowly in recyclable waste containers. Some of the containers are not yet full, while others have a capacity surplus. Both cases are undesirable situations, considering both unnecessary resource consumption and damage to the environment.

IoT based system is proposed for transportation which is part of a smart waste management system. In the study, the current and proposed systems are compared with the simulation study. In the current system, the containers in the region are collected all of them on a certain day and hour of the week. Some of the containers are not yet full, while others have a capacity surplus. In which case the collecting vehicle completes the tour with a longer distance. This causes both resources to be wasted and in terms of the environment, negatively. In the proposed model, the vehicle travels to the containers reaching the specified occupancy level thanks to the containers in which the sensor is placed. The tour is completed without other containers. The proposed model provides a dynamic scheduling. The flow diagram of the proposed model is given in figure 1.

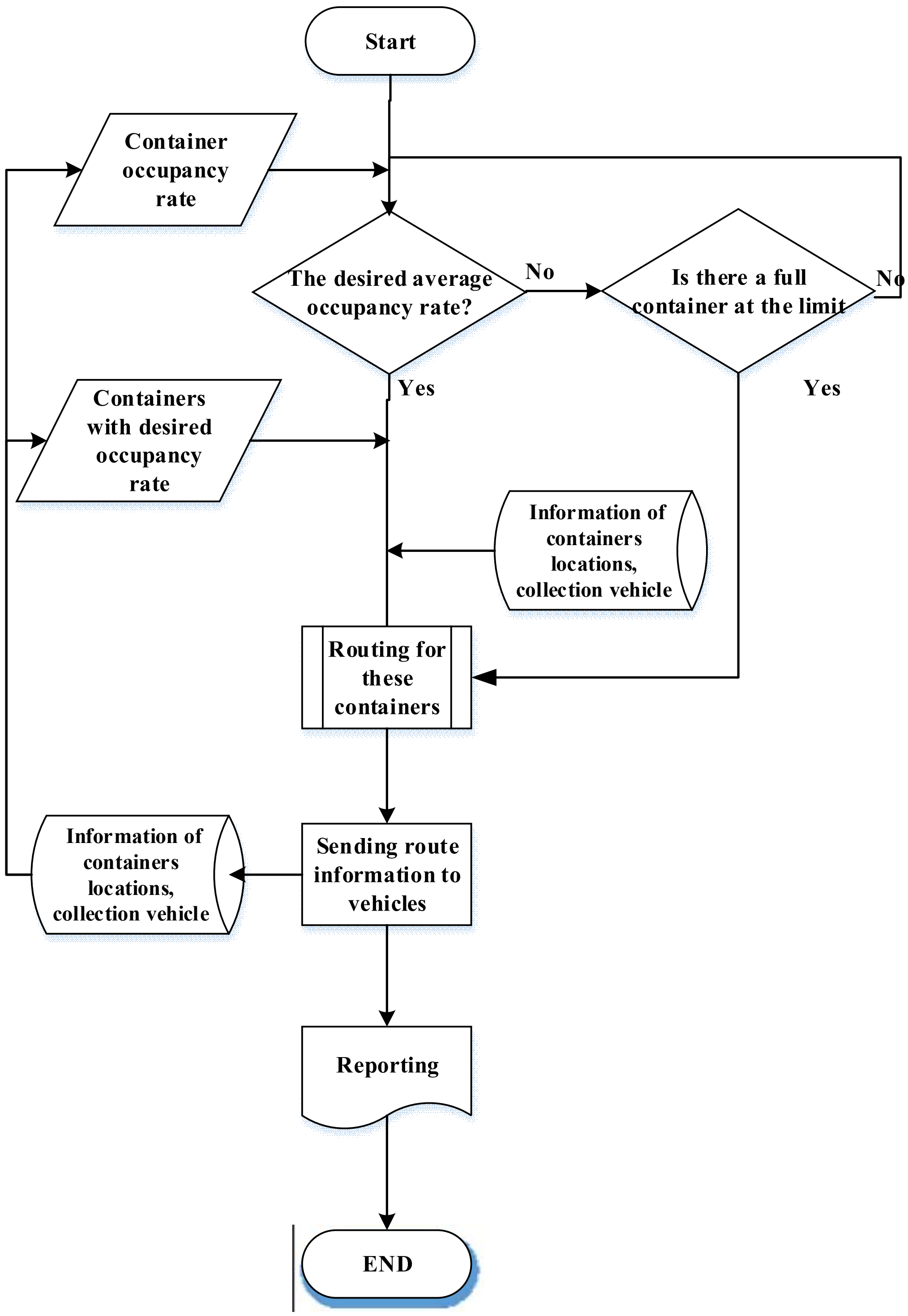

Figure 1. Flow Chart of Proposed System

The occupancy information of the containers in which the sensor is placed is transmitted to the main server according to the network protocols. When the average occupancy rate of the container in the district reaches the desired level of the system, warning is given to the management center and the waste collection vehicle is removed for the containers that have reached the specified occupancy rate. Information such as location and waste amount of containers is transmitted in real time and necessary information is reported.

SIMULATION MODELS

The study has simulated for a small sample. In the current case, the collection of wastes is modeled at a fixed time once a day. In the proposed model, if the average occupancy rate of the containers in the area reaches to 75%, the vehicle completes the tour by 50% and over filled containers. New wastes are allowed to come into the model during the collection period. The two cases were evaluated in terms of traveled times of the vehicles in a certain simulation running period. Figure 2 and Figure 3 show the simulation model of the current and proposed model, respectively.

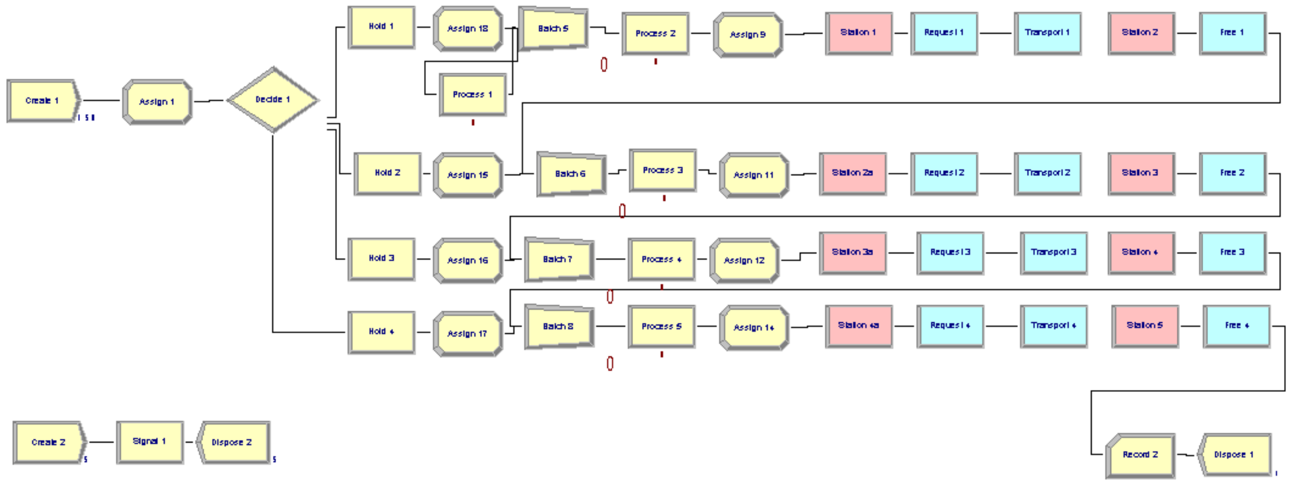

Figure 2. Simulation Model of Current System

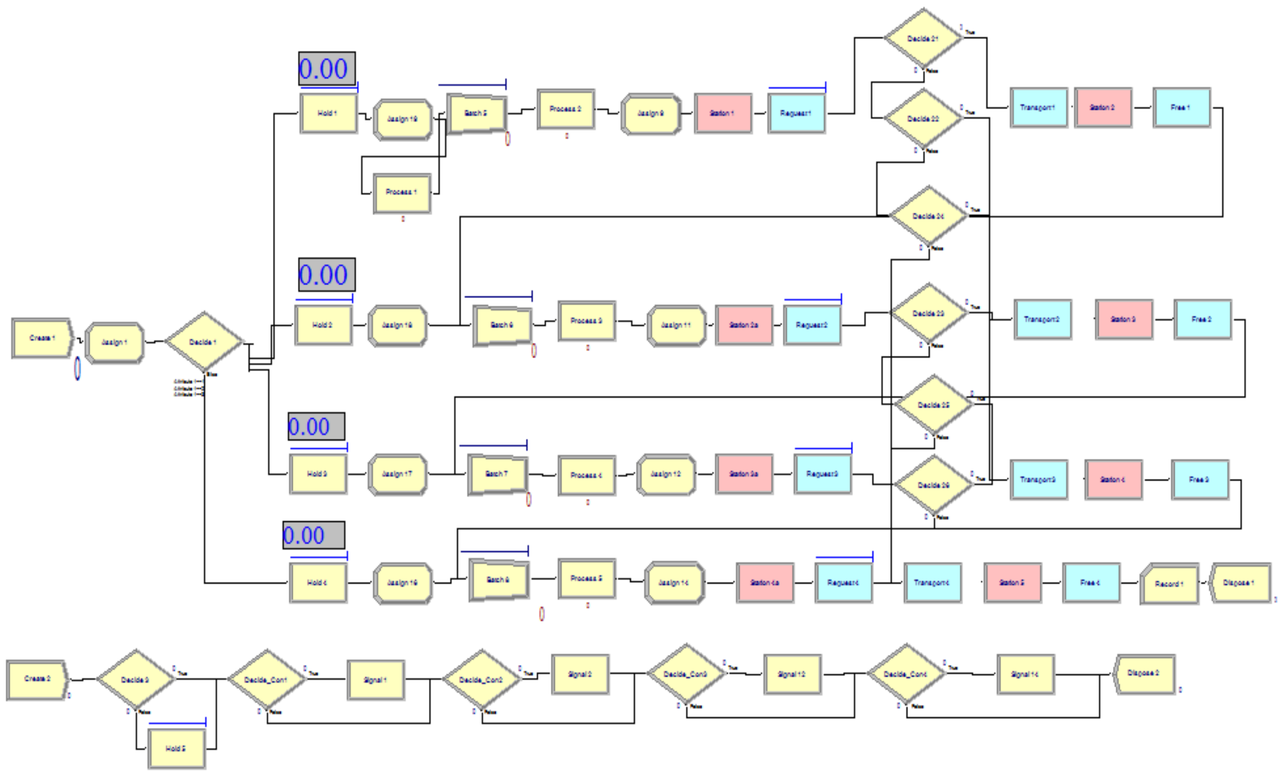

Figure 3. Simulation Model of Proposed System

Table 1. Results of Simulation Models (min)

Replication	Model of Current System	Model of Proposed System
1	41,166	30,228
2	37,518	31,692
3	38,328	31,02
4	39,102	28,26
5	40,41	23,826
6	40,98	23,16
7	47,04	34,122
8	37,674	30,798
9	44,244	27,276
10	37,884	31,44

The current system and the proposed system results in the simulation study are given in table 1. The simulated length is 5 days in the model running 10 times. It was concluded that there is a significant difference between the average travel times of each run and the confidence interval test conducted at the 1% significance level with the proposed model results.

CONCLUSION

A waste collection system based on the Internet of Things has been proposed for the collection of recyclable wastes in the study. The speed of accumulation of recyclable waste are not same the household waste and it is also influenced by different demographic characteristics of the region, the location of the container, consumer behavior etc. Accordingly, a different chart is required for each region. Instead of scheduling for each, planning with a smart system will be easier and more cost-effective. With the proposed system, carbon emission and total traveled distance are also reduced as well as transportation costs. In the study, the proposed model and the current system are compared with ARENA simulation program. The comparison revealed a difference between the average traveled times. Progressive studies can be tried for a larger sample by giving information of the technical infrastructure. Container locations, economic analysis studies can be done.

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THE ROLE OF ACCESSIBILITY FOR DETERMINING LOCATIONS IN AIRPORTS AND PASSENGER DEMANDS IN TURKEY

Gorkem Gulhan[1], Soner Haldenbilen[2], Halim Ceylan[3]*

Abstract – *The accessibility of airports and the airport preference of users' are significant criteria for the competitiveness of airports. When passengers choose a route, they actually expect the completion of the transportation chain and they want to travel to the door from the door. For this reason, the factors that affect the passenger's decision for a particular option go beyond the price and quality of air services. The decision for a specific air service and a particular airport depends on the accessibility of the airport to a considerable extent. Factors affecting the choice of the airport can simply be divided into two categories. The category that reflects the number of air fares, frequencies and served destinations is defined as "air side". The category of airport accessibility, namely access, is also called "land side". The locations of the airports are usually set up around the periphery of the city's with an reasonable length such as 50 km. The access of the airports may affects the passenger demands, so this study investigate the Turkish airport coverage in length of 50, 75 and 100 km radius from city centers. The main purpose of this study thus investigates whether a new airport construction is needed or not for domestic flights. Results showed that if 100 km radius length is used as a criterion for building new airport, only 10 cities with total population of about 2.5 million people will be outside the airport access.*

Keywords – *Airport, Location Choice, Logistics, Accessibility.*

INTRODUCTION

The rapid change of the world and the progress of globalization have directly and irrevocably affected many fields. Logistics, scope and efficiency have increased with the triggering of the developing technology (Keskin, 2009). Particularly fast-paced technology has led to an increase in transportation opportunities and accordingly the importance of more careful planning, integration and common use of transport systems has come to the forefront. The logistics concept, which is a new value in terms of competition, has become important in relation to transportation (Ozgen, 2018). The least and most recently utilized subsystem within transportation systems is air transportation (Kurt, 2010). Airlines are a frequent choice of transportation system since they travel faster and are safer than other modes of transportation (Evliyaoglu and Tezel, 2017). The time of travel between the start and the end of the journey made by air, the cost and comfort are influential on the choice of travel preference. The time of travel between the start and the end of the journey, the cost and the comfort are influential on the choice of travel preference. For this reason, it is possible for airports to be considered as accessible, with travel time and cost minimizing comfort and maximizing comfort. For this reason, in order to make airports accessible, it is necessary to reduce travel time and cost to a minimum and comfort to a maximum.

The accessibility of airports and the airport preference of users' are significant criteria for the competitiveness of airports. When passengers choose a route, they actually expect the completion of the transportation chain and they want to travel to the door from the door. For this reason, the factors that affect the passenger's decision for a particular option go beyond the price and quality of air services. The decision for a specific air service and a particular airport depends on the accessibility of the airport to a considerable extent (European Commission, 2010).

Factors affecting the choice of the airport can simply be divided into two categories. The category that reflects the number of air fares, frequencies and served destinations is defined as "air side". The category of airport accessibility, namely access, is also called "land side". In the past decades, several elements of airport

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accessibility have changed. Many airport operators across Europe have begun to see long-haul rail access as an important factor in expanding their sphere of influence. However, accessibility by car continues to play an important role as this type of transportation is still not dominated by the majority of the airports. With quality land transportation, some of the major airports have begun to turn into "airport cities". Here, real estate development facilities for inter-species functions, offices, shops and even residential areas were supported (European Comission, 2010).

There are many researches such as Pels et al. (2000, 2001) for demand modelling for multiple airport cities (e.g. Kanafani et al., 1975; De Neufville, 1976, 1984; Ashford and Benchemam, 1987; Harvey, 1987; Thompson and Caves, 1993). Derruder etc., (2010) has made a spatial analysis. Additively, location choice of an airports is a dynamic, multi-objective, mixed integer programming model which tries to find the optimal location under capacity and budgetary restrictions (Min etc., 1997). Concurrently, airport locations are analyzed in terms of role of land and airside accessibility (Yang etc., 2016). Decision makers are generally guided by the traditional concept of airport catchment area (Ashford and Bencheman, 1987; Cohas et al., 1995; Loo et al., 2005).

Aviation sector in Turkey is rapidly improving especially in last years (Avci, 2015). Airport location choice in Turkey depends on Airport Planning Guide which is generated by International Civil Aviation Organization (1987). Factors that influence the location choice of airports in Turkey may be listed as, aviation operations, development of environmental, atmospheric conditions, access to land transportation, be able to enlargement, topography, environment and the existence of other airports and accessibility of services (Arabaci, 2010). Assessing the relationship between population and accessibility and reflecting this correlation to site selection decisions is a factor that increases the accuracy of decisions.

In this study, 55 airport location choice decisions in Turkey are studied by of the Quantum Geographic Information System (QGIS) software in the axe of accessibility. Access roads of 50, 70 and 100 km circles are drawn on the map with the airports being in the center. Afterwards, the distances to the city centers and the periphery districts are evaluated. An accessibility analysis is performed for those three borders to assess which settlements are required an airport and passenger demand is predicted.

METHODS AND STUDY AREA

Method: The aim of this study is to determine the necessity of airports by considering accessibility measurements and passenger demand. For this purpose, a triple stepwise paradigm has been offered and each level have been defined in Figure 1.

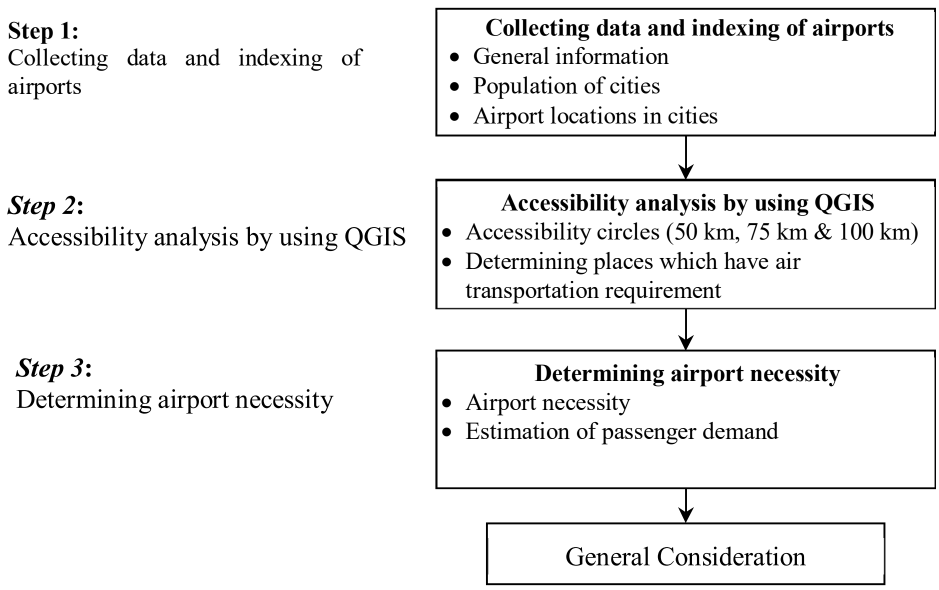


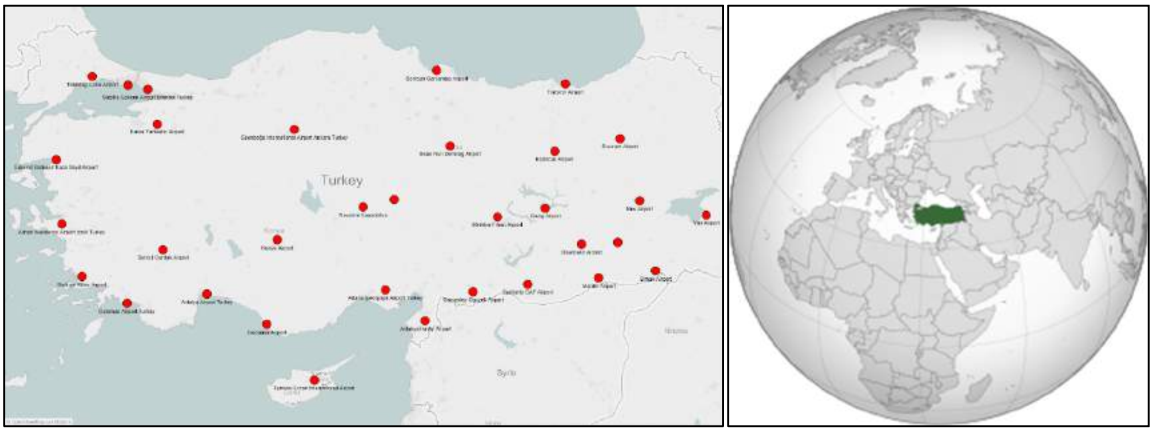
Figure 1. Flowchart of the stepwise paradigm

Step 1 starts with the obtaining data. Determination process of airport locations and obtaining city population values are conducted. The airport locations have been entered to QGIS software and the basic data has been indexed.

Step 2 is the accessibility analysis of airports by using QGIS software. Accessibility circles which have been determined in the diameter of 50 km, 75 km and 100 km. The cities which have high accessibility to airports and the cities which have low accessibility to airports are determined. Thus, the airport necessity have been obtained. The cities which have requirement for a better accessibility to airports are found.

In Step 3, the airport necessity and the passenger demand estimation have been found. Passenger demand estimation is made for the outsiders of 100 km diameter using estimated mobility numbers.

Study Area: Turkey is located between Asia and Europe and three sides of the country is surrounded by the sea. The capital city Ankara is located in the middle region of the country. The population is over 80 million and İstanbul, Ankara and Izmir is the most popular cities. The aviation sector is rapidly improving in the country. Moreover, Turkey may be leader in the related geographic region in near future. Airport locations and the location of the country is given in Figure 2.



(a) *(b)*

Figure 2. a) Airport locations in Turkey[1] b) Location of Turkey

In domestic flights, about 10 years ago, there were only 26 accessible airport by Turkish Airlines. With the opening of new airports, 7 airline companies started to fly to 55 destinations. Outer routes have flights to 268 destinations in 108 countries. The number of large-body aircraft in the airline fleet is close to 500. The number of employees in the sector, which was around 65.000 in 2003, now exceeds 200.000. In the last 10 years, the contribution of the sector's economy has reached to a level of 27 billion dollars from over 2.5 billion dollars . The number of passengers using airports across Turkey in 2003 reached an average of 30 million to 200 million[2].

ANALYSES

Determining of Airport Accessibility: By utilizing the software QGIS, 55 airports in Turkey is marked on the map. These airports are shown with 50, 70 and 100-kilometer circles so that they can be considered central. It was investigated which locations needed airports by considering accessible regions for the three different boundaries obtained. Figure 3 shows the coverage of 55 airport as a 50 km circular map in Turkey.

[1] http://www.planeflighttracker.com/2014/05/turkey-airports-map.html
[2] https://emlakkulisi.com/5-yeni-havalimani-insa-edilecek/378528

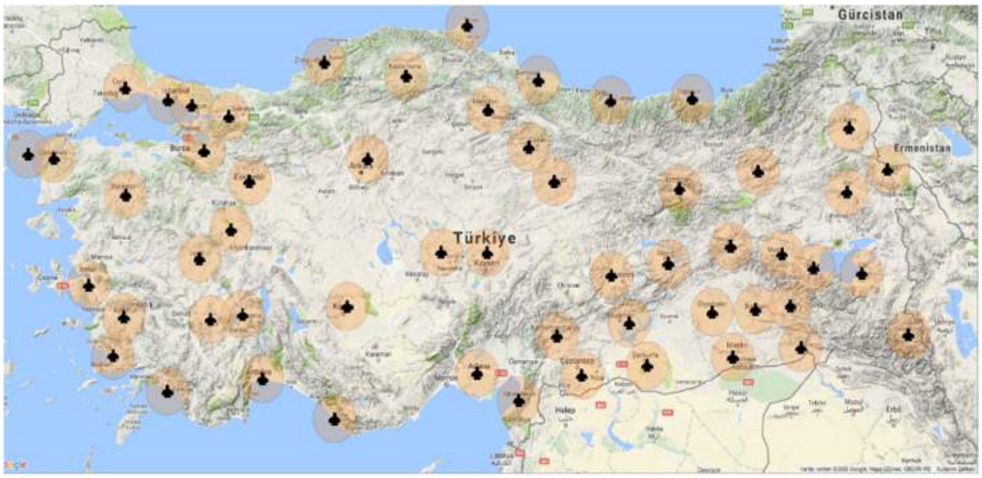


Figure 3. The coverage of 55 airport as a 50 km circular map by the QGIS

Figure 4 shows the coverage of 55 airport as a 75 km circular map in Turkey.

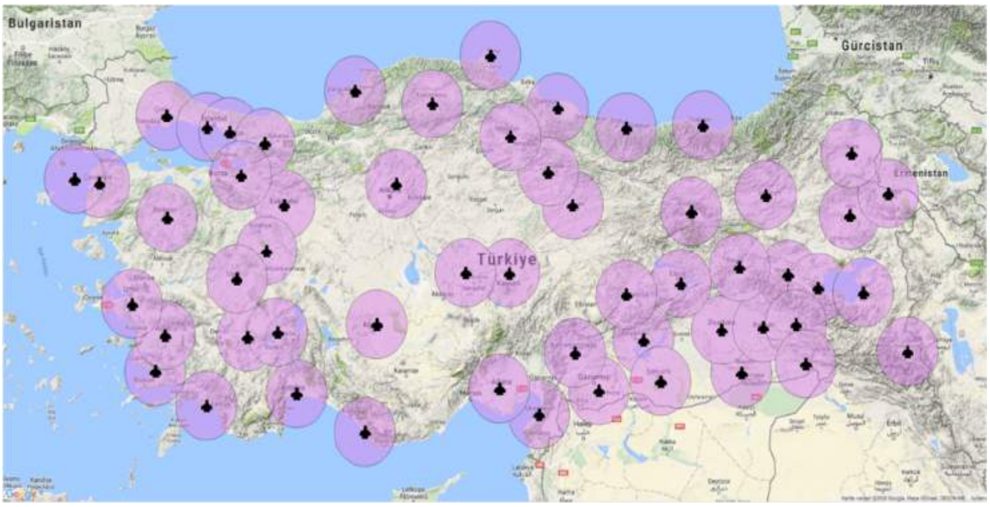


Figure 4. The coverage of 55 airport as a 75 km circular map by the QGIS

Figure 5 shows the coverage of 55 airport as a 100 km circular map in Turkey.

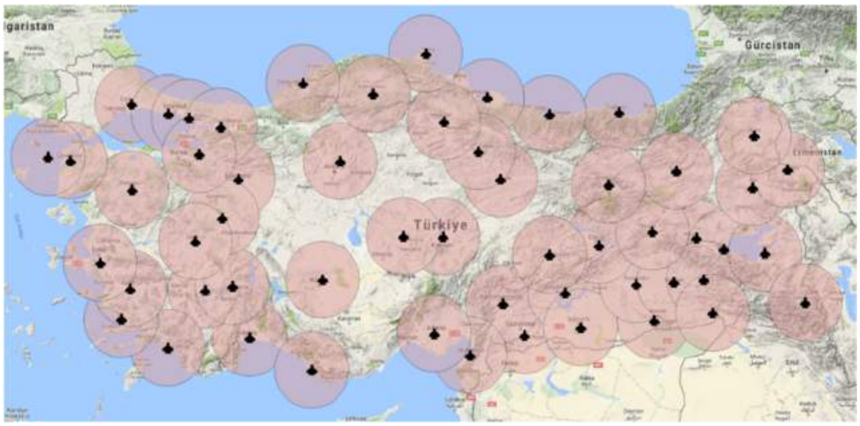


Figure 5. The coverage of 55 airport as a 100 km circular map by the QGIS

The summary of the cities that is covered by the 50, 75 and 100 km length of the airports centers are given in Table 1. Total of 21 cities with a total population of about 9 million people have not been an access to an airport within a 50 km length. Similarly, total of 14 cities with a total population of about 3.5 million people have not been an access to an airport within a 75 km length. In addition, total of 10 cities with a total population of about 2.5 million people have not been an access to an airport within a 100 km length.

In order to analyze the location airports and passengers demand, the domestic flights and passenger number are used. The obtained data for 50 active airports for which 5 of the airports are not active in 2017, in Turkey is given in Table 2. As can be seen in Figure 5, about 110 million passenger were used the 50 airports as domestic flights. As it is expected, the highest passenger is Istanbul and then Antalya Airport.

Table 1. The summary of the cities that is covered by the 50, 75 and 100 km length of the airports centers

Nu	Cities that is not covered by 50 km accessibility	Population (2017)	Cities that is not covered by 75 km accessibility	Population (2017)	Cities that is not covered by 100 km accessibility	Population (2017)
1	Kırklareli	278.749	Kırklareli	278749	Kırklareli	278749
2	Edirne	406.855	Edirne	406855	Edirne	406855
3	Manisa	1.413.041				
4	Düzce	377.610	Düzce	377610	Düzce	377610
5	Bolu	303.184	Bolu	303184	Bolu	303184
6	Karaman	246.672	Karaman	246672	Karaman	246672
7	Çankırı	186.074	Çankırı	186074		
8	Yozgat	418.650	Yozgat	418650		
9	Çorum	528.422				
10	Osmaniye	527.724				
11	Bayburt	80.417	Bayburt	80417	Bayburt	80417
12	Rize	331.041	Rize	331041		
13	Gümüşhane	170.173	Gümüşhane	170173		
14	Artvin	166.143	Artvin	166143	Artvin	166143
15	Ardahan	97.096	Ardahan	97096	Ardahan	97096
16	Aksaray	402.404				
17	Niğde	352.727	Niğde	352727	Niğde	352727
18	Kırıkkale	278.749				
19	Kırşehir	234.529	Kırşehir	234529	Kırşehir	234529
20	Mersin	1.793.931				
21	Karabük	244.453				
	Total =	8.838.644	**Total=**	3649920	**Total=**	2543982

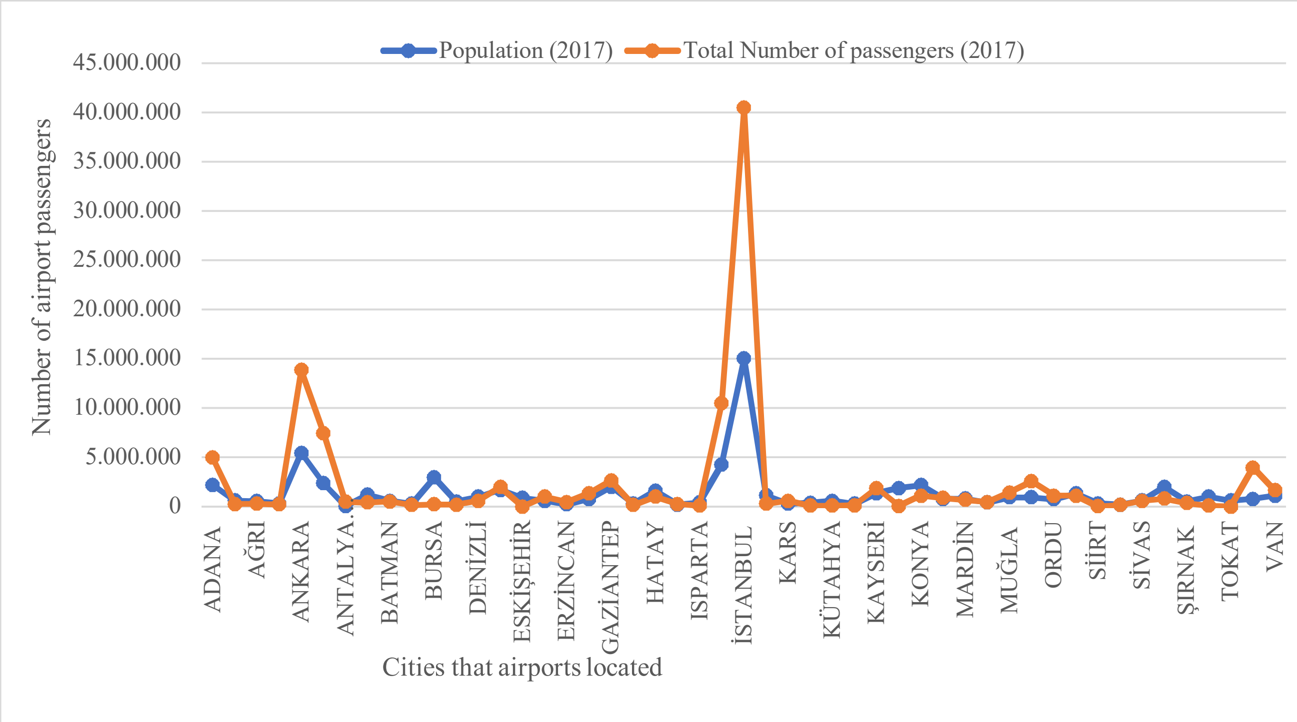


Figure 6. The population versus total number of domestic passengers for 2017

Airport Requirement and Estimation of Demand: The correlation between the population and the airport passenger demand values for cities between 2010 and 2017 have been found. In order to find the passenger demand for airports the time series approach is used. Average passenger volumes of airport with reference to population may be determined. Correlation between the population and passenger demand is given in Figure 6.

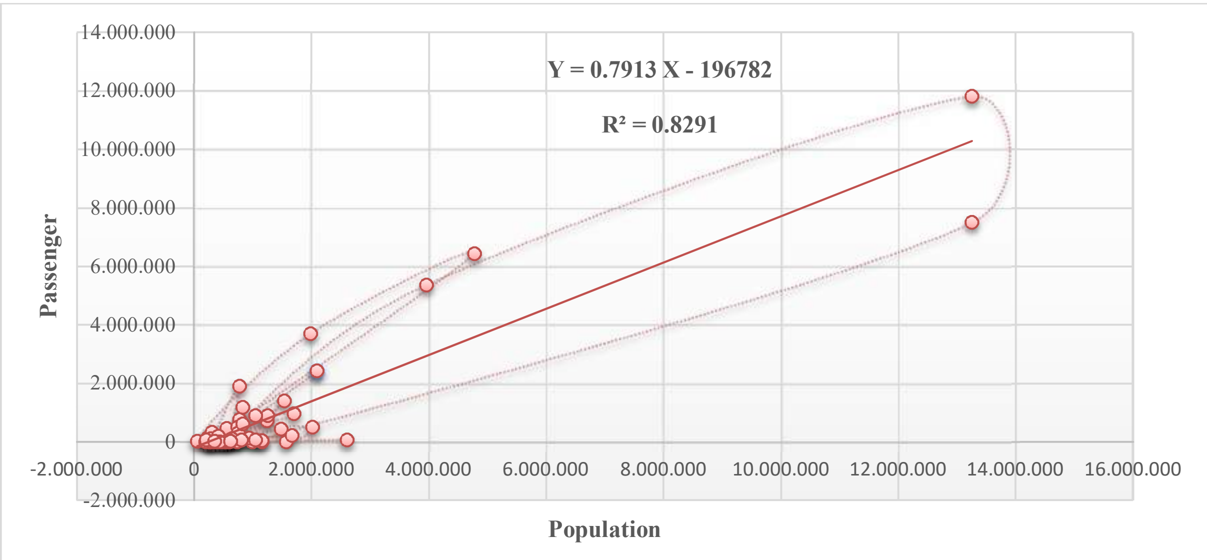


Figure 7. Correlation between the population and passenger demand

According to Figure 7, correlation between the population and passenger demand is may be interpreted as meaningful since $R^2=0.8291$ with the equation $y= 0.7913\ x-196782$.

50 km, 75 km and 100 kilometers within the boundaries of circular areas were identified. The numbers of the cities that need the airport, and the capacities of the airports to be built are identified. Table 2 shows the estimated annual number of passengers at airports is for the 100 km lengths of airport coverage. The estimated passenger demand is obtained by averaging the number of total passengers to a total number of population as a similar cities. The mobility is obtained 0.55 and it is used for passenger estimations.

Table 2. The estimated annual number of passengers

Cities that is not covered by 100 km accessibility	Population (2017)	Estimated Number of passengers (2017)
Kırklareli	**278749**	**154.508**
Edirne	**406855**	**225.517**
Düzce	**377610**	**209.306**
Bolu	**303184**	**168.053**
Karaman	**246672**	**136.728**
Bayburt	**80417**	**44.575**
Artvin	**166143**	**92.092**
Ardahan	**97096**	**53.820**
Niğde	**352727**	**195.514**
Kırşehir	**234529**	**129.998**
Total=	**2543982**	**1.410.110**

CONCUSIONS

This study investigates the airport coverage of the Turkey for 50, 75 and 100 km circular lengths. The following results may be drawn from this study. The access of the airports may affects the passenger demands, so this study investigate the Turkish airport coverage in length of 50, 75 and 100 km radius from city centers. Results showed that if 100 km radius length is used as a criterion for building new airport, only 10 cities with total population of about 2.5 million with an estimated values of about 1.4 million airport passenger will be outside the airport access. The main findings this study is that there are no new airport are not needed to newly be constructed since only 10 of the city is not covered by the 100 km length. The 10 of the cities access to nearest airport may be supported by the High Speed rail such as Bayburt, Corum, Edirne etc.

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IOT-BASED WAREHOUSE DESIGN FOR SMART LOGISTICS

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Abstract *− The concept of the Internet of Things (IoT), first introduced by Kevin Ashton in 1999, is a transformative technology that enables physical objects to be connected through the internet and to carry out their tasks in a desired manner. The IoT is a technology that must be integrated into business systems in order to achieve better results in production and logistics. This technology forms the basis of a smart logistics concept and connects people and businesses in our changing world. Along with all this changing and evolving technology, the changing needs of customers and the need for real-time data, have significantly changed the role of warehouses in logistics activities. In IoT-based warehouses; prevention of excessive amount of inventory, reduction of costs, real-time tracking of products in stock, shortening lead times, prevention of lost/stolen goods are the main goals of the industries. To achieve these goals, it is essential to capture the voice of the customers. The purpose of this study is to examine how the IoT technology can be integrated into the design processes of warehouses. In this direction, the Quality Function Deployment (QFD) approach has been used to transform customer needs into technical requirements with the help of House of Quality (HOQ) which includes the relationship matrix between customer needs and technical requirements as well as importance weights. Further, Grey Relational Analysis (GRA), a multi-criteria decision making (MCDM) technique, is used to analyze the QFD and technical requirements of IoT-based warehouse design for smart logistics are prioritized. The effectiveness of the methodology is verified with an application.*

Keywords − Smart logistics, QFD, warehouse design, internet of things, MCDM, GRA

INTRODUCTION

It is a fact that the use of the internet today is developing the communication and changing our everyday life at a significant level. With developing technology, the area of internet usage has been expanded. Devices that we use in everyday life are involved in network technology, which makes them able to communicate with each other when needed. (Ercan & Kutay, 2016). This technology, which enables objects to interact with each other through the internet network, is called the Internet of Things (IoT), allowing us to control and analyze the physical phenomena in the world (Gökrem & Bozuklu, 2016). Examples of devices that IoT technology uses in our daily lives include kitchen equipment, medical supplies, smart clocks, and so on. However, IoT is not only about personal life but also about companies, and today, consumers, industrial devices, and systems are fully connected to the internet (Whitepaper, 2018). It is vital for companies to keep pace with changing customer needs, increase productivity, provide quality and timely production and delivery, and logistics activities play a major role in fulfilling customer orders. At this point, smart logistics activities should be given importance for sustainable change and development, and logistics activities should be integrated with smart systems. The variability, diversity, need for real-time information has changed the role of warehouses in the field of logistics significantly, and now the warehouses that smart systems have created are begun to take the place of manual warehouse operations (Lee et al., 2017). An IoT-based smart warehouse will provide real-time visibility, access, and control for all businesses. This will also help prevent the loss and damage of the products, ensure the exact location of the goods and will facilitate the integration between the systems to ensure a smoother supply chain (Whitepaper, 2018).

In this study, IoT-based warehouse design for smart logistics is discussed. Using the Quality Function Deployment (QFD) technique with the help of House of Quality (HOQ), the needs of logistics warehouses are analyzed, and IoT-based solutions are presented under technical requirements. In classical QFD model, low

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accuracy and high subjectivity are the primary deficiencies. To deal with this problem, the Grey Relational Analysis (GRA)-based QFD methodology is used in this study in order to prioritize the technical requirements with more objective and more accurate results.

The paper is organized as follows: Next section provides a literature survey for smart warehouses. The following section presents the applied methodology. In latter, an application is given, and the last section concludes the study.

LITERATURE REVIEW

Based on the literature research, it is observed that several studies have been performed on smart warehouses. In this section, some of these studies will be discussed.

RFID systems are the first technology that comes to mind when it comes to smart systems in warehouses. With these systems, operations such as warehouse entry-exit movements, warehouse unloading-loading, counting or transfer can be controlled. Yan et al. (2008) and Poon et al. (2009) discussed the RFID technology in the warehouse management system (WMS). WMS is one of the key issues in warehouse activity control and supply chain management. Röhrig and Spieker (2008) proposed a technique to monitor the manual transportation processes of goods in a warehouse to update the database automatically. Pulungan et al. (2013) presented an intelligent WMS which integrates computer systems, material handling equipment, storage equipment, and users. IoT can also be used in warehouse management. Yanhui (2013) discussed the RFID technology in IoT applications. Juntao and Yinbo (2016) introduced the IoT technology in warehouse operations and discussed the development trend of IoT in warehouse management. Zhu et al. (2016) examined the warehouse problems of a case company and presented solutions for warehousing activities with intelligent systems. Lee et al. (2017) proposed an IoT based WMS with an advanced data analytical approach using computational intelligence techniques to enable smart logistics for Industry 4.0. More recently, Liu et al. (2018) discussed how the techniques in cyber-physical systems facilitate building smart warehouses. The literature has a wide range of topics for researchers and practitioners that will form the basis of smart warehouses for systems such as RFID, IoT technology, sensors, data analytics, etc.

METHODOLOGY

Quality Function Deployment (QFD)

Yoji Akao introduced quality Function Deployment (QFD) in Japan in 1966. It started to be used with the Japanese Mitsubishi firm in 1972, it was explored and used in the USA after 1984, and today, it is a quality approach accepted all over the world. It is a method that analyzes customer needs and associates them with technical requirements. A central structure of QFD is the HOQ, and it includes the relationship matrix between customer needs and technical requirements, importance weights and correlation matrices. QFD helps to improve the existing processes, provides an objective definition of product or service quality and provides a competitive advantage.

In this study, the main objectives of the implementation of the QFD approach can be summarized as follows: (Chang & Kim, 2010)

1. Identification and prioritization of warehouse customer requirements for smart logistics
2. Transformation of these customer requirements into IoT-based technical characteristics
3. Delivering a design approach for smart logistics warehouses

The fundamental structure of the QFD is the House of Quality (HOQ). With HOQ "What's" and "How's" can be defined in a short time. The HOQ matrix is shown in Fig.1.

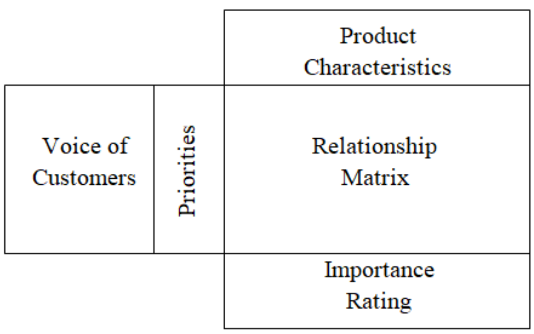

Fig.1. The HOQ matrix

In this study, in the HOQ matrix, the voice of the customer will be customer requirements for warehouses, priorities will be the importance of end-user needs, product characteristics will be IoT-based technical requirements. Relationship matrix shows the relationship between customer requirements and technical requirements.

The evaluation steps are summarized below.

Step 1- Identifying customer requirements for warehouses (CRs): In this step, we identified needs, which are presented on the left side of the HOQ as the "voice of the customer." These needs are identified by benefiting from literature researches.

Step 2- Identifying IoT-based technical requirements (TRs): After we created the voice of customers, namely "What's" in the first step, at this step we defined "How's" on HOQ about how "What's" will be presented.

Step 3- Developing relationship matrix between CRs and TRs: The third step in the preparation of the HOQ is the creation of the relationship matrix that indicates the extent to which the customer requirement influences each technical requirement. Then needs are scored from 1 to 9 according to their evaluations, where 1 is the lowest and 9 is the highest importance.

Step 4- Results and evaluations by using GRA methodology: After the relationship matrix is developed, GRA methodology is used to rank the TRs. The application steps of GRA methodology in QFD is described as follows.

Grey Relational Analysis (GRA) Methodology in Quality Function Deployment (QFD)

GRA is a method that combines quantitative and qualitative data, and it can produce more accurate results by eliminating the effects of personal prejudices. GRA specifies the relationship between each factor in a grey system and the factor considered as a reference for comparison. This is called the grey relational degree. The difference between GRA and other multi-criteria decision-making methods is that GRA can use reference series. The advantage of this method is that it can be implemented in a small data set and that the calculations are simple (Tayyar et al., 2014). Step 4 described below for implementing the GRA approach is detailed below (Chen & Chou, 2011), (Wei & Chuan 2013).

Step 4.1 – Creation of the decision matrix: In this study, the decision matrix for GRA was obtained by the relation matrix formed between TRs and CRs in QFD.

$$X = \begin{bmatrix} x_1(1) & x_1(2) & \dots & x_1(n) \\ x_2(1) & x_2(2) & \dots & x_2(n) \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ x_m(1) & x_m(2) & \dots & x_m(n) \end{bmatrix} \quad (1)$$

where $x_i(j)$ is the value of the number i customer requirement and the number j technical requirement.

Step 4.2 - Creation of reference series: The reference series to be determined in order to compare the factors in the decision problem is shown below in Eq. (2).

$$x_0 = \left(x_0(j)\right) \quad (2)$$

where $x_0(j)$ is the maximum value of the j^{th} criteria among the normalized values. Reference series is transformed to comparison matrix by adding the decision matrix as a first row.

Step 4.3 – Normalization of decision matrix: The normalization process is performed in 3 different ways according to the feature that the series has at the effect point for the objective function.

- Benefit type: If the larger series values are better for the objective function, Eq. (3) is used in the normalization process.

$$x_i^* = \frac{x_i(j) - min_j\, x_i(j)}{max_j\, x_i(j) - min_j\, x_i(j)} \tag{3}$$

- Defect type: If the smaller series values are better for the objective function, Eq. (4) is used in the normalization process.

$$x_i^* = \frac{max_j\, x_i(j) - x_i(j)}{max_j\, x_i(j) - min_j\, x_i(j)} \tag{4}$$

- Medium type or nominal-the-best: Eq. (5) is used for normalization of series values according to a specified optimal value.

$$x_i^* = \frac{x_i(j) - x_{0b}(j)}{max_j\, x_i(j) - x_{0b}(j)} \tag{5}$$

where $x_{0b}(j)$ is the optimal value which is the value of j^{th} criteria in the interval of $max_j\, x_i(j) \geq x_{0b}(j) \geq min_j\, x_i(j)$

After the normalization process, the decision matrix is transformed into a normalization matrix and denoted by X^*.

$$X^* = \begin{bmatrix} x_1^*(1) & x_1^*(2) & \dots & x_1^*(n) \\ x_2^*(1) & x_2^*(2) & \dots & x_2^*(n) \\ . & . & \dots & . \\ . & . & \dots & . \\ . & . & \dots & . \\ x_m^*(1) & x_m^*(2) & \dots & x_m^*(n) \end{bmatrix} \tag{6}$$

In this study, since the benefit status is concerned, Eq. (3) were used.

Step 4.4 - Calculation of the absolute value: The absolute difference between the compared series and the reference series is obtained by using the following formula.

$$\Delta_{0i} = |x_0^*(j) - x_i^*(j)| \tag{7}$$

Step 4.5 – Creation of grey relational coefficient matrix: The values of the grey relational coefficient matrix can be calculated with the below formulas. In these equations, δ is the distinguishing coefficient. The distinguishing coefficient δ is between 0 and 1. Generally, it is set to 0.5.

$$\gamma_{0i}(j) = \frac{\Delta_{min} + \delta\, \Delta_{max}}{\Delta_{0i}(j) + \delta\, \Delta_{max}} \tag{8}$$

$$\Delta_{max} = max_i\, max_j \Delta_{0i}(j) \tag{9}$$
$$\Delta_{min} = min_i\, min_j \Delta_{0i}(j)$$

Step 4.6 – Calculation of the grey relational degree: After the grey relational coefficient matrix is constructed, the grey relational degrees obtained by summing of each column for the TRs and multiplied by the CR column and the final priorities for the TRs are made.

APPLICATION

In this section, an application is examined in order to evaluate the implementation of IoT technology in the design processes of warehouses for smart logistics. In this example, customer requirements for warehouses and IoT -based technical requirements are determined by benefiting from literature research in order to evaluate the expectations of smart warehouses design and how these expectations can be responded to. The CRs and TRs are detected as follows based on the studies of Mueller (2018), Alyahya et al. (2016), Glockner et al. (2014), Univis (2018), Temesist (2018), Raymond Corporation (2015), Uzialko (2016), Chawla (2015), Vass (2018), Lucas Systems (2018), Craig (2016), Solutions (2018) and Cullen (2018).

Step 1 – Firstly, CRs are given as follows: Flawless customer service (CR1), Labor efficiency (CR2), Real-time visibility (CR3), Flexible warehousing (CR4), Energy efficiency (CR5), Adaptability (CR6) and Speedy and accurate delivery (CR7).

Step 2 – After the first step, the TRs formed by considering CRs are given as follows: Drones (TR1), Big data (TR2), RFID technology (TR3), Virtual reality applications (TR4), Container and pallet tracking system (TR5), Vision picking (TR6), Forklift tracking system (TR7), Automated Storage / Retrieval System (TR8), Radio Controlled Shuttle Rack Systems (TR9), Motion sensors for lighting and air conditioning (TR10), Smart lighting in horizontal space for barcode readers and forklifts (TR11), Warning or information signs on vertical surfaces and for warehouse shelves (TR12), Condition-based maintenance system (TR13), Voice picking (TR14), Robotic carts (TR15), Smart warehousing cloud (TR16), Shipping, location and return notifications by IoT devices (TR17) and Wearable IoT based devices (TR18).

Step 3 – In this step, firstly the HOQ matrix consisting of CRs and TRs was created. First, CRs were rated between 1 and 9, where 1 is the lowest and 9 is the highest. These evaluations are normalized and specified in the HOQ matrix. After evaluating the CRs, TRs were rated concerning each CR, between 1-9, where 1 is the low relationship, 3 is the medium relationship, and 9 is the high relationship. The relationship matrix of HOQ is given below in Table 1.

Table 1. The relationship matrix of HOQ

How's / What's	Importance	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10	TR11	TR12	TR13	TR14	TR15	TR16	TR17	TR18
CR1	0,1636	0	1	3	0	1	3	0	3	0	0	0	0	0	0	0	9	9	0
CR2	0,1455	1	0	3	9	1	9	0	9	3	0	0	1	1	3	9	0	0	3
CR3	0,1636	0	1	0	0	9	0	9	0	0	0	0	0	3	0	0	0	1	0
CR4	0,1455	3	9	3	3	1	3	1	3	1	0	0	0	9	0	0	3	1	1
CR5	0,0909	0	0	0	0	0	0	1	0	0	9	9	9	0	0	0	0	0	0
CR6	0,1273	1	3	1	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1
CR7	0,1636	9	1	9	1	1	9	0	3	0	0	0	0	0	0	1	0	0	0

As shown in Table 1, "Flawless customer service (CR1) ", "Real-time visibility (CR3)" and "Speedy and accurate delivery (CR7)" are determined as the three most important customer requirements for warehouses with the same importance degrees. After them, "Labor efficiency (CR2)" and "Flexible warehousing (CR4)" share the second place.

Step 4 – After the relationship matrix is developed, TRs are ranked by using GRA methodology with the steps proposed above in the Methodology section.

Step 4.1 – First, the decision matrix is constructed for GRA. In this step, the relationship matrix given above is formed the decision matrix.

Step 4.2 – The reference series is determined by using Eq. (2). In here, the maximum values of each column created the reference series. The matrix with the reference series is given below in Table 2.

Table 2. The matrix with the reference series

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10	TR11	TR12	TR13	TR14	TR15	TR16	TR17	TR18
Reference Series	9	9	9	9	9	9	9	9	3	9	9	9	9	3	9	9	9	3
CR1	0	1	3	0	1	3	0	3	0	0	0	0	0	0	0	9	9	0
CR2	1	0	3	9	1	9	0	9	3	0	0	1	1	3	9	0	0	3
CR3	0	1	0	0	9	0	9	0	0	0	0	0	3	0	0	0	1	0
CR4	3	9	3	3	1	3	1	3	1	0	0	0	9	0	0	3	1	1
CR5	0	0	0	0	0	0	1	0	0	9	9	9	0	0	0	0	0	0
CR6	1	3	1	1	0	0	0	1	1	0	0	0	0	0	0	1	0	1
CR7	9	1	9	1	1	9	0	9	0	0	0	0	0	0	1	0	0	0

Step 4.3 – In the third step, the decision matrix is normalized by using Eq. (3).

Step 4.4 – After the normalization, the absolute values are calculated by using Eq. (7).

Step 4.5 – In this step, the grey relational coefficient matrix is constructed by using Eq. (8)-(9). The grey relational coefficient matrix is given below in Table 3.

Table 3. The grey relational coefficient matrix

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10	TR11	TR12	TR13	TR14	TR15	TR16	TR17	TR18
CR1	0,33	0,36	0,43	0,33	0,36	0,43	0,33	0,43	0,33	0,33	0,33	0,33	0,33	0,33	0,33	1,00	1,00	0,33
CR2	0,36	0,33	0,43	1,00	0,36	1,00	0,33	1,00	1,00	0,33	0,33	0,36	0,36	1,00	1,00	0,33	0,33	1,00
CR3	0,33	0,36	0,33	0,33	1,00	0,33	1,00	0,33	0,33	0,33	0,33	0,33	0,43	0,33	0,33	0,33	0,36	0,33
CR4	0,43	1,00	0,43	0,43	0,36	0,43	0,36	0,43	0,43	0,33	0,33	0,33	1,00	0,33	0,33	0,43	0,36	0,43
CR5	0,33	0,33	0,33	0,33	0,33	0,33	0,36	0,33	0,33	1,00	1,00	1,00	0,33	0,33	0,33	0,33	0,33	0,33
CR6	0,36	0,43	0,36	0,36	0,33	0,33	0,33	0,36	0,43	0,33	0,33	0,33	0,33	0,33	0,33	0,36	0,33	0,43
CR7	1,00	0,36	1,00	0,36	0,36	1,00	0,33	1,00	0,33	0,33	0,33	0,33	0,33	0,33	0,36	0,33	0,33	0,33

Step 4.6 – After the grey relational coefficient matrix is constructed, the grey relational degrees are obtained by summing of each column for the TRs and multiplied by the CR column. The final results are given in Table 4.

Table 4. The final results

	TR1	TR2	TR3	TR4	TR5	TR6	TR7	TR8	TR9	TR10	TR11	TR12	TR13	TR14	TR15	TR16	TR17	TR18
Final Scores	0,464	0,456	0,489	0,452	0,459	0,569	0,449	0,572	0,456	0,394	0,394	0,398	0,450	0,430	0,435	0,460	0,451	0,456
Rank	4	8	3	9	6	2	12	1	7	16	16	15	11	14	13	5	10	7

When considering the technical requirements, "Automated Storage / Retrieval System (TR8)" is seen with the highest importance. AS / RS systems are one of the most important components for IoT-based warehouse design that perform storage, arrangement, evacuation and order collection of products through computers which will be very effective in saving energy and personnel in warehouses. The use of this system in storage will provide the maximum utilization of the storage volume. After that, "Vision picking (TR6)" shares the second place in the ranking of technical requirements. This application allows easy access to the place of order. It includes smart glasses which employees can see all the information they need to find the desired products in their retinas. Also, in continuation, "RFID technology (TR3)" seems the third most crucial technical requirement. By using this system, it will be possible to provide minimum or zero product damage and loss.

CONCLUSIONS

It is essential that the warehouses which are one of the most important parts of logistics are being changed and keeping up with the changes, as the developing technology, the changing customer needs and the need for real-time supply increase. Traditional processes are now beginning to take the place of the manual processes in warehouses to increase productivity, allow customized orders, and provide more accurate and timely delivery. In this process, the design of the warehouses under today's changes plays an important role. IoT technology, which is one of the most critical technology will be the technology that provides solutions to customer needs in the design of the warehouses and increases the quality and productivity.

This work suggests IoT-based warehouse design. Firstly customer requirements for warehouses were analyzed, and then technical requirements were created based on IoT technology. A literature review was conducted in the study, and a QFD model was created in this direction. The original QFD model is advanced by using GRA method in order to match CRs and TRs. The technical requirements of IoT-based warehouse design are prioritized by the GRA method. When designing IoT-based warehouses, "Automated Storage / Retrieval System (TR8)" is suggested as the most important technical requirement.

For future studies, Fuzzy QFD may be proposed to analyze more effectively uncertainty of the factors. By using different multi-criteria decision-making techniques, further studies could be done to enlarge the assessment. In addition to these, this study will be detailed by taking expert opinions in addition to literature research and will be applied to a real case study in future studies.

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AGILE SUPPLIER SELECTION IN DIGITAL SUPPLY CHAIN

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Abstract *– Today's competitive market necessitates supply chains to act and react faster and more flexible. Agile supply chains (ASCs) provide a quick response to the ever growing speed, uncertainty and complexity in today's market conditions. ASC basically refers to the use of quickness, flexibility, competency and responsiveness to manage how well supply chains operate on a daily basis, which constitute one of the main pillars of Digital Supply Chain (DSC). ASCs need to be highly flexible in order to reconfigure themselves quickly in response to changes in their environment. DSC provides this flexibility to act in such instances. The DSC is described as an intelligent best-fit technological system that is based on excellent communication capabilities of digital networks to synchronize the interaction between entities by making services more accessible with consistent, agile and effective outcomes. ASCs use updated information and real-time data to leverage current operations to improve the overall productivity and efficiency of the given entity. The determination of an appropriate agile supplier in the DSC environment provides greater benefits. The rapidly changing and highly uncertain market environment makes the selection of ASC service providers an extremely complex and vague problem. In order to find a solution to this complex decision, this study identifies suitable decision points in the process of ASCs supplier selection by considering the vagueness that affect the process. Intuitionistic Fuzzy Sets provide a powerful method to cope with uncertainty by considering the degree of membership and non-membership function as well as hesitancy. For this purpose, VIKOR technique is combined with Intuitionistic Fuzzy Sets in a Group Decision Making setting for effective evaluation of the most appropriate ASC supplier. The application of this decision-making approach is illustrated in a case study to validate the proposed methodology.*

Keywords – Agile Supply Chains, Digital Supply Chain, Supplier Selection, Group Decision Making, Intuitionistic Fuzzy Sets

INTRODUCTION

With each passing day, modern supply chains grow in complexity. Supply chains' functions are altered by the digital transformation, artificial intelligence, and augmented reality, beside others. In the past, the most effective form of supply chain management was considered to be the lean supply chain. However, Agile Supply Chains (ASCs), a new concept in the supply chain, is quickly emerging to substitute this often-over-used term. Nonetheless, many supply chain entities do not grasp or fail to understand the full concept and scope of agility. ASCs basically refer to the use of speed, flexibility, competency, and responsiveness to manage how well an entity operates on a daily basis. ASCs use updated information and real-time data to leverage current operations to improve the overall productivity and efficiency of the given entity.

Decision-making is a daily life activity which is mostly associated with selecting the best among many. During the past quarter-century, real-life decision-making has gained in popularity and complexity, which can be overcome by taking the impact of multiple criteria into account. Multiple-criteria decision-making (MCDM) methods are being developed to consider the impact of many criteria at the same time since the early 1970s. MCDM approaches are divided into Multi-Objective approaches and Multi-Attribute approaches. The fundamental difference among these is based on the determination of the alternatives. In Multi-Objective, the alternatives are not a fixed set but instead predetermined objectives are optimized subject to a fixed set of constraints. In Multi-Attribute, the set of alternatives are fixed and predetermined number of alternatives are evaluated against a set of criteria. A set of objects having common features are stated as a crisp set, in which

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the membership values are presented in binary terms. Crisp sets are insufficient to manage real problems, given the fuzziness in decision-making. Zadeh presented the concept of the fuzzy set theory (Zadeh, 1965), by assigning a degree of membership to each element with the help of a membership function generating a value between 0-1. Atanassov extended it into the Intuitionistic Fuzzy set theory by assigning degrees of membership, non-membership, and hesitancy to each element in the set (Atanassov, 1986). The Intuitionistic Fuzzy sets have been previously applied to several multi-criteria decision-making (MCDM) problems. They describe the fuzzy characters of things more comprehensively, and are more practical in dealing with uncertainty and vagueness than other theories. Moreover, most of the MCDM problems require more than one decision maker's (DM) participation. Hence, many are extended to a group decision making (GDM) environment (Büyüközkan & Göçer, 2017). VIKOR (VIse Kriterijumsa Optimizacija I Kompromisno Resenje) (Opricovic, 1998) is an advanced MCDM methodology with capabilities in selecting the best alternative. It is a compromise ranking method, which can offer a feasible solution to most of the MCDM problems. It looks for maximum "group utility" for the "majority" and minimum "individual regret" for the "opponent". Thus, Intuitionistic Fuzzy VIKOR approach is proposed in this paper to assess the ASC supplier alternatives. These aspects make the proposed methodology a very attractive tool for ASC supplier selection processes. As far as the authors are aware of, there is no study in the literature that uses the Intuitionistic Fuzzy VIKOR for ASC supplier evaluation.

This paper is structured as follows. Section 2 presents an overview of extant literature, followed in Section 3 by the detailed description of ASC criteria under DSC settings. The proposed methodology is presented in Section 4. Section 5 presents the case study results, illustrating the numerical values. The last section concludes the study with some future study suggestions.

ASC CRITERIA UNDER DSC ENVIRONMENT

This extensive review of literature uncovers a gap in supply chain area for ASC related publications on DSC environment. Presently, there is very few numbers of studies on DSC and as far as we know there are no academic studies explicitly discussing the ASC concept on DSC settings. There are some supply chain studies discussing DSC technologies and their applications in supply chains. The book named Managing Digital Enterprise (J. Xu, 2014) is one of the earliest to substantiate the DSC concept as a dedicated chapter. Another book discussing DSC in great detail is named as Digital Enterprise Transformation (Uhl & Gollenia, 2014). It is committed to present the combination of transformation ability and novel digital skills. The challenges and approaches in secure collaboration among partners are examined for DSCs to suggest a novel approach relying on the use of trust brokers and taint analyses (Bhargava, Ranchal, & Ben Othmane, 2013). The practice examples for new digital solutions and its illustration of how companies can have a role in digital access and digital delivery is presented in (Skilton, 2015). The criteria to evaluate ASC are comprehensively evaluated in (Büyüközkan & Arsenyan, 2009; Dursun, 2016). The latest studies explicitly presenting DSC concept deals with all aspect of it and offers frameworks and solution methodologies (Büyüközkan & Göçer, 2018b). Another study dealing with supplier selection in the context of DSC is done by (Büyüközkan & Göçer, 2018a). To the best of our knowledge, such a study has not yet been published in any literature.

ASC CRITERIA UNDER DSC ENVIRONMENT

Creating value for their supply chain in their operations and enabling digitalization to adopt company's values are essential components of firms' approach to become a truly DSC organization. When choosing their suppliers, they pay particular attention to the core benefits of DSC. Therefore, the widespread adoption of DSC will depend on the realization of the following critical success factors in Table 1.

Table 1. Critical Success Factors for ASC on DSC Environment

Criteria	**Description**
Alignment (C1)	Suppliers' strategic alignment on agility (Büyüközkan & Göçer, 2018b).
Collaboration (C2)	Suppliers' collaboration strategy under competitive and volatile environment (Büyüközkan & Göçer, 2018a).
Cost (C3)	Suppliers' marketability costs on agility (Büyüközkan & Arsenyan, 2009).
Customization (C4)	Suppliers' response to changing customer preferences quickly(Büyüközkan & Göçer, 2018a).
Flexibility (C5)	Scheduling or planning for an unforeseen development (Büyüközkan & Göçer, 2018b).
Integration (C6)	Suppliers' ability to integrate digital and non-digital ASC management (Büyüközkan & Göçer, 2018b).
Reputation (C7)	Suppliers' reputation in agile environment as management capability (Büyüközkan & Göçer, 2018b).
Reliability (C8)	Suppliers' reliability on consumers demand and delivery (Büyüközkan & Göçer, 2018a).
Speed (C9)	Suppliers' sensitivity to consumers demand and delivery speed (Büyüközkan & Arsenyan, 2009).
Technology (C10)	Suppliers' technologic capability (Dursun, 2016).

OVERVIEW OF INTUITIONISTIC FUZZY VIKOR METHOD

This section presents Intuitionistic Fuzzy VIKOR MCDM methodology. Let us denote D = {D1, D2, . . . , Dk) as a set of DMs, with their importance values λk for each Dk; $\sum_{k=1}^{K} \lambda_k = 1$. They evaluate the set of alternatives: A=$\{A_1, A_2, \ldots, A_m\}$, each assessed on n criteria {C1, C2, . . ., Cn}. Let $w = \{w1, w2, \ldots, wn\}$ denote the weights of criteria, where $wj \geq 0$, $j = 1, 2, \ldots, n$, and $\sum_{j=1}^{n} w_j = 1$. Assume that both the alternatives and criteria are in the form of Intuitionistic fuzzy values rated by DMs and weights of criteria and importance of DM are both unknown and need to be determined. Following linguistic variables in Table 2 are used in the evaluation process.

Table 2. Linguistic Variables

Linguistic Variables		Intuitionistic Fuzzy Values		
		μ	υ	π
Absolutely Low	AL	0.00	0.90	0.10
Very Low	VL	0.10	0.85	0.05
Low	L	0.25	0.60	0.15
Medium Low	ML	0.40	0.50	0.10
Fair	F	0.50	0.45	0.05
Medium High	MH	0.60	0.30	0.10
High	H	0.75	0.10	0.15
Very High	VH	0.90	0.05	0.05
Absolutely High	AH	1.00	0.00	0.00

The weights of the kth DM are obtained using Equation (1), adapted from (Boran, Genç, Kurt, & Akay, 2009). The alternatives are ranked using IF VIKOR method adapted from the studies of (Chatterjee, Kar, & Kar, 2013) and (Wan, Wang, & Dong, 2013).

The steps of the method for IF VIKOR MCDM are as follows.

Step 1: Define attributes and alternatives to assess them.

Step 2: Get DMs' judgments on each factor based on DMs' prior knowledge and expertise on the topics as a linguistic term.

Step 3: Determine the weights of DMs

Let Dk = (μ_k,v_k,π_k) be an IF number for rating of the k^{th} DM.

$$\lambda_k = \frac{\left[\mu_k+\pi_k\left[\frac{\mu_k}{1-\pi_k}\right]\right]}{\sum_{k=1}^{K}\left[\mu_k+\pi_k\left[\frac{\mu_k}{1-\pi_k}\right]\right]}, \text{ where } \sum_{k=1}^{K}\lambda_k=1 \quad (1)$$

Step 4: Aggregate individual Intuitionistic Fuzzy values into group Intuitionistic Fuzzy values for the alternatives. In this framework, the intuitionistic fuzzy weighted averaging (IFWA) operator is preferred. This operator has been first proposed in (Z. Xu, 2011).

Step 5: Calculate the Criteria Weights. Aggregate DMs judgment by IFWA on criteria and the use entropy to calculate criteria weights. The entropy weights and the final entropy weights are calculated according to the Equation (3) and (4):

$$r_{ij} = IFWA_{\lambda}\left(r_{ij}^{(1)}, r_{ij}^{(2)}, \dots, r_{ij}^{(3)}\right) = \lambda_1 r_{ij}^{(1)} \oplus \lambda_2 r_{ij}^{(2)} \oplus \dots \oplus \lambda_K r_{ij}^{(3)}$$

$$= \left(1-\prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_K}, \prod_{k=1}^{K}\left(\left(\upsilon_{ij}^{(k)}\right)^{\lambda_K}\right), \prod_{k=1}^{K}\left(1-\mu_{ij}^{(k)}\right)^{\lambda_K} - \prod_{k=1}^{K}\left(\left(\upsilon_{ij}^{(k)}\right)^{\lambda_K}\right)\right) \quad (2)$$

$$\overline{\overline{w_i}} = -\frac{1}{n\ln 2}\left[\mu_i \ln\mu_i + v_i \ln v_i - (1-\pi_i)\ln(1-\pi_i) - \pi_i \ln 2\right] \quad (3)$$

$$w_i = \frac{1-\overline{\overline{w_i}}}{n-\sum_{j=1}^{n}\overline{\overline{w_i}}} \qquad \text{where} \qquad \sum_{j=1}^{n} w_i = 1 \quad (4)$$

Step 6: Calculate the negative and positive ideal solutions:

Defining J_1 as the set of benefit criteria and J_2 as the set of cost criteria, A* is the positive ideal solution, and A- is the negative ideal solution,

$$A^* = \left(\widetilde{r_1^*}, \widetilde{r_2^*}, \dots, \widetilde{r_n^*}\right), \widetilde{r_j^*} = \left(\mu_j^*, v_j^*, \pi_j^*\right), \text{ j=1,2,..,n} \quad (5)$$

$$A^- = \left(\widetilde{r_1^-}, \widetilde{r_2^-}, \dots, \widetilde{r_n^-}\right), \widetilde{r_j^*} = \left(\mu_j^-, v_j^-, \pi_j^-\right), \text{ j=1,2,..,n} \quad (6)$$

Where

$$\mu_j^* = \left\{\left(\max_i\{\mu_{ij}\} \mid j \in J_1\right)\right\}, \left\{\left(\min_i\{\mu_{ij}\} \mid j \in J_2\right)\right\}$$

$$v_j^* = \left\{\left(\min_i\{v_{ij}\} \mid j \in J_1\right)\right\}, \left\{\left(\max_i\{v_{ij}\} \mid j \in J_2\right)\right\}$$

$$\mu_j^- = \left\{\left(\min_i\{\mu_{ij}\} \mid j \in J_1\right)\right\}, \left\{\left(\max_i\{\mu_{ij}\} \mid j \in J_2\right)\right\}$$

$$v_j^- = \left\{\left(\max_i\{v_{ij}\} \mid j \in J_1\right)\right\}, \left\{\left(\min_i\{v_{ij}\} \mid j \in J_2\right)\right\}$$

Step 7: Compute the group utility value and the individual regret value for each of the alternatives. The weighted Hamming distance is utilized to find the separation measures, as suggested in (Z. Xu, 2011);

$$S(A_i) = \sum_{j=1}^{n} w_j \frac{d(\hat{a}_j^*, \hat{r}_{ij})}{d(\hat{a}_j^*, \hat{a}_j^-)}, \quad (7)$$

$$R(A_i) = \max_{1\le j\le n}\left\{w_j \frac{d\left(\hat{a}_j^*, \hat{r}_{ij}\right)}{d\left(\hat{a}_j^*, \hat{a}_j^-\right)}\right\}, \quad (8)$$

$$d\left(\hat{a}_j^*, \hat{r}_{ij}\right) = \sqrt{\frac{1}{2}\left((\mu_j^* - \mu_{ij})^2 + (\upsilon_j^* - \upsilon_{ij})^2 + (\pi_j^* - \pi_{ij})^2\right)} \quad (9)$$

$$d(\hat{a}_j^*, \hat{a}_j^-) = \sqrt{\frac{1}{2}\left((\mu_j^* - \mu_j^-)^2 + (\upsilon_j^* - v_j^-)^2 + (\pi_j^* - \pi_j^-)^2\right)} \quad (10)$$

Step 8: Calculate the degree of closeness coefficients for each alternative.

$$Q(A_i) = \propto \frac{S(A_i) - S^*}{S^- - S^*} + (1-\propto)\frac{R(A_i) - R^*}{R^- - R^*} \quad (i=1, 2,\dots,m) \quad (11)$$

Where

$$S^* = \min_{1\le i\le m}\{S(A_i)\} \qquad R^* = \min_{1\le i\le m}\{R(A_i)\}$$

$$S^- = \max_{1\le i\le m}\{S(A_i)\} \qquad R^- = \min_{1\le i\le m}\{R(A_i)\}$$

Let $\propto$ be the maximum group utility weight. Accordingly, (1-$\propto$) is the individual regret weight, $\propto \in [0,1]$.

Step 9: Rank the web service alternatives in ascending order of the $Q(A_i)$, $S(A_i)$ and $R(A_i)$. This gives three lists that rank the $Q_{[.]}$, $S_{[.]}$ and $R_{[.]}$ values.

Subsequently, a compromise solution is proposed as the best alternative Q[1] with the minimum $Q(A_i)$ value, based on the ascending order $Q_{[.]}$, if the following conditions are met:

The proposed alternative (i.e. the minimum $Q(A_i)$) has a meaningful advantage over the second ranking alternative in the ranking list of $Q(A_i)$: Q[2]-Q[1] ≥ DQ.

$$DQ = \frac{1}{(i-1)} \tag{12}$$

The proposed alternative (i.e. the minimum $Q(A_i)$) has an acceptable stability, i.e. it also ranks 1st in the $S_{[.]}$ and $R_{[.]}$ lists. If any of these two conditions explained above is not met, then one single solution cannot be proposed. Instead, a set of compromise solutions will be determined, as follows; If the second condition is not met, the set consisting of the alternatives Q[1] and Q[2] is proposed. If the first condition is not met, the set consisting of Q[1], Q[1], … , Q[k] is proposed.

Where

Q[k] - Q[1]< DQ, Q[k] is the position of the alternative of maximum k in closeness.

APPLICATION OF THE PROPOSED APPROACH

A case study is presented here to examine the validity of the proposed evaluation method. The proposed methodology is applied to the Turkish Apparel Industry, which plays a significant role in the industrial development of the Turkish economy. With a comprehensive literature review (Büyüközkan & Arsenyan, 2009; Dursun, 2016) and consultation with three DMs, ten main ASCs supplier evaluation criteria are determined, as given in Table 2 to evaluate four suppliers. Following steps displays the outcome of the analysis.

Step 1. Three DMs, ten evaluation criteria and four alternatives are defined for evaluation process.

Step 2. DMs' judgments on each alternatives and criteria are given in linguistic terms as follows in Table 3 and Table 4, respectively.

Table 3. Linguistic Evaluation of Alternatives

	A1			A2			A3			A4	
1	2	3	1	2	3	1	2	3	1	2	3
F	H	ML	ML	AH	L	L	F	F	MH	AH	AH
ML	ML	H	VH	F	AH	VH	MH	AH	ML	VL	F
H	F	F	VH	L	F	ML	F	F	H	AH	F
ML	ML	L	F	F	VH	F	AH	H	VH	AH	MH
MH	H	F	F	H	F	VH	AH	AH	F	H	F
H	F	F	MH	VL	AL	AH	VH	AH	ML	VL	L
H	VH	L	ML	AL	L	VH	VH	L	H	VH	L
F	L	L	VH	AH	AH	H	MH	H	L	VL	AL
VH	F	VH	AH	AH	VH	AH	VL	VH	H	MH	VH
H	VL	VH	MH	VL	AH	VH	H	AH	H	AH	L

Table 4. Linguistic evaluation of criteria

Criteria	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
DM1	VL	L	VH	VL	VH	VL	AL	L	VH	AL
DM2	F	ML	VH	AL	MH	VL	L	ML	H	L
DM3	VL	L	L	VL	F	L	MH	L	ML	VL

Step 3. Each DM can have a different level of influence in the overall decision-making process. A sample calculation for the DM1 is shown below. You can see the importance weight of the three experts in Table 5.

$$\lambda_{DM2} = \frac{\left(0.95 + 0.05 * \frac{0.95}{0.95 + 0.00}\right)}{\left(0.95 + 0.05 * \frac{0.95}{0.95 + 0.00}\right) + \left(0.75 + 0.05 * \frac{0.75}{0.75 + 0.20}\right) + \left(0.90 + 0.05 * \frac{0.90}{0.90 + 0.05}\right)}$$

Table 5. Importance weights of the experts

	DM_1	DM_2	DM_3
Linguistic Terms	VI	EI	I
Weight	0.347	0.365	0.288

Step 4. DMs' opinions are aggregated by using the IFWA operator in Equation (10). Table 6 presents the main criteria aggregation of three DMs

Table 6. Aggregated matrix

	C1			C2			C3			C4			C5		
	μ	υ	π	μ	υ	π	μ	υ	π	μ	υ	π	μ	υ	π
A1	0.44	0.44	0.11	0.37	0.50	0.13	0.49	0.41	0.10	0.21	0.66	0.13	0.51	0.41	0.08
A2	0.59	0.29	0.11	0.74	0.14	0.12	0.51	0.32	0.17	0.53	0.32	0.15	0.47	0.42	0.10
A3	0.30	0.62	0.09	0.76	0.14	0.11	0.34	0.54	0.12	0.70	0.20	0.09	0.86	0.07	0.08
A4	0.81	0.12	0.07	0.23	0.65	0.12	0.72	0.19	0.09	0.78	0.12	0.10	0.47	0.42	0.10
	C6			C7			C8			C9			C10		
A1	0.49	0.41	0.10	0.57	0.28	0.15	0.23	0.69	0.08	0.67	0.17	0.16	0.53	0.32	0.16
A2	0.26	0.67	0.06	0.13	0.76	0.11	0.86	0.07	0.08	0.87	0.06	0.07	0.60	0.31	0.09
A3	0.86	0.06	0.07	0.64	0.18	0.18	0.57	0.34	0.09	0.73	0.15	0.11	0.77	0.12	0.11
A4	0.13	0.76	0.11	0.57	0.28	0.15	0.07	0.86	0.06	0.62	0.25	0.13	0.68	0.22	0.10

Step 5. Criteria Weights are calculated by procedure in step 5. First of all, individual judgments of DMs are fused into a GDM. Following Table 7 present the aggregated Intuitionistic Fuzzy values for all DMs.

Table 7. Aggregated GDM Matrix of Criteria

C1			C2			C3			C4			C5		
μ	υ	π	μ	υ	π	μ	υ	π	μ	υ	π	μ	υ	π
0.26	0.69	0.05	0.30	0.57	0.13	0.83	0.10	0.08	0.07	0.87	0.07	0.75	0.17	0.08
C6			C7			C8			C9			C10		
0.14	0.77	0.08	0.29	0.58	0.12	0.30	0.57	0.13	0.78	0.12	0.10	0.12	0.78	0.11

After that entropy weights are calculated as shown in Table 8. As obvious, C1 has the highest importance while C7 and C10 has the least.

Table 8. Criteria Weights

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10
Entropy	0.085	0.094	0.053	0.042	0.071	0.066	0.093	0.094	0.061	0.061
Final	0.097	0.094	0.108	0.109	0.098	0.099	0.096	0.092	0.101	0.106

Step 6. Table 9 lists the positive and negative ideal solutions calculated for each individual attribute.

Table 9. Positive and negative ideal solutions.

	C1			C2			C3			C4			C5		
	μ	υ	π	μ	υ	π	μ	υ	π	μ	υ	π	μ	υ	π
A^*	0.81	0.12	0.07	0.78	0.12	0.10	0.72	0.19	0.09	0.79	0.11	0.10	0.86	0.07	0.08
A^-	0.30	0.62	0.09	0.23	0.65	0.12	0.34	0.54	0.12	0.21	0.66	0.13	0.04	0.88	0.08
	C6			C7			C8			C9			C10		
A^*	0.86	0.06	0.07	0.64	0.18	0.18	0.86	0.07	0.08	0.87	0.06	0.07	0.77	0.12	0.11
A^-	0.13	0.76	0.11	0.13	0.76	0.11	0.07	0.86	0.06	0.62	0.25	0.13	0.53	0.32	0.16

Step 7. The group utility values and the individual regret value for each of the alternatives are calculated as shown in Table 10.

Table 10. Group utility and individual regret values

	A1	A2	A3	A4
$S(A_i)$	0.68	0.45	0.31	0.49
$R(A_i)$	0.11	0.10	0.11	0.10

Step 8. The closeness of each alternative is calculated with Equation (11).

$S^* = 0.27$ $S^- = 0.67$

$R^* = 0.09$ $R^- = 0.10$

Step 9. Ranking of alternatives in decreasing order for $Q(A_i)$, (i= 1,2,3,4,5), shows us that there is a set of compromise solutions for the best suitable choice. Table 11 present the ranking order and closeness coefficient values for each alternative.

Table 11. Ranking order and Closeness Coefficient

	A1	A2	A3	A4
$Q(A_i)$	1.00	0.22	0.51	0.46
Rank	1	4	2	3

CONCLUSION

In this study, an integrated method consisting of IVIF sets, VIKOR technique and GDM settings is proposed for an effective ASC supplier selection problem. In general, MCDM problems are to be handled with imprecise and uncertain data and the IVIF set theory is proven to be an adequate environment than other theories to deal with the case. That is why VIKOR under IVIF set environment is applied. In order to exemplify the proposed approach, a case study is used and empirical results are presented. The proposed methodology is expected to provide additional contributions and decision support to the entities in establishing effective ASCs on DSC environment. As the methodology is generic, it may assist different entities in having fitting decisions during the supplier selection process. The major contribution and the originality of the proposed study is its introduction of a novel VIKOR approach in GDM setting under IVIF sets environment for the first time to contemplate with the ASC supplier selection problem in the context of DSC concept.

As a further research direction, the proposed methodology can be extended for other types of selection processes. Further research can also focus on the extensions of the proposed methodology to other fuzzy environments with different MCDM problems based on classical fuzzy, IF or IVIF, and Pythagorean Fuzzy sets and compare the outcome by employing both subjective and objective weight assessments of the criteria.

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SMART TECHNOLOGY SELECTION FOR SMART WAREHOUSE

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Abstract *– In the logistics environment, advanced technologies, such as the Internet of Things, sensors, robotics, etc. entered our warehouses, which are not only indispensable in sorting centers but also even in the final-mile delivery. Amid these changes in the technology, smart systems in a warehouse are becoming ever critical for effective logistics services. Nowadays, smart systems are vital for error-free processes, reducing equipment damage, increasing productivity and efficiency, which mean a competitive advantage for the company. Considering the variety of smart products and their suppliers, companies that want to integrate smart technologies in their processes need to decide on the best supplier that matches their specific needs and expectations. This study focuses on the smart technology selection subject for the smart warehouse to address this research gap. A 2-Tuple Linguistic Model-based Axiomatic Design (AD) is developed for this selection problem. Key indicators are identified as decision criteria to be able to select the most appropriate smart technology. In this setting, a 2-Tuple-based SAW method is applied to designate the weights of the criteria. At this problem, 2-Tuple linguistic representation provides a flexible environment to the decision makers, and it enables the use of linguistic variables during evaluation. Furthermore, the AD suggests a consistent selection process with the minimum information required. This study contributes as the first-time application of 2-Tuple-based AD for a smart technology selection subject, and it provides a decision-making model to a smart system selection subject for a smart warehouse. A case study is conducted in order to test the applicability of the proposed methodology. This application covers the smart technology selection problems for a warehouse. Finally, the results of the case study are discussed, and the conclusions are provided.*

Keywords – Smart Technology Selection, Smart Supplier Selection, Multi-Criteria Decision Making, 2-Tuple Linguistic Model

INTRODUCTION

Thanks to new technological developments, more efficiency and optimization have been provided in logistic technologies. Amid different technologies, smart technologies become more and more indispensable for logistics services. They have been using to provide error-free processes, to reduce equipment damage and to provide efficiency. This advantageous utilization of smart systems contributes competitive advantage to the companies.

On the other hand, deciding the integration of this systems into the processes is a very complex operation where multiple criteria need to be evaluated. The needs and expectations of each company are different, and the integration process is unique for each company. It is essential to generate criteria accordingly to the companies needs and willing.

Besides, finding the most appropriate supplier for the smart technology is one of the critical points in this selection problem. Opportunities that the supplier have must have concordance with the company's needs. When the supplier and the company's system match, the cooperation is much more successful. For that propose, deciding the supplier as a first step is the backbone of the technology integration operation, and it could also be approached as a multi-criteria decision- making (MCDM) process.

This paper is motivated by this need for selecting the most appropriate supplier and the smart technology matching the company's needs. The main aim of this paper is to propose a generalized model for supplier and smart technology selection problem with MCDM tools. As a consequence, 2-Tuple linguistic model based Axiomatic Design (AD) have been proposed to apply for this selection problem.

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As a first step in the proposed methodology, critical indicators for technology supplier and a smart system selection have been detected with an in-depth literature review and Delphi-based group decision making (GDM). 2-Tuple-based Simple Additive Weighting (SAW) have been suggested to weight the detected criteria to use in the 2-Tuple AD.

First, the SAW has been suggested integrated with 2-Tuple to weight criteria considering its easy computational steps and quick calculations to obtain weights. Then AD has been proposed integrated with 2-Tuple to choose the most appropriate smart technology provider and the smart technology selection.

Finally, a real case study has been applied in order to test the plausibility of the suggested methodology. In this case study, two different selection problem has been applied: first is the smart technology supplier selection and the second one is the smart technology selection from the selected supplier.

The following of this paper is organized as in the next section; detailed literature review has been provided for the AD and Fuzzy Axiomatic Design (FAD) application subject. Later, in Section 3 suggested procedure for the selection problem have been given in details and with preliminaries. In Section 4 real case study for the proposed model have been provided with results and discussions. Finally, conclusions and acknowledgments have been given at the end.

LITERATURE REVIEW

Various studies have been proposed AD and FAD for different design and selection problems. Studies that have been applied AD or FAD in recent years have been provided in Table 1.

Table 5. Recent studies with AD and FAD

Reference	Subject
(Cebi & Kahraman, 2010)	Passenger car indicator design
(Ferrer, Rios, Ciurana, & Garcia-Romeu, 2010)	Designing a manufacturing model
(K. S. Lee et al., 2011)	Designing a chemical product
(Vinodh, 2011)	Designing an agile production system
(Hong & Park, 2014)	Designing a modular product
(Cebi, Celik, & Kahraman, 2010)	Ship design project approval mechanism
(Cebi & Kahraman, 2010)	Group decision support system
(Cicek & Celik, 2010)	Material selection problem
(Büyüközkan, 2012)	Green supplier evaluation
(Büyüközkan, Arsenyan, & Ruan, 2012)	Personal digital assistant selection
(Atalay & Eraslan, 2014)	Electronic device evaluation for customer use
(Buyukozkan, Karabulut, & Arsenyan, 2017)	RFID service provider selection
(Buyukozkan & Gocer, 2017)	Supplier selection problem
(Ijadi Maghsoodi, Hafezalkotob, Azizi Ari, Ijadi Maghsoodi, & Hafezalkotob, 2018)	Selection of waste lubricant oil regenerative technology
(Kahraman, Cebi, Onar, & Oztaysi, 2018)	Landfill site selection
(Khandekar & Chakraborty, 2018)	Cotton fiber selection
(Seiti, Hafezalkotob, & Fattahi, 2018)	Maintenance strategy selection

In this study, 2-Tuple integrated AD have been proposed for the first time for the technology supplier and the smart system selection problem. The proposed methodology will be presented in the next section with details.

METHODOLOGY

MCDM tools are accurate and robust models to solve a decision-making problem with multi-criteria. In this study, the smart technology provider and smart technology selection problem has been approached as MCDM, and the computational phases for each problem have been divided into two phases.

The first phase is the preparation for the MCDM tool application. This phase covers the selection of experts and gathering necessary information from experts and literature. Moreover, in this phase decision criteria will be weighted with the 2-Tuple integrated SAW.

The second phase is the application of the proposed MCDM tool. In this case, it is the 2-Tuple integrated AD to choose the most appropriate smart technology provider and technology. The detailed steps of the suggested methodology are represented in Figure 1.

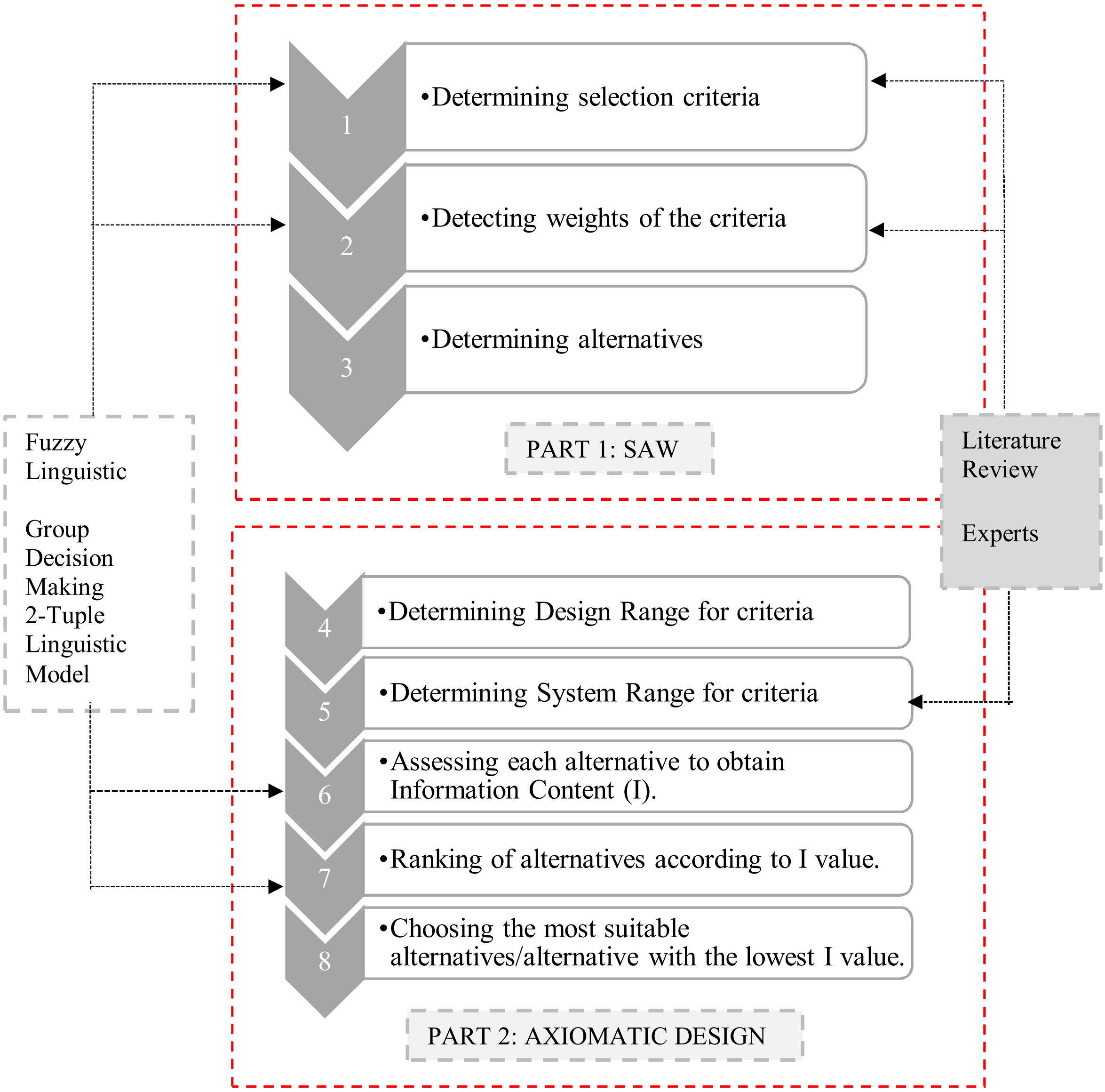

Figure 2. Main steps of the suggested technique

Preliminaries

In this study, AD and SAW techniques have been proposed with their 2-Tuple linguistic model extension. Basic properties of 2-Tuple Model and general formulations of the offered methodology are provided in this section.

2-Tuple Linguistic Model

Definition 1(Martínez, Rodriguez, & Herrera, 2015)*:* First linguistic term sets have converted into 2-Tuple form by adding zero value as in the following relation:

$$S_i \epsilon\ S \implies (S_i, 0) \tag{1}$$

where S is the linguistic term set.

Definition 2(Martínez et al., 2015)*:* The 2-Tuple fuzzy linguistic representation model represents the linguistic information using a 2-Tuple (S, α), where S is a linguistic label and α is a numerical value. The formulation is as follows:

$$\Delta_S\colon\ [0, g] \longrightarrow \bar{S}$$

$$\Delta_S(\beta) = (S_i, \alpha), with \begin{cases} i = round\ (\beta) \\ \alpha = \beta - i \end{cases} \quad (2)$$

Moreover, the reverse function is as in (3):

$$\Delta_S{}^{-1}\colon\ \bar{S}\ \longrightarrow [0, g]$$
$$\Delta_S{}^{-1}(\beta) = i + \alpha \quad (3)$$

Definition 3(Martínez et al., 2015)*:* Linguistic Hierarchies is one of the helpful tools of 2-Tuple Model to aggregate and normalize different granulated data into one homogeneous form. Following relation is for the transformation of LH is from t^{th}level to t'^{th} level:

$$TF_{t'}^{t}\left(S_i^{n(t)}, \alpha^{n(t)}\right) = \Delta\left(\frac{\Delta^{-1}\left(S_i^{n(t)}, \alpha^{n(t)}\right).(n(t') - 1)}{n(t) - 1}\right) \quad (4)$$

where TF is the transformation function, S is a linguistic label and $\alpha$is a numerical value that represents the value of the symbolic translation.

Axiomatic Design

The AD is a design technique firstly introduced by Suh (Suh, 1998). It contributes the chance to measure how system capabilities with minimum information required can meet functional requirements (FRs). It uses two axioms: the first one is the independence axiom, which sets out that FRs must be independent, and the second one is the information axiom, which sets out that the design with the minimum information content is better than all the other designs that satisfy the Function Requirements (FRs) (Suh, 1998).

Related formulations are represented as followings:

$$I_i = log_2\left(\frac{1}{p_i}\right) \quad (5)$$

where I_i represents the information content of a design with a probability of success p_i. In classic AD probability functions used to calculate I value; but in FAD, triangular fuzzy values are used to calculate I value. Figure 2 represents the triangular form for system ranges and design ranges.

Information content in a fuzzy environment is;

$$I_i = \begin{cases} \infty, & no\ intersection \\ log_2\left(\frac{area\ of\ the\ system\ range}{common\ area}\right), & otherwise \end{cases} \quad (6)$$

Total weighted information content for the main criteria is calculated by;

$$I = \sum_{i=1}^{n} w_i\, I_i \quad (7)$$

where w_i value is weight assigned to the criteria.

CASE STUDY

Today, we are talking about advanced robotics and connected systems. In the logistics environment, advanced technologies, such as the Internet of Things, sensors, robotics, etc. entered our warehouses, which are not only indispensable in sorting centers but also even in the final-mile delivery. Amid these changes in the technology, efficient smart systems in a warehouse are becoming ever critical for effective logistics services. Nowadays, smart systems are vital for error-free processes, reducing equipment damage, increasing productivity and efficiency, which mean a competitive advantage for the company.

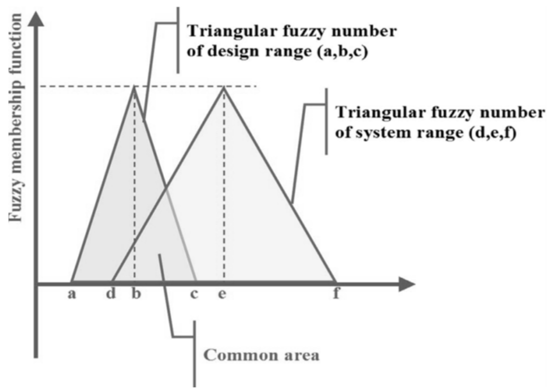

Figure 3. Fuzzy Axiomatic Design Areas (Buyukozkan et al., 2017)

In this section, a real case study has been applied to the logistics sector. First a smart technology supplier selection then a smart technology selection has been applied to a smart warehouse.

Computational Steps

Smart Technology Provider Selection

Step 1: Determining selection criteria with sector experts to make an appropriate smart technology provider selection. Determined criteria have been given in Table 2 with their detected weights.

Table 6. Criteria for smart technology supplier selection

Evaluation Criteria	Weight	
Supplier's Smart Product Characteristics	0,125	C1
Supplier's Smart Product Functionality	0,209	C2
Cost	0,245	C3
After Sale Services	0,265	C4
Brand Reliability	0,156	C5

Step 2: Selection of linguistic scales for experts and determining criteria weights with the 2-Tuple integrated SAW as represented in Table 2. Also, linguistic scales provided for experts have been given in Figure 3.

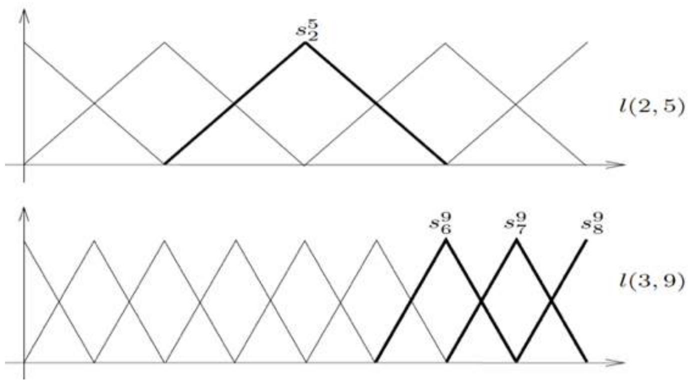

Figure 4. Second level five-scaled (None-Low-Equal-High-Perfect) and the third level nine-scaled (None-Very Low-Low-Almost Equal-Equal-Almost High-High-Very High-Perfect) hierarchy of letters

Two experienced experts have been evaluated with nine scaled labels, and the third one has been assessed in five scaled labels accordingly to their experience about the subject.

Step 3: Determining alternatives. Because of anonymousness of alternatives, their company name is not mentioned in the selection problem. Three different smart technology provider alternatives have been detected for this problem.

Step 4: Selecting the most appropriate smart technology supplier alternative with 2-Tuple-based AD.
Design ranges (DRs) and system ranges (SRs) have been assigned, and AD computational steps have been followed, after obtaining experts evaluations. Design range linguistic scale is as in Table 3.

Table 7. Linguistic scale for DRs

	Abbreviations	Fuzzy Number		
At least very low	LVL	0	1	1
At least low	LL	0,05	1	1
At least medium low	LML	0,1	1	1
At least almost medium	LAM	0,35	1	1
At least medium	LM	0,45	1	1
At least medium-high	LMH	0,6	1	1
At least high	LH	0,7	1	1
At least very high	LVH	0,8	1	1
At least perfect	LP	0,9	1	1

First non-homogeneous data have been normalized under nine scaled linguistic data with (4). Three assessment of experts have been aggregated with Weighted Aggregation Operator (OWA):

$$\vec{x} = \left(\frac{\sum_{i=1}^{n} \Delta^{-1}(r_i, \alpha_i) \times \Delta^{-1}(w_i, \alpha_i)}{\sum_{i=1}^{n} \Delta^{-1}(w_i, \alpha_i)} \right) \quad (8)$$

The final aggregated decision matrix is given in Table 4, and furthermore, Table 5 gives the weighted I values for the AD calculated with (7). Since only A1 supplies information required for each criterion. It is the best choice for this decision-making problem.

Table 8. Aggregated decision matrix for smart technology supplier selection

Criteria	C. IMP.	A1	A2	A3
Supplier's Smart Product Characteristics	0,11	(S7,0,12)	(S6,0,02)	(S5,-0,37)
Supplier's Smart Product Functionality	0,16	(S6,0,02)	(S5,0,36)	(S5,-0,37)
Cost	0,26	(S7,0,12)	(S6,0,02)	(S6,0,02)
After Sale Services	0,22	(S7,0,12)	(S5,-0,37)	(S3,0,34)
Brand Reliability	0,15	(S7,0,12)	(S6,0.02)	(S3,0,34)

Smart Technology Selection
Same steps have been followed for this selection problem. As a result, from supplier selection problem, first alternative have been chosen as a smart technology supplier. Its smart technologies have been assessed as alternatives. Four different alternatives have been detected for this problem. The same methodology has been applied to smart technology selection for a smart warehouse.

Table 9. Weighted I value for each alternative

Criteria	Design Range	A1	A3	A4
Supplier's Smart Product Characteristics	LMH	0,35	0,66	∞
Supplier's Smart Product Functionality	LMH	1,10	0,60	∞
Cost	LMH	0,69	1,28	1,28
After Sale Services	LM	0,66	∝	1,14
Brand Reliability	LH	0,51	0,35	2,22

As first step criteria have been detected to evaluate smart technology alternatives. They have been evaluated according the five different criteria such as (A. H. Lee, 2009; Liu & Wang, 2009; Sanayei, Mousavi, & Yazdankhah, 2010): Smart technology's price (C1), Smart technology's functionality (C2), Adaptability for future (C3), Processing speed(C4) and Technological level (C5). Its aggregated final decision matrix and final weighted I valued have been given Table 6.

Table 10. Final decision matrix and weighted I values for smart technology selection

	Aggregated Decision Matrix					Weighted I Values			
	Design Range	ST1	ST2	ST3	ST4	ST1	ST2	ST3	ST4
C1	LM	(S6,0,02)	(S1,0,22)	(S5,-0,37)	(S6,0,02)	0,06	∞	∞	0,06
C2	LH	(S6,0,02)	(S6,0,02)	(S7,-0,35)	(S7,-0,35)	0,14	0,14	∞	∞
C3	LML	(S5,-0,37)	(S6,0,02)	(S7,-0,35)	(S7,-0,35)	0,77	∞	∞	∞
C4	LM	(S5,-0,37)	(S7,-0,35)	(S6,0,02)	(S3,0,34)	0,02	0,02	0,12	0,26
C5	LM	(S5,-0,37)	(S7,-0,35)	(S7,-0,35)	(S8,-0,24)	0,01	0,01	0,01	0,05

Finally, as a result of this two-leveled selection problem. The first alternative has been chosen as the most suitable smart technology supplier for the company. Moreover, at the second level, the smart technology selection problem has been applied to the proposed methodology, and the first alternative has been selected as the most suitable one for the company.

CONCLUSIONS

New technological developments brought about a vast industrial challenge called Industry 4.0. Within Industry 4.0, great necessity to adopt new technologies into existing systems was born. In order to catch this new system adaptation choosing to right supplier and smart technology is the most critical issue. Due to that importance, this paper aims to approach this adaptation process as an MCDM system.

For that approach, two different tools integrated new decision-making model have been proposed. In this model SAW and AD, techniques have been suggested to deliver a robust selection. Furthermore, to supply flexibility to the decision makers, these two methods have been integrated with 2-Tuple Linguistic Model.

First 2-Tuple SAW is used to generate weights of criteria, then the 2-Tuple AD is used to select the most appropriate smart technology supplier and smart technology. To test the plausibility of the suggested techniques, it has been applied to a real case where a company wants to integrate a smart technology to its smart warehouse. Both supplier and technology selection have been applied accordingly to the suggested model.

For further studies, comparison of different methodologies with same application area will be made in order to test the applicability of the proposed model. Besides, sensitivity analysis could be provided, to see the real effects of criteria weights on the results.

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CLOUD COMPUTING TECHNOLOGY SELECTION FOR SUPPLY CHAINS

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Abstract *– Cloud Computing (CC) is a trending topic nowadays. It has become a widely used concept and a catchy buzzword in almost every industry. However, many businesses have not yet fully understood the term and its implications on their business line. Different perceptions in the literature exist with regards to CC. The U.S. National Institute of Standards and Technology (NIST) defines CC as a ubiquitous, convenient and on-demand network model that possess access to a common pool of adjustable computing resources such as networks, servers, storage, etc. that can be quickly provisioned and released with minimal provider interaction. With its adjustable, on-demand network models, the CC technology attracts businesses. It has several advantages, such as no up-front investments, lowered operational costs, scalability, easy access, and flexibility. These advantages help businesses to gain a competitive advantage over competitors by enhancing their cost structure and operational efficiency. Furthermore, CC can be a handy and innovative way to gain a competitive edge as it can optimize the processes in the supply chain management (SCM). Before starting to use cloud SCM systems, businesses struggle to select the most suitable CC technology. For this purpose, companies first identify their technical requirements for the needed system. CC technology selection is a vital decision for a company. To this end, this study proposes a new CC technology selection framework for supply chains (SC) that is necessarily a fuzzy logic-based EDAS method. The CC technology requirements are identified first with a literature review and opinions of industry specialists to apply this methodology. Then, the proposed Fuzzy-EDAS method is applied to select the most appropriate CC technology provider for an SC company. To test the applicability of the integrated method, a short case study is presented for a company from Turkey, and the results are evaluated.*

Keywords – Cloud computing, Cloud computing technology selection, Fuzzy-EDAS, Group decision making

INTRODUCTION

Shortly cloud computing technology (CCT) is a model to empower universal, advantageous, on-demand network access. It is accessible to a shared pool of build-up computing resources which can be easily maintained (Mell & Grance, 2011). CCT enables businesses to move their simple computing tasks to remote servers. This transformation process results in an investment cost. Specialization of third party service providers that focus on defined tasks with related equipment and human resources can provide more affordable and high-quality services.

Besides choosing the best third party supplier for the company, choosing the most appropriate CCT for the business is also possess a critical role for the competitive advantage. Therefore, CCT offering products need to be well assessed with its negative and positive properties.

Also, in the logistics sector where supply chains are the backbone of the system, their integration with a CCT system is an essential advantage in the market. In a global market, the internet contributes to various opportunities that cause a technology-driven competitive advantage(Hazen, Allison Jones-Farmer, Cegielski, & Wu, 2012). IT is a very well accepted critical resource for a successful supply chain management (SCM). It augments the supply chain's performance, and it provides better planning(Boyer & Hult, 2005; Giménez & Lourenço, 2008).

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Nevertheless, companies struggle with complicated e-SCM systems that can diminish the efficiency of the organization. Hence, the adoption of the right CCT for SCM is very critical, and this importance motivates this study.

Since various criteria must be evaluated to obtain a better assessment of CCT, this process could be approached as a multi-criteria decision-making (MCDM) problem. This study proposed a new combined MCDM methodology for a CCT provider selection. For that propose, first, an in-depth literature review has been made to gather key index criteria to choose the CCT provider. Simple Additive Weighting Method (SAW) have been suggested to weigh the criteria and to be able to make the selection EDAS method has been proposed.

Both SAW and EDAS method have been used with their fuzzy extensions to better deal with uncertainties and to create flexible decision-making environments for decision makers (DMs).

SAW method is one of the oldest weighting methods that is based on weighted average(Hwang & Yoon, 1981). An evaluation score is calculated for each alternative by multiplying the scaled value given to the alternative of that attribute with the weights of relative importance directly assigned by decision maker followed by summing of the products for all criteria (Afshari, Mojahed, & Yusuff, 2010). Enabling a proportional linear transformation of the raw data is the advantage of this method.

EDAS method has been first introduced by Ghorabaee et al. in 2015(Keshavarz Ghorabaee, Zavadskas, Olfat, & Turskis, 2015). It uses the average solution to examine the alternatives. Negative Distance from Average (NDA) and Positive Distance from Average (PDA) are attended as the appraisal for this method.

Both methods' fuzzy extension has been generated and applied to various MCDM problems. In this study, two methods have been combined to provide a robust and secure CCT selection problem.

The organization of this paper is as follows: the next section gives a literature review about CCT evaluation criteria and EDAS tool. Latter provides the detailed steps of the proposed methodology with preliminaries. Afterward, the case study application is provided, and finally, conclusions are given at the end.

LITERATURE REVIEW

There are different variety of cloud technologies available for users. Hence, the literature has been broadly motivated by related problems with this subject. For example, a new model has been developed by Li et al. to evaluate the reliability of cloud services(Zecheng Li, Liao, Leung, Li, & Li, 2017). In this study, the importance of confidentiality, integrity, auditability, and availability have been emphasized. Furthermore, Bose at al. have proposed trust related factors as evaluation criteria for CCT(Bose, (Robert) Luo, & Liu, 2013). Also, Manuel has suggested assessing trust related issues with the following parameters: availability, reliability, turnaround efficiency and data integrity(Manuel, 2015).

On the other hand, the cost dimension is essential for the companies, it has various dimensions, and it should be considered with all its characteristics to make the correct evaluation of IT infrastructure alternatives (Menzel, Schönherr, & Tai, 2013). A wide variety of authors proposes investment, maintenance, integration and flexibility as the cost dimensions.

Another issue addresses in the literature about CCT is the service quality. It has three different dimensions such as service stability, SLA (Service-Level-Agreement) management, and enriched content(Garg, Versteeg, & Buyya, 2013; Zheng Li, O'Brien, Zhang, & Cai, 2012).

Moreover, vendor-related criteria are also very essential for evaluation. It covers the capacity and ability of the vendor in related product besides with vendor's reputation(Ghosh, Ghosh, & Das, 2015).

In literature, when it comes to management services, different components such as deployment, configuration, billing, reporting, and monitoring exist(Zheng Li et al., 2012).

According to the literature review, this study has grouped CCT assessment criteria. Criteria and sub-criteria have been given in Table 1.

Table 11. Evaluation attributes for CCT

1st level criteria	2nd level criteria
Cost	Investment cost Maintenance cost Flexibility cost Support cost Integration cost
Service quality	SLA management Service stability Enriched content
Vendor-related	Vendor reputation Experience in related product
Management services	Billing Monitoring Reporting
System qualifications	Communication Computation Memory Speed
Cloud security	Confidentiality Availability Multi-tenant trust

EDAS Method and Its Applications

In this study, the fuzzy extension of EDAS has been used to select among the different CCT providers. In literature, the same method has been suggested for a different variety of selection problems with its various fuzzy extensions. Table 2 shows the works that have applied the EDAS method in recent years.

Table 12. Recent EDAS studies and their application areas

Reference	Application Area
(Stevic, Vasiljevic, Zavadskas, Sremac, & Turskis, 2018)	Selecting the most suitable manufacturer of PVC carpentry for the apartment refurbishing
(Ren & Toniolo, 2018)	Developing a life cycle sustainability decision-support framework for ranking hydrogen production pathways
(Keshavarz-Ghorabaee, Amiri, Zavadskas, Turskis, & Antucheviciene, 2018)	Subcontractor evaluation
(Keshavarz Ghorabaee, Amiri, Zavadskas, & Antucheviciene, 2018)	Construction equipment evaluation with sustainability considerations
(Karasan & Kahraman, 2018)	Interval-valued neutrosophic EDAS for prioritization of UN's goals
(Ilieva, 2018)	New GDM approach proposition
(Turskis, Morkunaite, & Kutut, 2017)	Cultural heritage item preservation, renovation, and adaptation
(Keshavarz Ghorabaee, Amiri, Zavadskas, Turskis, & Antucheviciene, 2017b)	Supplier evaluation and order allocation with environmental considerations with type-2 fuzzy sets
(Keshavarz Ghorabaee, Amiri, Zavadskas, Turskis, & Antucheviciene, 2017a)	Service quality evaluations in airlines
(Keshavarz Ghorabaee, Amiri, Zavadskas, Turskis, & Antucheviciene, 2017c)	Stochastic EDAS method for multi-criteria decision-making with normally distributed data
(Keshavarz Ghorabaee, Amiri, Zavadskas, & Turskis, 2017)	Interval type-2 fuzzy sets integrated EDAS for subcontractor selection
(Keshavarz Ghorabaee, Zavadskas, Amiri, & Turskis, 2016)	Supplier selection in the fuzzy environment

METHODOLOGY

This paper approached CCT provider selection as the MCDM problem, and Fuzzy EDAS (F-EDAS) have been suggested for the selection methodology. The offered methodology consists of 2 phases.

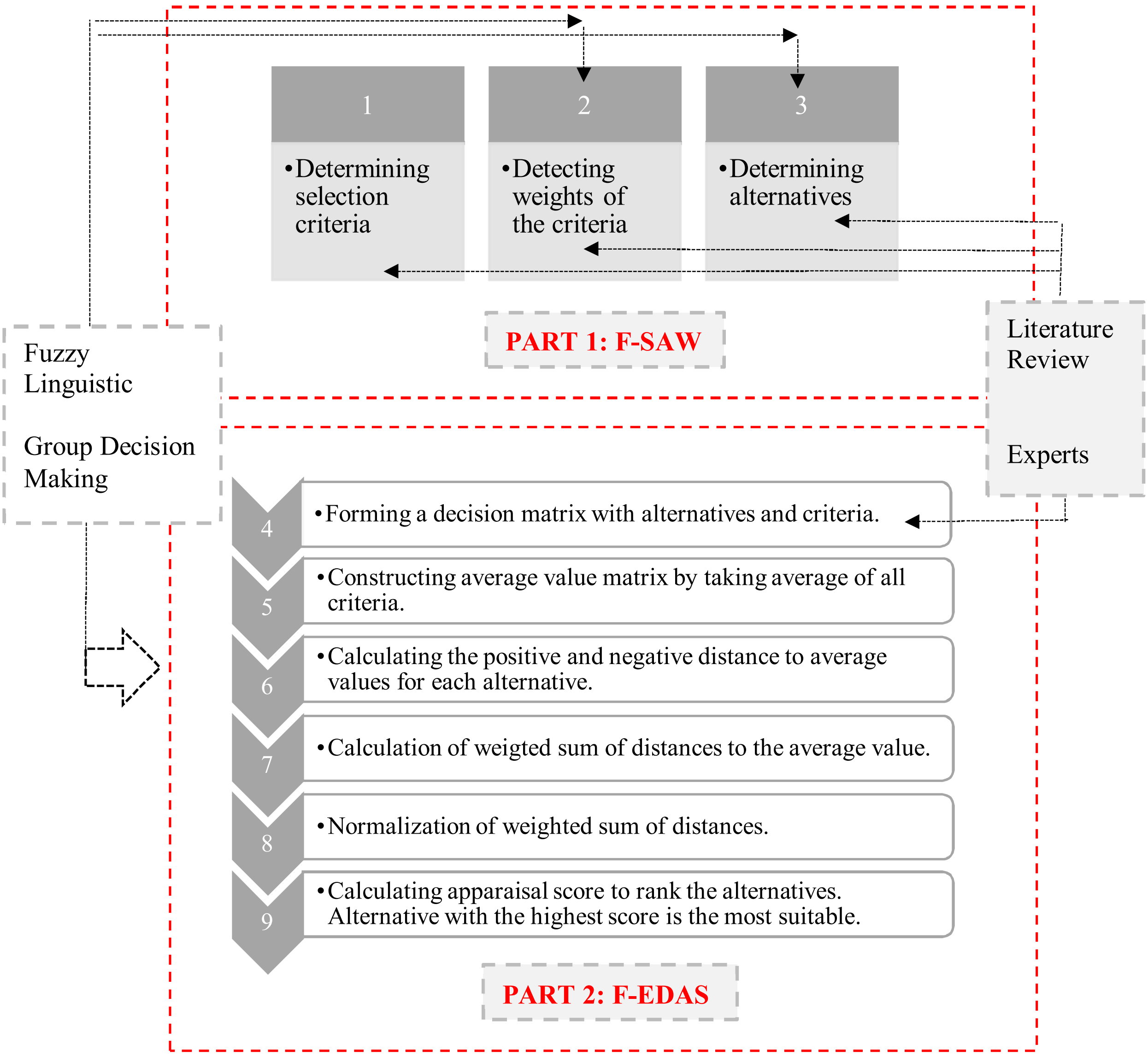

Figure 5. Detailed steps of the proposed methodology

The first phase covers the preparation before the selection. The weighting of the detected criteria will be done at this stage with the fuzzy SAW (F-SAW). Each DM will assess criteria detected with an in-depth literature review, and their ranking will be obtained at the end of this phase.

Later in the second phase, F-EDAS will be applied to choose the most appropriate CCT provider. In this stage, aggregation of different experts' opinion has been applied by taking the average of DMs evaluations. Detailed steps of the suggested technique are represented in Figure 1.

Preliminaries

Fuzzy extension of MCDM tools have been suggested in this study. Basic operations from fuzzy logic(Zadeh, 1976) have been used to make calculations. General operations for F-EDAS application are as follows (Keshavarz Ghorabaee et al., 2016):

Definition 1: A trapezoidal fuzzy number's (TFN) membership function is defined as follows:

$$\mu_{\tilde{A}} = \begin{cases} (x-a_1)/(a_2-a_1) & a_1 \leq x \leq a_2 \\ 1 & a_2 \leq x \leq a_3 \\ (a_4-x)/(a_4-a_3) & a_3 \leq x \leq a_4 \\ 0 & otherwise \end{cases} \quad (1)$$

Definition 2: $\tilde{A} = (a_1, a_2, a_3, a_4)$ and $\tilde{B} = (b_1, b_2, b_3, b_4)$ are TFNs and k is a crisp number. The arithmetic operations with these numbers are defined as follows:

Addition:

$$\tilde{A} \oplus \tilde{B} = (a_1 + b_1, a_2 + b_2, a_3 + b_3, a_4 + b_4) \quad (2)$$

$$\tilde{A} + k = (a_1 + k, a_2 + k, a_3 + k, a_4 + k) \quad (3)$$

Subtraction:

$\tilde{A} \ominus \tilde{B} = (a_1 - b_1, a_2 - b_2, a_3 - b_3, a_4 - b_4)$ (4)

$\tilde{A} - k = (a_1 - k, a_2 - k, a_3 - k, a_4 - k)$ (5)

Multiplication:

$\tilde{A} \otimes \tilde{B} = (a_1 \times b_1, a_2 \times b_2, a_3 \times b_3, a_4 \times b_4)$ (6)

$$\tilde{A}/k = \begin{cases} (a_1 \times k, a_2 \times k, a_3 \times k, a_4 \times k) & if\ k > 0 \\ (a_4 \times k, a_3 \times k, a_2 \times k, a_1 \times k) & if\ k < 0 \end{cases} \quad (7)$$

Division:

$\tilde{A} \oslash \tilde{B} = (a_1/b_1, a_2/b_2, a_3/b_3, a_4/b_4)$ (8)

$$\tilde{A}/k = \begin{cases} (a_1/k, a_2/k, a_3/k, a_4/k) & if\ k > 0 \\ (a_4/k, a_3/k, a_2/k, a_1/k) & if\ k < 0 \end{cases} \quad (9)$$

Definition 3: Defuzzified value of a TFN $\tilde{A}$ can be defined as follows:

$$\kappa(\tilde{A}) = \frac{1}{3}\left(a_1 + a_2 + a_3 + a_4 - \frac{a_3 a_4 - a_1 a_2}{(a_1 + a_1) - (a_1 + a_1)}\right) \quad (10)$$

CASE STUDY

The viability and the effectiveness of the framework will be tested with a case study application. An SME faced with the difficulties of choosing an efficient cloud computing technology provider and spent much time on this issue. To meet the needs of a customer, CCT evaluation criteria will be used to make a CCT provider selection. For this purpose:

Step 1: First, three DMs have been gathered to set up a decision-making group. Criteria have been settled as it is mentioned in Table 1.

Step 2: Linguistic scales have been given and explained to DMs, and they have made their assessments to identify criteria weights. Table 3 represents the linguistic scale, and Table 4 gives the related importance of criteria.

Table 13. Linguistic scaled for DMs (Kahraman et al., 2017)

Linguistic Term	Abbreviation	Fuzzy Scale			
Absolutely High	AH	0,80	0,90	1,00	1,00
Very High	VH	0,70	0,80	0,80	1,00
High	H	0,50	0,60	0,70	0,80
Equal	E	0,40	0,50	0,50	0,60
Low	L	0,20	0,30	0,40	0,50
Very Low	VL	0,10	0,20	0,20	0,30
Absolutely Low	AL	0,00	0,00	0,10	0,20

Table 14. Weights obtained from F-SAW

1st Level Criteria	Weight	2nd Level Criteria	Weight
Cost	0,191	Investment Cost	0,254
		Maintenance Cost	0,124
		Flexibility Cost	0,241
		Support Cost	0,268
		Integration Cost	0,113
Service Quality	0,199	Sla Management	0,233
		Service Stability	0,417
		Enriched Content	0,350
Vendor Related	0,085	Vendor Reputation	0,391
		Experience In Related Product	0,609
Management Services	0,157	Billing	0,485
		Monitoring	0,258
		Reporting	0,258
System Qualifications	0,163	Communication	0,434
		Computation	0,162
		Memory	0,118
		Speed	0,285
Cloud Security	0,205	Confidentiality	0,359
		Availability	0,462
		Multi-Tenant Trust	0,179

Step 3: Alternatives have been identified. First, eight CCT providers' information gathered from experts and research. Possible provider list has been given in Table 5. Five possible alternatives were selected to keep the alternatives nameless during the election phase.

Table 15 Possible CCT providers

List of possible providers			
1	SkyAtlas	5	Microsoft
2	Maximus	6	Alibaba Cloud
3	Oracle	7	Turkcell
4	DorukCloud	8	Vodafone

Step 4: Decision matrix is constructed, and F-EDAS steps have been applied. Table 6 represents the evaluation of first DM as an example, and Table 7 gives the appraisal scores with the weighted sum of the distance from average.

Table 16 Evaluation of the first expert for F-EDAS

	Investment Cost	Maintenance Cost	Flexibility Cost	Support Cost	Integration Cost	SLA Management	Service Stability	Enriched Content	Vendor Reputation	Experience in related product	Billing	Monitoring	Reporting	Communication	Computation	Memory	Speed	Confidentiality	Availability	Multi-tenant Trust
A1	VH	H	H	H	M	VH	AH	AH	AH	H	H	AH	H	VH	VH	VH	VH	H	H	VH
A2	H	H	M	M	M	M	VH	M	AH	VH	H	AH	H	VH	VH	H	VH	VH	H	H
A3	VH	H	M	VH	M	M	VH	M	M	H	H	M	H	M	VH	H	M	M	H	H
A4	H	H	M	M	M	M	VH	M	VH	VH	H	H	H	VH	VH	H	VH	M	H	H
A5	H	H	M	H	M	M	M	M	L	L	H	H	H	M	VH	H	M	M	H	H

Table 17. Appraisal scores with summed, weighted distances from average

	nsp_i					nsn_i				as_i			$\kappa(sp_i)$
A1	0,49	0,49	0,57	0,51	1,23	1,23	1,26	1,23	0,86	0,86	0,92	0,87	**1,729**
A2	0,36	0,30	0,27	0,36	1,14	1,14	1,14	1,17	0,75	0,72	0,71	0,76	**1,469**
A3	-0,33	-0,33	-0,31	-0,36	0,85	0,85	0,86	0,83	0,26	0,26	0,27	0,23	**0,521**
A4	-0,02	-0,02	-0,05	0,01	0,99	0,99	0,80	0,78	0,48	0,48	0,38	0,40	**0,938**
A5	-0,44	-0,44	-0,48	-0,52	1,22	1,22	1,21	0,76	0,39	0,39	0,37	0,12	**0,754**

Step 5: Highest appraisal score gives the most suitable alternative for this problem. Hence, first alternative with the appraisal score 1,729 is the appropriate CCT provider for this company.

CONCLUSIONS

Cloud computing is the backbone of the networks that we use today. It enables flexibility with low capital investment and scalability for all companies. These benefits also provide a compelling competitive advantage in the market.

Some companies still have some problems due to complex electronic systems. They struggle to adapt or to use the system for their benefits. As we have seen this kind of struggles, the importance of making the right choice for CCT is become more and more essential for the company.

Motivated by this problem, this study proposed a selection methodology for CCT. The process has been approached as an MCDM problem. Combination of two different MCDM tool has been suggested for the methodology.

The first technique is SAW, it is suggested with its fuzzy extension, and it is applied to weight the criteria for selection problem. Then the EDAS method has been suggested to select the most suitable CCT provider alternative. Also, the fuzzy extension of EDAS has been suggested in order to deal with uncertainties. Moreover, fuzzy linguistic scales have provided a more flexible and efficient environment to DMs while making their assessment.

For further studies, the interactions between evaluation criteria may be invested with different MCDM tools such as DEMATEL. In our study an in-depth literature survey helped us to generate the evaluation criteria, in the future, they can be enriched by taking information from the sector's applications and experienced experts.

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A NEW SERVICE QUALITY MODEL FOR AVIATION INDUSTRY

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Abstract – *Today, many companies focus on their service quality to obtain competitive advantage in a global market. Service quality is achieved by meeting the expectations and demands of customers. However, it is becoming a challenge to meet customer demands because of competition due to globally growing service channels and the complexity of logistics and supply chain activities. But it is becoming hard to measure service quality. Hence, the world is being influenced by digital transformation. Behavior of customers is changing, and their experience are digital now. Hence, firms have started to see digital transformation as a necessity. Supply chain networks that connect customers and firms have also had to keep up with this transformation to meet customer demands. One of the most important logistics and supply chain channels is the aviation industry. The aviation industry is an industry where digital transformation effects are most common. In this study, a new service quality model for aviation industry has been proposed with the view of digital transformation. In order to meet digital customers and their digital expectations, aviation companies need to accurately measure their performance. For this purpose, a detailed literature survey is carried out for the SERVQUAL model. Additionally, different research reports and white papers are reviewed. Various service quality measurement methods are examined by focusing on the electronic and mobile service quality models. Researches showed that there is no appropriate model to measure service quality in the aspect of digital transformation yet, in the literature in our best of knowledge. The main service quality dimensions and their sub-criteria are determined for this purpose, and a new model is constructed that can guide business managers and researchers in better designing digital services.*

Keywords – *Aviation 4.0, aviation industry, digital transformation, service quality, SERVQUAL*

INTRODUCTION

With the rapid increase in technological developments, the Industry 4.0 revolution has finally begun. According to the PwC Global Industry 4.0 Survey report, industry 4.0 is no longer a trend, and many companies put it to the center of their strategic decisions and research agendas (PwC, 2016). This revolution creates a network of new technologies to create value and it has introduced a new concept that is "digitalization" (PwC, 2016). Digitalization is a process rather than a word used alone. Hence, it may seem insufficient in terms of meaning in this way. Therefore, going out as "digital transformation" will lead to more consistent direction (Karagöz, 2016). Digital transformation refers to the investment of an enterprise in terms of a reasonable development of relevant business models and technology (KPIT, 2015). Digital transformation influences many industrial areas such as education, health, agriculture mining, and transportation (Karagöz, 2016). It can clearly be seen that the most influenced area is the aviation industry. Many research reports show that the aviation industry is the area where digital transformation effects are seen firstly. According to the Accenture's research report in 2016, top executives of the world's leading airlines say it is one of the most important channels of struggle for digital preparation around the world (Accenture, 2016).

For companies to be able to take place in the digital world, they need to identify new strategies to help their transformation. The goal is to improve customer experience and enterprise operations. Because, with the development of technology, customers who can easily express their expectations and demands through social media, web sites and mobile phone applications, who can do all their work from where they are instantly, and who can establish an individual contact with the environment where they are in service, has become one of the

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driving forces of this digital transformation. Top executives of the world's leading airline companies also voiced the importance they place on digital transformation processes (Büyüközkan & Havle, 2018). At this stage, service quality is at the forefront in meeting customer expectations, competing, providing profitability and being sustainable. In addition to evolution of the aviation industry through digital transformation, the classical customer experience service has also begun to change and now is going to digital. This leads differentiation on service quality perception (Yakut, 2016; Büyüközkan & Havle, 2018). With the help of the literature survey, there are e-service quality and mobile service quality measurement methods based on technological developments but there is no sign for the digitalization-based service quality.

In the light of all this, a new service quality model has been established by the fact that the classical service quality has changed with the digital transformation, in this study. Scope and study area are selected as aviation industry. Digital transformation, aviation industry and different service quality measurement tools based on SERVQUAL are examined. New dimensions and sub-criteria are determined. Different white papers, research and annual reports are searched with a detailed literature survey and following roadmap during the study is constructed and steps of the study are given as following:

(1) Service quality and e-service quality measurement methodologies are examined.

(2) Digital transformation in aviation industry has been examined.

(3) In this step, research has been done whether the electronic service quality concept meet the new service quality based on digital transformation or not. The main dimensions and sub-criteria of these models are examined and then compared with the new concepts obtained by literature survey on digital transformation. A new model has been proposed after the new main dimensions and sub-criteria have been determined.

(4) Explanations, comments and suggestions on the proposed model are made. Developable aspects are emphasized. It is then foreseen for its application.

SERVICE QUALITY / E-SERVICE QUALITY MEASUREMENT

Service Quality

Service quality has been an important research area for last three decades by many researchers and administrators, and many applications such as explanations, modeling and measurement related to this topic have been revealed (Seth, Deshmukh & Vrat, 2005; Ladhari, 2008). And now, the service sector is very important in modern economies (Olorunniwo, Hsu & Udo, 2006) and dominant (Ghobadian, Speller & Jones, 1994). As competition has increased, the importance given to service quality has increased much more (Asubonteng, McCleary & Swan, 1996). Service quality is the difference between the perception of the customer and the customer expectancy of the service provided by a service provider (Asubonteng, McCleary & Swan, 1996). Therefore, customer perception and expectation are the determining factors of service quality. That is why Parasuraman et al. have revealed and explained the perception of service (Parasuraman, Zeithaml & Berry, 1988) and they have proposed a model for service quality measurement method as SERVQUAL (Parasuraman, Zeithaml & Berry, 1985).

SERVQUAL is a multiple item scale to measure customer perceptions in terms of service quality and it includes perception (Parasuraman, Zeithaml & Berry, 1988). Until now, this model which includes totally five main dimensions as tangibles, reliability, responsiveness, assurance and empathy has been used in many studies in the literature which serve different purposes and applied in different industrial fields. These main dimensions are given in Table 1 with their brief explanations and some studies based on SERVQUAL from the literature are shown in Table 2 (Parasuraman, Zeithaml & Berry, 1988; Ladhari, 2008; Feyzioğlu, Havle & Büyüközkan, 2017).

Table 1. SERVQUAL dimensions and their brief explanations

Dimensions	Brief explanations
Tangibles	Appearance of physical facilities, equipment, and personnel.
Reliability	Ability to perform the promised service dependably and accurately.
Responsiveness	Willingness to help customers and provide prompt service.
Empathy	Provision of individual care and attention to customers.
Assurance	Knowledge and courtesy of employees and their ability to inspire trust and confidence.

In literature, there are different service quality measurement methods based on SERVQUAL. Each method is developed for the focused study area and aim. Previous studies are searched to studies to highlight the application areas of SERVQUAL. It has been seen that this methodology is used in different industrial areas such as aviation (Feyzioğlu, Havle & Büyüközkan, 2017; Rezaei et al., 2018), banking (Charles & Kumar, 2014), education (Yousapronpaiboon, 2014), healthcare (Li et al., 2015; Büyüközkan, Çifçi & Güleryüz, 2011), hotel (Stefano et al., 2015), logistics (Roslan, Wahab & Abdullah, 2015) and transport (Sam, Hamidu & Daniels, 2018) industries. Some studies are examined in terms of their application areas based on SERVQUAL and it is seen that SERVQUAL is used in different industrial areas including aviation industry. Hence, it is a useful technique to measure service quality.

Table 2. Different service quality measurement tools

Methodology	Purpose of methodology	Sources
Lodgeserve	To measure consumers' expectations in the hotel experience.	(Knutson et al., 1990)
Servperf	To measure performance of a service provider based on customer perception.	(Cronin & Taylor, 1994)
Servpex	To measure airline service quality.	(Robledo, 2001)
Sitequal	To evaluate site quality.	(Yoo & Donthu, 2001)
E-sq	To measure electronic service quality.	(Büyüközkan & Çifçi, 2012)
Hedperf	To evaluate higher education service quality.	(Abdullah, 2006)

With developing and changing needs, service quality measurement methodologies have changed. Table 2 shows that there are different service quality measurement tools and they have different purposes. But, technological developments and increased online processes has revealed a new concept for service quality. Almost last 15 years, e-service quality has gained importance due the usage of internet and online resources. By considering this, e-service quality is examined.

E-service Quality

Technological developments have changed the service quality perception and most of the processes has started to be performed online with used web sites. Due to this fact, e-service quality phenomenon has raised in almost last two decades. E-service quality concept was firstly developed by Zeithaml, Parasuraman & Malhotra (2000) to measure electronic service quality. It involves all phases of a service from pre-purchase to post-purchase including the customer satisfaction. Customer satisfaction is online, and it is hard to keep loyalty when customers are online (Kadir, Masinaei & Rahmani, 2011) Because of this, different service quality measurement approaches such as SITEQUAL (Yoo & Donthu, 2001), eTailQ (Wolfinbarger & Gilly, 2003), E-S-QUAL (Parasuraman, Zeithaml & Malhotra, 2005) are developed to measure e-service quality based on SERVQUAL methodology.

In literature there are many studies based on e-service quality and they used different criteria for measurement. Some of main dimensions and their sub-criteria are given as following to show the differentiation of service quality in terms of electronic service quality:

•***Information Quality:*** Includes the accuracy, currency, understandability, and richness of the information proposed via electronic channel (Ho & Lee, 2007; Büyüközkan & Çifçi, 2012; Chou & Cheng, 2012; Büyüközkan & Güleryüz, 2016).

•***System Quality:*** Represents accessibility, navigability, and usability of the used system (Lin, 2010; Chou & Cheng, 2012; Díaz, E., Martín-Consuegra, 2016).

•***Involvement:*** Contains experience platforms, social network and feedback for customers (Ho & Lee, 2007; Hsu, Hung & Tang, 2012; Díaz, E., Martín-Consuegra, 2016).

•***Privacy / Security:*** Represents not sharing customers' information and reputable company for this (Ho & Lee, 2007; Nemati et al., 2002; Hsu, Hung & Tang, 2012).

•***Website functionality:*** Include efficiency of navigation, clarity of website, accessibility, easiness of the website (Bauer, Falk & Hammerschmidt, 2006; Ho & Lee, 2007; Hsu, Hung & Tang, 2012).

•***Reliability:*** Includes specialization, standardization and reliable website performance (Nemati et al., 2002; Büyüközkan & Çifçi, 2012; Büyüközkan & Güleryüz, 2016).

Service quality transformed to e-service quality with technological development and nowadays digital transformation has been witnessed. It means that service quality perception is changing. One of this area where influences of digital transformation can be clearly seen is aviation industry. To examine this digital transformation in aviation industry is given in following section.

DIGITAL TRANSFORMATION IN AVIATION INDUSTRY

Digital transformation is the process of transitioning from new organizational structures to adding value to customers and ecosystems, developing business processes and enhancing the competencies of the entire company, starting with organizational structures using the elements of digital, social, mobile and new technology to adapt companies, brands and structures to the digital age (Infoloji, 2018). Digital transformation has begun to impact many industrial realms, including education, healthcare, agriculture, retail, finance, and transportation. The ones that trigger the change in all these industrial areas is; consumer behavior, digitalization and analytics, exponential growth technologies (Infoloji, 2018). According to a report published by the Infoloji, different countries of the world are at different stages in terms of digital conversion and accordingly, Turkey is among the countries which breaks the shell (Infoloji, 2018).

Digital technologies allow many things done by people to be done autonomously by traditional methods up to now, and in order to increase productivity, quality, speed, flexibility, and reduce loss of workload with digital transformation, many developed countries have prepared digital transformation road maps by developing new strategies (T.C. Bilim, Sanayi ve Teknoloji Bakanlığı, 2018). PwC chairman of Turkey, emphasized that with the technological leaps and the mobile evolution, steps have been taken towards a new world from traditionalism, in the 14. solution partnership platform (PwC-Yalçın, 2015). This transformation has influences on aviation industry.

At the ACI- NA World Annual Conference (2016) from Roland Berger Canada, Alexis Gardy revealed the following areas when examining digital competition areas in the aviation industry; These are: airports, airlines, passengers, ground handlers, vendors or new market players (ACI-NA, 2016). According to the Accenture research report, top executives of the world's leading airlines declare that it is one of the most important channels of struggle for digital preparation around the world (Accenture, 2016). For companies to be able to take place in the digital world, they need to identify new strategies to help their transformation. According to the researches have been performed, investment in the digital future is inevitable (Accenture, 2016). Digital technologies shed light on problems that airline companies have not been able to solve before. Digitalization creates operational synergies for the benefit of the customer. Being a digital airline requires much more than automation. New business models, technology and operation models are needed. Many airline companies digitize channels such as "individual processes", "equipping ground staff with tablets", "growth in social media presence", "moving data to cloud" and "providing mobile access to travel document" (Accenture, 2016).

Additionally, in literature survey process of digital transformation in aviation industry new structures are observed such as aviation 4.0, smart airports and airport 4.0 (Arthur D. Little, 2015; Wavestone Research Report, 2017) It is declared that there is a progressive evolution of aviation industry in the same way with industry 4.0 and this era for aviation industry is called as aviation 4.0 (Valdes & Comendador, 2018). According to Wavestone Research Report, the airport industry has begun the process of digitization under the pulse of the airline industry (Wavestone Research Report, 2017). In fact, in the mid-1980s, owners of airline and ground services wanted to share their information technology facilities across the airport in order to reduce the necessary investments while moving to new routes. After this process airport industry had three different eras up to airport 4.0. The fourth wave, called as digitalization, emerged earlier than anticipated and began to manifest itself in 2012. This wave was supported by extreme performance by technology giants with open and big data sources such as Google and Facebook. This wave is seen as the beginning of digitalization and the transformation has been initiated by very few airports.

The goal is to improve customer experience and enterprise operations (Accenture, 2016). In all of these, it is possible to say that the place and the importance of the customer within the scope of the digital transformation has increased even more. This demonstrates the necessity of focusing on service quality. However, we clearly see that the customer profile and experience have changed. Therefore, speaking of service quality in a classical sense will not be right from the perspective of digital transformation. Hence, in this study, the service quality, which is changed by digital transformation, is examined based on the aviation industry in the following section.

A NEW MODEL PROPOSAL

Service quality has been a field of research that has been a focus of attention from the past. It is also difficult to measure because it varies according to perception and expectation. Therefore, many service quality measurement models have been developed to serve different purposes. But customer behaviors and therefore expectations have changed with digital transformation. Therefore, a new service quality measurement model is needed. According to the researches that have been done, there is no study on service quality with digital transformation perspective in the literature yet. There is electronic service quality, mobile service quality, but there is no service quality measurement model based on digitalization or digital transformation (Jansen, & Ølnes, 2016) To fill this gap in the literature a new model is developed for digital transformation with aviation industry perspective. Model is shown in Figure 1.

To develop the model different research papers, whitepapers and annual reports are examined (IMD, 2014; CGI, 2015; KPMG, 2015; Accenture, 2016; Detecon, 2016; Mattila, & Seppälä, 2016; Capgemini, 2017; KPMG, 2017; CA Technologies, 2018) According to this model there are five main dimensions and they have their own sub-criteria. These sub-criteria can be explained as following:

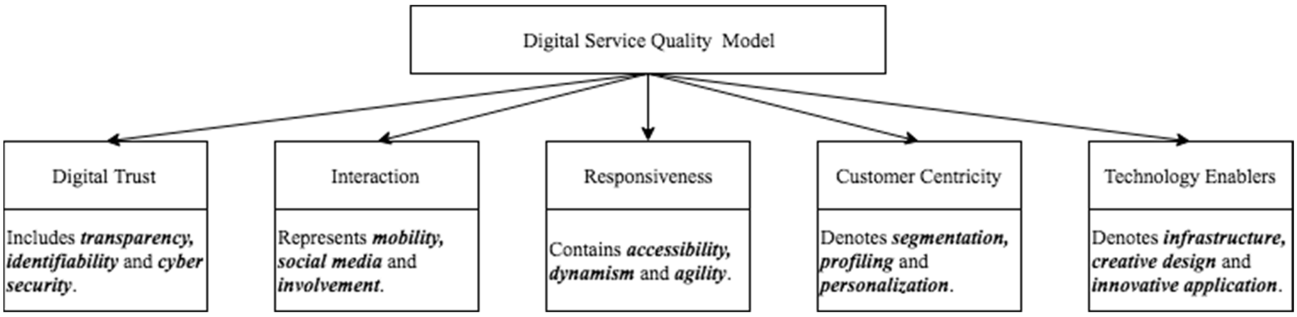

Figure 1. Developed new service quality model for digital transformation

Digital Trust

- ***Transparency*****:** Transparency of how customer data is used.
- ***Identifiability*****:** The included service or service provider is indeed declared, factual and identifiable.
- ***Cyber security*****:** Preventing misuse of personal data with malware.

Interaction

- ***Mobility*****:** To be accessible everywhere with mobile devices.
- ***Social media***: Presence and integration of technological platforms, where individuals, groups and companies can interact with service.
- ***Involvement***: Integrating and incorporating customers into the service process.

Responsiveness

- ***Accessibility:*** Accessibility to digital services and networks.
- ***Dynamism:*** To support and continuously adapt customer experience evolving with technological developments.
- ***Agility:*** Ability to respond effectively and quickly by making decisions based on information and rapid implementation together.

Customer Centricity

- ***Customer segmentation:*** Grouping of customers (passengers) based on analytics that are obtained from their behavior.
- ***Profiling***: Creation of a profile based on what the user or the customer needs.
- ***Personalization***: Providing a personalized, customized and targeted service to a customer.

Technology Enablers

- ***Technological infrastructure***: How digital is used, how it is observed and how feedback is received.
- ***Creative design***: It is the use of evolving technology that can adapt to user experiences continuously.
- ***Innovative applications (apps):*** The existence of applications following technological developments and innovations.

CONCLUSION

The rapid progress of technological developments has started a new era (Industry 4.0). This movement, which is described as a revolution, has created the phenomenon of digitalization and the "Digital

Transformation" process has begun. Senior corporate executives see digital transformation as the Tsunami of the 21st century. With digital transformation, all business processes have begun to change. Mobile applications, social media use, virtual reality, cloud technology, and many more are beginning to be involved into many industries. With this transformation, as companies have the ability to communicate with customers in a one-to-one manner, customers have become digitized, the concept of classical customer has been replaced by digital customers and digital expectations have come to the forefront. In this study, "A New Service Quality Model for Digital Transformation" is proposed with considering the changing customer expectations with digital transformation and the change of service quality perception. In the literature, many service quality models have been found, but a service quality model for digital transformation has not been found in accordance with changing customer profile as far as we can reach with our best research.

Along with digital transformation, changing customers, their experiences and expectations will create new dimensions in the measurement of service quality of firms. Therefore, such a model is needed. In future studies, the model can be improved further, sub-criteria breaks can be elaborated. The model can be manipulated with the addition or subtraction of different main dimensions or sub-criteria. Different analytical methods can be applied to reach numerical illustrations.

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DIGITAL TRANSFORMATION STRATEGY ANALYSIS OF TURKEY AVIATION INDUSTRY

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Abstract *– The consequences of technological developments penetrate almost every sector today, and a new era has begun as digital transformation. One of the most affected sectors in this transformation is the aviation industry, which is closely bound to logistics services and supply chains that connect firms with customers. Behavior of customers and structures of these supply chains are changing with the digital transformation. Changing demands due to new technological possibilities offered to customers, are observed and, customers are digital now. Customers' digital expectations influence the aviation industry in the global marketplace, forcing them to define competitive digital transformation strategies. To determine digital transformation strategies and to be sustainable and competitive in the market, companies in the aviation industry must determine their strong and weak sides with opportunities and threats. So, in this paper, a SWOT-based integrated fuzzy multi-criteria decision making (MCDM) method is used to determine these strategies. For this purpose, digital transformation factors are determined with a SWOT analysis based on expert opinions and literature review. The hierarchical structure is constructed, and weights of criteria are determined via AHP method. Alternative strategies are revealed as output of AHP. Finally, the strategy selection is performed by using the VIKOR method. Analytic tools are extended to fuzzy sets by considering uncertainty.*

Keywords – Aviation industry, digital transformation, fuzzy AHP, fuzzy VIKOR, SWOT analysis, strategy analysis

INTRODUCTION

Progressing digitalization of today has been a research area for information systems for many years (Legner et al., 2017). Digitalization has taken a diversified aspect and is being steered by customers, in accordance with their more sophisticated digital service and product anticipation (Brenner et al., 2014). Digital transformation denotes the automation of business models with processes that is combination of digital information, digital technology and people (Mattig & Hausweiler, 2017). This transformation not only influences other industrial areas all over the world but also influences the aviation industry. Many white papers, research and annual reports on digital transformation declare that aviation industry is an area where the influences of the digital transformation first appeared.

It can be seen that airport operators mostly use their own applications to directly communicate with customers via having closer look at airports specifically (Gardy, 2016). The entitled digital airport index traces the digitalization of airports, accentuating this transformation and differentiations within the industry (Mijksenaar, 2017). From the viewpoint of airlines, companies such as Lufthansa and Ryanair have built innovation laboratories where development and marketing of digital travel products for the web, mobile phones and next-generation new technologies are performed (Gardy, 2016).

Etihad Airlines has focused on mobile applications, business intelligence, information technology management, digital customer innovation, cargo management systems, business transformation and data center empowerment into strategic programs with the digital transformation perspective (Webb, 2016). AirFrance-KLM announced that they have increased their digital investments in more than 400 million euros within three years. The company incorporates mobility, artificial intelligence, and digital platforms as an ecosystem to manage this transformation process from both customer and employee aspects. Even if the digital transformation

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process in the aviation industry has already started, there is a fact that the path is long. Besides, this is the case in Turkey.

One of the most important contents of the Innovation Week held in Istanbul in December 2017 was "Innovation in Aviation Industry". President of corporate innovation and projects of Turkish Airlines declared that their growth prospects are directly related with innovation and digital transformation. He announced that digitalization is the Tsunami of 21st century. Mr. Karakaş, the head of regional flights of Anadolu Jet, declared that almost all passengers are mobile phone users. In addition to this, he emphasized that mobile platforms are more important than the web for direct contact with people. The CIO of the Turkish Airlines stated the need for growth, which can be achieved by a differentiation in the travel industry in International Air Transport Association's 6th World Passenger Symposium in Dubai in October 2016. He emphasized that the way how airlines connect with people. Customer experience is transforming into a digital experience. Regarding to his declaration it is possible with changing technology and transformation.

In the light of above-mentioned statements and examples, investment for digital future is an inevitable necessity to improve customer experience and corporate operations. This emphasizes the need for new strategies (Accenture, 2016). In this study, digital transformation factors are determined with SWOT analysis based on expert opinions and literature survey. A hierarchical structure is revealed to weigh the SWOT factors and to determine digital transformation strategies by using the AHP method. During this process, fuzzy linguistic terms sets are used. This way, strategy selection is performed by fuzzy VIKOR method.

This study is organized as follows: Section 2 gives the theoretical background of SWOT analysis. Following section 2, section 3 describes the fuzzy AHP method. Section 4 explains fuzzy VIKOR method. Then, a numerical illustration of the proposed approach is given in section 5. Finally, section 6, gives the concluding remarks. In the light of these, general framework is shown with Figure 1 to illustrate the steps of the study:

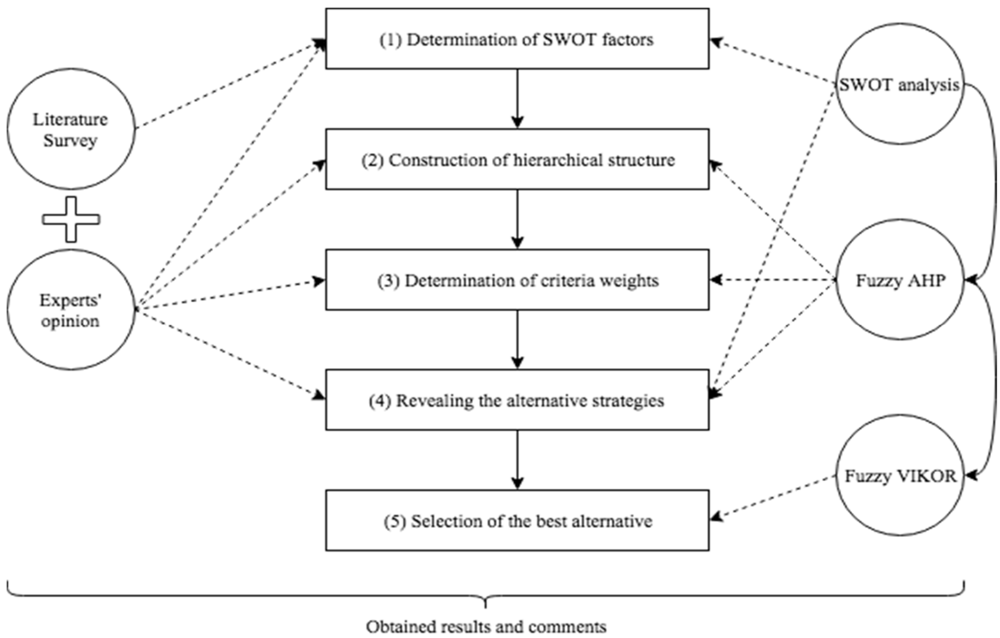

Figure 1. Steps of the study

SWOT ANALYSIS

There are different strategic management tools and SWOT analysis is one of them. It is used to reveal the strengths, weaknesses, opportunities, and threats and it gives answers how you want to be (Ansoff, 1965). Analyzing internal and external environments to sustain competitive forces is quite vital for companies. For determination of new strategies and to prepare new business plans in terms of strategic decision-making, SWOT analysis can be seen as a very helpful technique (Valentin, 2001). Revealing feasible and infeasible situations based on SWOT dimensions helps companies to understand which area should be focused on (Helms & Nixon, 2010). SWOT analysis is used in various sectoral areas and is a useful tool for management and strategies (Helms & Nixon, 2010), including the aviation industry (Ahmed, Zairi & Almarri, 2006; Sevkli et al., 2012). Steps of the SWOT analysis are given as follows:

Step 1: *Determine the SWOT factors*: SWOT factors are gathered under the main dimensions, which are "Strengths", "Weaknesses", "Opportunities", and "Threats". Expert opinions and literature survey is used for this process.

Step 2: *Reveal the alternatives*: Four different types of alternative strategies can be developed as the following (Doğan & Sözbilen, 2014):

- "SO" Strategy: Using strengths to gain benefit from opportunities.
- "WO" Strategy: Using opportunities to decrease weaknesses.
- "ST" Strategy: Focusing strengths to eliminate threats.
- "WT" Strategy: Eliminating weaknesses by considering threats.

FUZZY AHP METHOD

The Analytical Hierarchy Process (AHP), which is very widely used, is a multi-criteria decision making (MCDM) technique developed by Thomas Saaty (Saaty, 1980). The AHP is used to transform complex problems into a hierarchical structure and to identify the sub-factors that serve the purpose. In the classical AHP method, the principle of pairwise comparison with absolute expressions is used (Dožić, Lutovac & Kalić, 2018). However, it is not always possible to prioritize and evaluate with definite judgments. The uncertainty of human thinking during the assessment process has put the use of the classical AHP approach at a different point (Büyüközkan, Çifçi & Güleryüz, 2011; Dožić, Lutovac & Kalić, 2018). People's perceptions and feelings are fuzzy. Therefore, the AHP method has been expanded to fuzzy sets (Van Laarhoven & Pedrycz, 1983) based on the fuzzy set theory developed by Zadeh (1965). In this approach, triangular fuzzy numbers are used in evaluations to determine the priority of one criterion over another one (Büyüközkan, Çifçi & Güleryüz, 2011). Application steps of fuzzy AHP method are given as following (Şengül, Miraç & Shiraz, 2012):

Step 1: *Built a hierarchical structure:* A hierarchical structure is constructed by determining the main dimensions and sub criteria of these dimensions that serve the purpose to be achieved.

Step 2: *Construct pairwise comparison matrix:* For both main dimensions and sub-criteria reciprocal comparison matrix is developed.

Let $X = \{x_1, x_2, \ldots, x_n\}$ be the object set and $U = \{u_1, u_2, \ldots, u_m\}$ be the goal set. By following this, m pairwise comparison matrices or m level analysis values are obtained. These values can be shown as in (1):

$$\tilde{A}_{gi}^1, \tilde{A}_{gi}^2, \ldots, \tilde{A}_{gi}^m, \qquad i = 1,2,\ldots,n \tag{1}$$

where $\tilde{A}_{gi}^j$ $(j = 1,2,\ldots,m)$ are triangular fuzzy numbers (TFN). To construct pairwise comparison matrix linguistic variables are used. These variables with their triangular fuzzy number values are given with Table 1 (Saaty, 1989):

Table 1. Triangular fuzzy conversion scale for pair of elements i and j.

Intensity of importance	Fuzzy number	Definition	Membership Function
1	$\tilde{1}$	Equal importance (EI)	(1, 1, 2)
3	$\tilde{3}$	Moderate importance (MI)	(2, 3, 4)
5	$\tilde{5}$	Strong importance (SI)	(4, 5, 6)
7	$\tilde{7}$	Very strong importance (VSI)	(6, 7, 8)
9	$\tilde{9}$	Extremely more importance (EMI)	(8, 9, 10)

Step 3: *Calculate synthetic values:* Fuzzy synthetic level values according to i^{th} object, are defined with (2) (Chang, 1992):

$$S_i = \sum_{j=1}^{m} \tilde{A}_{gi}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{A}_{gi}^j\right]^{-1} \tag{2}$$

where

$$\sum_{j=1}^{m} \tilde{A}_{gi}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j,\right) \tag{3}$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} \tilde{A}_{gi}^j = \left(\sum_{i=1}^{m} l_i, \sum_{i=1}^{m} m_i, \sum_{i=1}^{m} u_i,\right) \tag{4}$$

and

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m}\tilde{A}_{gi}^{j}\right]^{-1}=\left(\frac{1}{\sum_{i=1}^{n}u_i},\frac{1}{\sum_{i=1}^{n}m_i},\frac{1}{\sum_{i=1}^{n}l_i}\right) \quad (5)$$

Step 4: *Calculate the weights:* To calculate the weights of the criteria there are different methods. One of them is Liou and Wang Method (Liou & Wang, 1992).

This method is used to rank fuzzy numbers by using integral value method. Let $\tilde{A}=(l,m,u)$ be a fuzzy number, then integral value is calculated via (6):

$$I_T^{\alpha}(\tilde{A})=\frac{1}{2}\alpha(m+u)+\frac{1}{2}(1-\alpha)(l+m)=\frac{1}{2}[\alpha.u+m+(1-\alpha).l] \quad (6)$$

where, $\alpha\in[0,1]$ is the optimism index. If the index value increases, it represents an optimistic decision maker, if it decreases, it represents a pessimistic decision maker (Liou & Wang, 1992).

Step 5: *Calculate the relative importance values:* Normalization is applied for this process via formula (7):

$$w_r=w_i/\sum_{i=1}^{n}w_i \quad (7)$$

where w_r represents normalized weight of the r^{th} criterion.

Step 6: *Determine alternatives:* Calculate local and global weights of the criteria and determine possible alternatives over weights.

FUZZY VIKOR METHOD

The method of VIKOR (VIseKriterijumsa Optimizacija I Kompromisno Resenje), which is used for multi-criteria decision making, was proposed by Opricovic (1998). The VIKOR method is used to select the most appropriate alternative by ranking the alternatives under contradictory criteria (Opricovic & Tzeng, 2004). The aim of the method is to find a conciliatory solution in order and choice (Akyüz, 2012). As is the case with other multi-criteria decision-making methods, the classic VIKOR method takes weights of criteria as exact values. However, uncertainties arise when real life and human perception take part in the account. Thus, the classical VIKOR method is expanded to fuzzy sets. One of the methods of involving uncertain information into solving procedure is to use linguistic variables (Moeinzadeh, & Hajfathaliha, 2009). Steps of the method are given as following (Chen & Wang, 2009; Moeinzadeh, & Hajfathaliha, 2009; Yıldız & Deveci, 2013):

Step 1: *Determine alternatives and evaluation criteria*

In this step, a group of decision makers are constructed, alternatives and evaluation criteria are determined. It is assumed that there are n decision makers, m alternatives and k evaluation criteria.

Step 2: *Define fuzzy numbers*

In this stage, linguistic variables and their corresponding fuzzy numbers are defined. These variables are used to determine the weight of the criteria and to rank alternatives. Linguistic variables and fuzzy triangular numbers are given in Table 2:

Table 2. Linguistic variables for evaluation of criteria and alternatives (Chen & Wang, 2009)

Variables for criteria weights		Variables for evaluation of alternatives	
Linguistic variables	Triangular Fuzzy Numbers	Linguistic variables	Triangular Fuzzy Numbers
Very Low (VL)	(0.00, 0.00, 0.25)	Very Bad (VB)	(0.00, 0.00, 2.50)
Low (L)	(0.00, 0.25, 0.50)	Bad (B)	(0.00, 2.50, 5.00)
Medium (M)	(0.25, 0.50, 0.75)	Medium (M)	(2.50, 5.00, 7.50)
High (H)	(0.50, 0.75, 1.00)	Good (G)	(5.00, 7.50, 10.00)
Very High (VH)	(0.75, 1.00, 1.00)	Very Good (VG)	(7.50, 10.00, 10.00)

Step 3: *Aggregate the evaluations*

Preferences and evaluations of decision makers are integrated. To perform aggregation, formula (8) is used:

$$\widetilde{w}_j=\frac{1}{n}\left[\sum_{e=1}^{n}\widetilde{w}_j^{e}\right] \quad (8)$$

where $j=1,2,...,k$ and to calculate importance weight of i^{th} alternative over j^{th} criterion formula (9) is executed:

$\tilde{x}_{ij} = \frac{1}{n}\left[\sum_{e=1}^{n} \tilde{x}_{ij}^{e}\right]$ (9)

where $i = 1, 2, \ldots, m$.

Step 4: *Construct fuzzy decision matrix*

To construct fuzzy decision matrix $\widetilde{D}$ based on aggregated experts' opinion is revealed via formulas (10) and (11):

$$\widetilde{D} = \begin{matrix} A_1 \\ A_2 \\ A_3 \\ A_4 \end{matrix} \begin{bmatrix} C_1 & C_2 & \cdots & C_k \\ \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mk} \end{bmatrix} \quad (10)$$

$\widetilde{W} = [\widetilde{w}_1, \widetilde{w}_2, \cdots, \widetilde{w}_k]$ (11)

where $i = 1,2,\ldots,m$ and $j = 1,2,\ldots,k$. $\tilde{x}_{ij}$ shows the degree of alternative A_i according to C_j in matrix $\widetilde{D}$, and $\widetilde{w}_j$ is the weight of criterion j.

Step 5: *Calculate fuzzy best ($\tilde{f}_j^*$) and worse ($\tilde{f}_j^-$) values*

To calculate fuzzy best and worse values formula (12) is used:

$\tilde{f}_j^* = max_i(\tilde{x}_{ij}), \quad \tilde{f}_j^- = min_i(\tilde{x}_{ij})$ (12)

Step 6: *Calculate $\tilde{S}_i$ and $\tilde{R}_i$ values*

$\tilde{S}_i$ indicates the sum of distances to fuzzy best value of criteria value in alternative A_i. $\tilde{R}_i$ is the maximum distance to fuzzy the worst value of alternative A_i according to criterion j. To calculate $\tilde{S}_i$ and $\tilde{R}_i$ values formulas (13) and (14) are used:

$\tilde{S}_i = \sum_{j=1}^{k} \widetilde{w}_j\left(\tilde{f}_j^* - \tilde{x}_{ij}\right)/\left(\tilde{f}_j^* - \tilde{f}_j^-\right)$ (13)

$\tilde{R}_i = max_i\left[\widetilde{w}_j\left(\tilde{f}_j^* - \tilde{x}_{ij}\right)/\left(\tilde{f}_j^* - \tilde{f}_j^-\right)\right]$ (14)

$\tilde{S}_i$ and $\tilde{R}_i$ denote average and the worst score of alternative A_i, respectively.

Step 7: *Calculate $\tilde{S}^*$, $\tilde{S}^-$, $\tilde{R}^*$, $\tilde{R}^-$, $\tilde{Q}_i$ values*

$\tilde{S}^*$ represents maximum group benefit and $\tilde{R}^*$ indicates minimum regret of disagreed ones. Index $\tilde{Q}_i$ is obtained via both group benefit and minimum regret. To calculate these values following formulas are used:

$\tilde{S}^* = min_i(\tilde{S}_i),\ \tilde{S}^- = max_i(\tilde{S}_i)$ (15)

$\tilde{R}^* = min_i(\tilde{R}_i),\ \tilde{R}^- = max_i(\tilde{R}_i)$ (16)

$\tilde{Q}_i = v(\tilde{S}_i - \tilde{S}^*)/(\tilde{S}^- - \tilde{S}^*) + (1 - v)(\tilde{R}_i - \tilde{R}^*)/(\tilde{R}^- - \tilde{R}^*)$ (17)

where value v indicates the weight of strategy that provides maximum group benefit. Reconciliation is provided with following conditions (18):

$$reconciliation = \begin{cases} majority\ vote, if\ v > 0.5 \\ consensus, if\ v = 0.5 \\ veto, if\ v < 0.5 \end{cases} \quad (18)$$

Step 8: *Calculate index Q_i*

In this step, defuzzification procedure is applied for $\tilde{Q}_i$. Best Non-Fuzzy Performance (BNP) value method proposed by Hsieh (Hsieh, Lu & Tzeng, 2004) is used for this process. This index is used to rank the alternatives and the smallest value shows the best alternative. To performance BNP value method formula (19) is used:

$BNP_i = [(u_i - l_i) + (m_i - l_i)]/3 + l_i$ for $\forall_i$ (19)

where u_i, m_i, and l_i indicate upper, middle and lower values of fuzzy number, respectively.

Step 9: *Determine the conciliative solution*

If the following two conditions are provided, then the solution which is determined by using index Q_i is the conciliative solution (a').

- *Condition I - Acceptable advantage:*

$Q(a'') - Q(a') \geq DQ$ (20)

where a'' value is the second alternative according to Q value and DQ is calculated as following:

$$DQ = 1/(m-1), \quad (If\ m \leq 4, then\ DQ = 0.25) \tag{21}$$

- *Condition II - Acceptable stability in decision making:* Alternative a' is the best alternative in the order according to S and /or R values. This conciliative solution is stable in the decision-making process.

If $Q(a^{(m)}) - Q(a') \leq DQ$, and condition-I is not provided, then $a^{(m)}$ and a' are similar conciliative solutions. Hence, conciliative solutions $(a', a'', \ldots, a^{(m)})$ have similarity, a' has not have comparable superiority. If condition-II is not provided, even though a' has comparable superiority, there is no stability in decision-making process; therefore, conciliative solutions of a' and a'' are same.

Step 10: *Choose the best alternative* - The alternative which has minimum Q value is selected as the best solution.

NUMERICAL ILLUSTRATION

In this study, an integrated SWOT based fuzzy AHP and fuzzy VIKOR method is applied to Turkey's aviation industry to analyze digital transformation factors and strategies. First section of this part gives the application of SWOT analysis, followed by second section, that illustrates the fuzzy AHP application steps to calculate the weights of the SWOT factors and to determine alternative strategies. Finally, last section shows the fuzzy VIKOR application steps to rank alternative strategies.

Determination of SWOT factors via SWOT Analysis

SWOT factors of aviation industry from digital transformation perspective are collected via literature survey and experts' opinion and these are shown with Figure 2. Sub-criteria of this SWOT model are given with Figure 3.

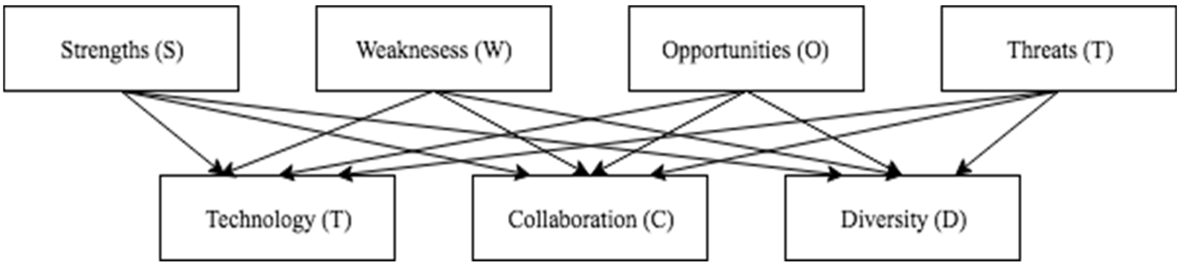

Figure 2. SWOT model main dimensions and their sub-dimensions

Technology (T)	Collaboration (C)	Diversification (D)

Strengths (S)	S_{T1}:Mobile and web-based attempts S_{T2}:Existence of technology portfolio S_{T3}:Technology innovation S_{C1}:Technological alliances S_{C2}:Creation of platforms for digital transformation S_{C3}:Projects about digital transformation S_{D1}:Technological alliances S_{D2}:Creation of platforms for digital transformation S_{D3}:Projects about digital transformation	Opportunities (O)	O_{T1}:Focusing on architecture of information technologies O_{T2}:Accessibility and existence of technology partners O_{T3}:Optimized operations and the customer journey O_{C1}:Airline companies' collaboration O_{C2}:Collaboration of organizations and IT O_{C3}:Building brand loyaltyW_{D1}:Lack of flexibility O_{D1}:Creation of an emotion filled relationship O_{D2}:Increment of digital customers and their demands O_{D3}:New and improved business services
Weaknesses (W)	W_{T1}:Internet access inability in some regions W_{T2}:Competing with IT priorities W_{T3}:Difficulty of integrating digital channels W_{C1}:Deficiency of collaboration between departments W_{C2}:Bulkiness of decision making mechanisms W_{C3}:Lack of efficient use of competent resources W_{D1}:Lack of flexibility W_{D2}:Competing with business priority W_{D3}:Improper business models for transformation	Threats (T)	T_{T1}:Possibility of data loss and cyber security threats T_{T2}:Wrong right social media, web and mobile attempts T_{T3}:Challenges with big data analytics T_{C1}:Difficulty of digital culture development T_{C2}:Hyper competition T_{C3}:Resistance of departments to change T_{D1}:Changes and diversification of customer behavior T_{D2}:Competing with tradition T_{D3}:Taking a part in a larger ecosystem

Figure 3. Sub-criteria of the SWOT model

Calculation of the weights of SWOT factors via fuzzy AHP: In this stage, decision makers evaluate the priority of the SWOT factors by using Table 1 and calculation steps of fuzzy AHP method are applied. After calculation process, Table 3 is obtained:

Table 3. Determined weights of criteria via fuzzy AHP

Dimensions	Weight	Sub-Dimensions	Local Weight	Global Weight	Sub-Criteria	Local Weight	Global Weight
Strengths (S)	0.219	Technology (T)	0.365	0.08	S_{T1}	0.498	**0.182***
					S_{T2}	0.241	0.088
					S_{T3}	0.262	0.095
		Collaboration (C)	0.246	0.054	S_{C1}	0.282	0.069
					S_{C2}	0.306	0.075
					S_{C3}	0.412	0.160
		Diversity (D)	0.389	0.085	S_{D1}	0.282	0.110
					S_{D2}	0.306	0.119
					S_{D3}	0.412	0.160
Weaknesses (W)	0.252	Technology (T)	0.365	0.08	W_{T1}	0.282	0.103
					W_{T2}	0.412	0.150
					W_{T3}	0.306	0.112
		Collaboration (C)	0.246	0.054	W_{C1}	0.248	0.061
					W_{C2}	0.270	0.066
					W_{C3}	0.483	0.119
		Diversity (D)	0.389	0.085	W_{D1}	0.286	0.111
					W_{D2}	0.197	0.077
					W_{D3}	0.516	**0.201***
Opportunities (O)	0.290	Technology (T)	0.365	0.08	O_{T1}	0.200	0.073
					O_{T2}	0.219	0.080
					O_{T3}	0.580	**0.212***
		Collaboration (C)	0.246	0.054	O_{C1}	0.310	0.076
					O_{C2}	0.333	0.082
					O_{C3}	0.357	0.139
		Diversity (D)	0.389	0.085	O_{D1}	0.192	0.075
					O_{D2}	0.393	0.153
					O_{D3}	0.415	0.161
Threats (T)	0.239	Technology (T)	0.365	0.08	T_{T1}	0.310	0.113
					T_{T2}	0.333	0.122
					T_{T3}	0.357	0.130
		Collaboration (C)	0.246	0.054	T_{C1}	0.473	0.116
					T_{C2}	0.177	0.043
					T_{C3}	0.351	0.086
		Diversity (D)	0.389	0.085	T_{D1}	0.516	**0.201***
					T_{D2}	0.275	0.107
					T_{D3}	0.209	0.081

Calculated weights of SWOT factors help to identify alternative strategies. These strategies are determined as follows:

- A_1: Reaching optimized operations and customer journey with mobile and web-based attempts,
- A_2: Rearrangement of improper business models for transformation via optimized operations and the customer journey with technological tools,
- A_3: Conformance to changes and diversification of customer behavior via mobile and web-based attempts,
- A_4: Eliminating improper business models by considering changes and diversification of customer behavior.

To select best appropriate alternative strategy, fuzzy VIKOR method is used.

Selection of the best alternative via fuzzy VIKOR:

Selection of the best alternative from the determined ones via fuzzy AHP is performed by fuzzy VIKOR and all steps of the method is applied. Weights of the criteria are determined with fuzzy AHP instead of fuzzy VIKOR in this methodology. Decision makers evaluated alternatives according to criteria. Q_i, S_i, R_i values of alternatives are calculated and shown in Tables 4.

Table 4. Q_i, S_i, R_i values of alternatives and their orders.

Alternatives	Q_i		S_i		R_i	
	Value	Order	Value	Order	Value	Order
A_1	0.732	2	1.545	2	0.160	2
A_2	0.817	3	1.841	3	0.160	2
A_3	1.000	4	1.935	4	0.182	3
A_4	0.000	1	0.239	1	0.112	1

For the calculation process of Q_i, v value is taken as 0.5 to provide consensus. According to Q_i index value, A_4 alternative is the best solution but to check whether it provides best conciliative solution or not, following two conditions should be controlled.

Condition I: $Q(a'') - Q(a') \geq DQ$ should be checked. Since, $0.732 - 0.000 \geq 0.25$, alternative A_1 provides best conciliative solution.

Condition II - Acceptable stability in decision making: Alternative A_1 should have the best value according to S_i and/or R_i. R_i values show that alternative A_1 has the best solution. Hence, this alternative provides the condition II. Due to this fact, alternatives A_4 and A_1 should be accepted as conciliative solution alternatives. To show all last ranking, Table 5 is given.

Table 5. Ranking the alternatives according to $Q_i, S_i, and\ R_i$ values

Q_i	**A_4**	>	**A_1**	>	A_2	>	A_3
S_i	**A_4**	>	**A_1**	>	A_2	>	A_3
R_i	**A_4**	>	A_1	=	A_2	>	A_3

Results show that in case of selection of only one alternative, A_4 is the best alternative but if two candidates are selected A_1, and A_4 should be selected together.

CONCLUSION

Along with the developing technology, companies have started to adapt to these developments in order to stay competitive market, to meet customer expectations and to increase their profits. This adaptation process is now called digital transformation. Companies should know what their requirements are to be able to perform digital transformations. One of the industrial areas most affected by this transformation and taking steps to achieve change is the aviation industry. Companies in the aviation industry should be aware that initiating the digital transformation process is a necessity. Therefore, digital transformation strategies are needed to be defined. In this study, the strengths and weaknesses, opportunities and threats of Turkey's aviation industry, have been revealed by the SWOT analysis from the digital transformation perspective. The determined SWOT factors are evaluated by industry experts using the fuzzy AHP method and the weights of these factors are calculated. Subsequently, alternative digital transformation strategies have been identified with the aid of the obtained criteria weights. Alternative strategies are analyzed using the fuzzy VIKOR method and the most appropriate strategy is selected. Accordingly, if a single alternative is to be selected, then "*A_4: Eliminating improper business models by considering changes and diversification of customer behavior.*" alternative is the best alternative. However, in the case of the choice of two alternatives, then "*A_1: Reaching optimized operations and customer journey with mobile and web-based attempts* " and *A_4* alternatives should be selected together.

Additionally, the proposed SWOT-based fuzzy AHP-VIKOR approach has been very helpful in strategy for determination and selection. However, during the expert evaluation process, it has been observed that experts feel hesitancy and uncertainty about criteria and alternative evaluations. Thus, it is envisaged that the use of hesitant and/or intuitionistic fuzzy sets in the further stages of the study will provide much more consistent results.

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EVALUATION OF SMART CITY LOGISTICS SOLUTIONS WITH FUZZY MCDM METHODS

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Abstract *– City logistics, which started to examine as a subdivision of logistics, aims the planning and management of transportation, efficiency, protection of the environment, reduction of traffic, security and energy saving. Rapidly growing population and migration from rural to urban areas have an important place in many of the problems of cities. The smart city is an approach that has a significant potential to solve urban logistics problems with information technologies. "Smart city logistics solutions" such as full adaptive traffic management system, security and emergency systems, electronic detection system etc. present based on information technologies to meet the increasing demand for logistics services more efficiently, safely and environmentally. In this study, the evaluation of smart city logistics solutions that contain many components is considered as a multi criteria decision-making (MCDM) problem. Considering the complex profile of this problem need to be taken into account by experts for deciding on the suitable solution when information is in uncertain nature. In this context, the smart city logistics solutions in Istanbul determined by literature review and expert opinions are modeled, analyzed and the results are interpreted by using the House of Quality matrix of Quality Function Deployment (QFD) approach with fuzzy MCDM methods.*

Keywords – Fuzzy MCDM, House of Quality, Smart city logistics, Smart city logistics solutions.

INTRODUCTION

The majority of the population in the world and our country lives in cities. Therefore, cities are the most complex and significant impact on our daily life, the area of logistics. Parallel to population growth, the use of private vehicles that feeds the growing population needs to cause the increase of the traffic, air pollution, transportation costs in cities and therefore the product prices. City logistics, which started to examine as a subdivision of logistics at the beginning of the 1990s, aims the planning and the management of distribution and transportation (Taniguchi et al., 1999).

The primary objectives of city logistics are efficiency, protection of the environment, reduction of traffic, security and energy saving. These aims are related to the three cornerstones of city logistics that are sustainability, mobility, and livability. Parallel to the rapid development of information technologies, one of the affected and developing sectors has become logistics. "Smart city logistics solutions" are presented by information technologies to meet the increasing demand for logistics services more efficiently, safely and environmentally (Nowicka, 2014).

Smart city logistics is a fundamental approach for the more efficient organization of physical and information logistics in international transportation chains. It means an optimized form for the transport of people and goods, which increases mobility, security and the benefits of users and at the same time, reduces pollution, consumption, and bottlenecks (BVRLA, 2016).

Logistics networks are exposed to uncertainty environments. Therefore, the need for robustness, flexibility, and agility has become a focal point for future logistics system designs. Smart city logistics solutions have developed to reduce the harmful effects of increased transport in urban areas (Kirch et al.,2017). In this study,

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the evaluation of smart city logistics solutions that contain many components is considered as a multi criteria decision making (MCDM) problem. Considering the complex profile of this problem need to be taken into account by experts for deciding on the suitable solution. However, it is difficult to decide on the most appropriate solution when information is in uncertain nature.

This study aims to evaluate smart city logistics solutions with analytical methods. In this context, the smart city logistics solutions which include customer and technological requirements in Istanbul determined by literature review and expert opinions are modeled. This model is evaluated by using the House of Quality matrix of Quality Function Deployment (QFD) approach with fuzzy MCDM methods. Fuzzy Simple Additive Weighting (SAW) method is used to calculate the weights of customer requirements.

The structure of the paper is as follows: The related studies about smart city logistics summarized in next section. The third section presents the proposed model and methodology. The fourth section presents the application, and finally, conclusions have provided.

SMART CITY LOGISTICS

Smart city logistics approach provides economic, environmental and social sustainable solutions by ensuring that information can be achieved quickly and efficiently. The goals of smart city logistics are to provide multidimensional data exchange between passenger-vehicle-infrastructure-center, to increase traffic safety and mobility, to make use of roads in accordance with their capacity, to reduce energy loss by providing energy efficiency (T.C. Ministry of Transport, 2014). Smart city logistics applications can provide coordination between different modes of transportation to create ideal traffic conditions and increase the efficiency and speed of services related to freight movements. By optimizing travel times and reducing the risk of crashes and injuries, the performance of modern transport systems is improved (Zanelli, 2016).

Today, smart city logistics is a system based on advanced technologies in the regulation and management of transportation. These systems use real-time and up-to-date databases and serve to improve efficiency, safety and service quality in transportation. There are many benefits of smart transportation with systems such as traffic tracking systems, advanced passenger information systems, pricing systems, advanced transportation management systems and advanced public transportation systems (ASCIMER, 2017).

There are many studies about smart city logistics in the literature. Some of these studies have shown in Table 1. According to Table 1, there are generally theoretical studies related to this subject and the number of studies with application area are small. In this study, this subject is proposed with an application area, Istanbul.

Table 1. Literature Review of Smart City Logistics

Authors (Year)	Aim of the Study	Application Area
Eitzen et al. (2017)	to propose an urban goods movement for smart city logistics	-
Shuai & Hong-Chun (2017)	to present smart city logistics concept	China
Bektaş et al. (2017)	to present from urban freight to smart city logistics networks	-
Melo et al. (2017)	to develop a performance evaluation of re-routing	Lisbon, Portugal
Kauf (2016)	to present the basic development in the sustainable logistics area	-
Nocerino et al. (2016)	to present the final results of the Italian pilots of Pro-E-Bike	-
Nathanail et al. (2016)	to evaluation framework for smart logistics solutions	-
Baudel et al. (2016)	to present smart deliveries	-
Guerlain et al. (2016)	to describe a Geographical Information System (GIS)	Luxembourg
Navarro et al. (2015)	to present new models for energy efficiency in urban freight transport for smart cities	Barcelona and Valencia
Nowicka (2014)	to present Smart City logistics on the cloud computing model	-
Malecki et al. (2014)	to present influence of Intelligent Transportation Systems	Szczecin
Taniguchi (2014)	to present city logistics for sustainable and livable cities	-
Thompson & Hassall (2014)	to present High Productivity Freight Vehicles in urban areas	-
Zidi et al. (2014)	to propose a solution for congestion with an intelligent support system	-
Cagliano et al. (2014)	to present e-grocery by developing an ITS	-
Lu (2014)	to present an innovative solution	-
Tesch et al. (2011)	to present an innovative approach for road transportation	-
Oliveira et al. (2010)	to present the intelligent delivery points	Brazil
Ambrosini & Routhier (2007)	to compare the objectives, methods, and results of urban freight transport	USA, Canada, Australia, Japan, UK, Germany, Switzerland, The Netherlands, France

PROPOSED MODEL AND METHODOLOGY

A four-step methodology in this study is as follows:

Step 1: Determination of customer requirements in the House of Quality matrix for smart city logistics.

Step 2: Determination of technological requirements in the House of Quality matrix for smart city logistics.

Step 3: Determination of customer requirements weights by fuzzy SAW method.

Step 4: Evaluation of relationship between customer requirements and technological requirements, prioritization of technological requirements.

The House of Quality Matrix of the QFD

QFD is an important design technique, that enables the transformation of customers' needs to product or service characteristics in all functional components, and it is a planning, development and communication tool (Akao et al., 1990). QFD is a strategic tool that used to develop improved products and services responsive to customer needs. This approach aims to translate customer requirements into appropriate technical or technological requirements.

The House of Quality is the most frequently used matrix in QFD process. The Quality House matrix is conducted by a team of multidisciplinary experts to translate customer requirements from market research and to benchmark data into technical requirements that to be met by designing a new product or service (Hauser & Clausing, 1988). These matrix is used to evaluate the the technological requirements in the smart city logistics system by meeting customer needs. With this approach, customer needs have determined comprehensively, and customer satisfaction has tried to increase. At the same time, design optimization and efficiency will improve. It is a systematic algorithm that is used as the essential design tool of QFD. It organizes data and establishes relationships.

Customer Requirements:

- *Accessibility and travel time (CR1):* Limited access in some cases increases travel quality. It is the restriction of individual vehicles in certain roads or areas. For example, borders to reduce intensity in the city center during peak hours, the use of only environmentally friendly vehicles in some special cases such as low emission zones, etc. (Civitas, 2015).
- *Road pricing (CR2):* Road pricing is about on the size of the cities and the transportation capacities. Price areas are determined, and tariffs have created accordingly. In the peak periods, the tariffs may change according to the hours of the day (Cohen, 2013).
- *Lane management (CR3):* Lane management is the flexible use of lanes in certain situations. Specific lanes reserved for public transport, temporary closure of roads in cases of accident, maintenance work and construction measures are the lane management works (UNECE, 2012).
- *Public transportation priority (CR4):* The public transport priority is setting of traffic control sets to minimize the stopping times of public transport. The timing of the traffic lights should be arranged accordingly (T.C. Ministry of Transport, 2014).
- *Park guidance (CR5):* Park guidance presents dynamic information to drivers for parking in controlled areas. It is designed to help drivers navigate to parking garages and look for empty parking spaces. The system combines traffic-monitoring, communication, processing and electronic variable message technologies (Deloitte, 2015). Thus, traffic volumes reduced. The accessibility of the city center increased.
- *Travel and traffic information (CR6):* Providing real-time information to drivers about road situations, accidents, traffic congestion, etc. At the same time, according to the transportation between the two points, it is possible to plan the travel based on the individual or public transport options (Ilıcalı et al., 2016).
- *Network robustness and road safety (CR7):* Robust and reliable roads, bridges and other infrastructure elements are essential for the transport quality. Controls of these networks should frequently be fulfilled, and if a problem is encountered, it should be intervened immediately (T.C. Ministry of Transport, 2014).
- *Traceability (CR8):* Traceability is the real-time communication between modes. Central traffic monitoring systems are high-speed tracking systems, red light infringement detection, bus line control, ticket gate control systems, traffic intensity tracking and security applications (Cohen, 2013).

Technological Requirements:

- *Demand and access management (TR1):* Demand and access management usually implemented with the use of additional implementation strategies and variable message markings. It focuses on reducing the intensity of congestion and air pollution in large cities (Civitas, 2015). It facilitates access to transportation means and services for those with restricted mobility.

- *Full adaptive traffic management system (TR2):* It is a working system in which the parameters have optimized for minimizing average vehicle delay times and average stop numbers. It accelerates traffic flow by intervening in real time on blocked roads and reduces delay times. It reduces travel time and emissions on the road network (Giffinger & Gudrun, 2010).
- *Security and emergency systems (TR3):* It detects and prevents emergency intervention events such as traffic accidents (Deloitte, 2015). Security systems consisting of cruise control systems and anti-lock braking systems have developed. New generation systems such as emergency brake-force distribution, electronic stability control and advanced speed control systems have designed (T.C. Ministry of Transport, 2014).
- *Variable message system (TR4):* Variable Message Systems graphics-based fonts, shapes, and images can be displayed using LEDs for traffic purposes. Messages are used to inform drivers about traffic intensity, traffic accidents, weather, and road conditions and to control traffic flow. Thus, road traffic capacity could more efficiently used to reducing local traffic densities (ASCIMER, 2017).
- *Intelligent public transport systems (TR5):* The system that enables the most convenient use of the public transportation needs that arise with the increasing population. Passenger information systems and electronic payment systems are the most common methods used in public transport. These systems include smart stops and contactless smart cards (UNECE, 2012).
- *Road and meteorological observation sensors (TR6):* These sensors support the drivers for safe travel and road and weather conditions. Road sensors collect data to detect traffic flow information in the city. Weather sensors are powerful and versatile sensors that measure atmospheric conditions, monitor ground temperatures (Ilıcalı et al., 2016).
- *Lane control systems (TR7):* Lane control system includes intelligent vehicle system and automatic road system. This system aims to reduce traffic accidents and ensure the safety of drivers (T.C. Ministry of Transport, 2014).
- *Parking guidance systems (TR8):* An intelligent system that provides utilization of parking spaces more efficient. Park orientation systems direct drivers to convenient parking spaces with sensors that detect occupancy or space conditions (Deloitte, 2015).
- *Electronic detection system (TR9):* It is a system, which the vehicles that violate the rules have detected with the sensors. Using cloud technology, it has 12 different violation detection systems (Civitas, 2015).
- *Communication systems (TR10):* It provides communication between the area and central equipment of Intelligent Transportation Systems. This connection can be reached with wired and wireless networks. The communication systems solutions offered by İSBAK are fiber optic solutions, 4G / LTE, 3G, Wi-Fi and WIMAX (Ilıcalı et al., 2016).

Fuzzy SAW Method

The SAW method, also known as the weighted sum method, is the most widely used MCDM method (Hwang & Yoon, 1981). The basic principle of SAW is to obtain a weighted sum of the performance ratings of each alternative. An evaluation score is calculated for each alternative. The advantage of this method is that there is a proportional linear transformation of raw data; this means that the relative order of the sizes in the standardized points remains the same (Chang & Yeh, 2001).

Chou et al. (2008) proposed the fuzzy SAW method to solve problems under fuzzy environment. The steps of the fuzzy SAW method are as follows:

Step 1. Decision makers (DM) evaluate criteria using linguistic terms in Table 2.

Step 2. Let $Dt = \{d_1,d_2,...,d_k\}$ be a committee of k DMs, $Ai = \{a_1,a_2,...,a_I\}$ be a discrete set with I member alternatives, $Cj = \{c_1,c_2,...,c_J\}$ be a set consisting of the decision criteria, be the degree of importance of each DM, where $0 \leq I_t \leq 1$, $t = 1,2,...,k$, and $\sum_{t=1}^{k} I_t = 1$, $\widetilde{\omega t}$ be the fuzzy weight of the DMs. The degree of importance I_t is computed as:

$$I_t = \frac{d(\widetilde{w_t})}{\sum_{t=1}^{k} d(\widetilde{w_t})}, t = 1,2,\dots,k \tag{1}$$

where $d(\widetilde{w_t})$ gives the defuzzified value of the fuzzy weight by using the signed distance.

Table 2. Linguistic Scale for fuzzy SAW (Beg & Rashid, 2013)

Linguistic term	S_i	Abb.	Fuzzy Numbers
None	s_{-3}	N	(0,0,0.17)
Very Low	s_{-2}	VL	(0,0.17,0.33)
Low	s_{-1}	L	(0.17,0.33,0.5)
Medium	s_0	M	(0.33,0.5,0.67)
High	s_1	H	(0.5,0.67,0.83)
Very High	s_2	VH	(0.67,0.83,1)
Perfect	s_3	P	(0.83,1,1)

Step 3. Aggregated fuzzy weights of individual attributes $(\widetilde{W_j})$ are computed. The aggregated fuzzy attribute weight, $\widetilde{W_j} = (a_j, b_j, c_j)$ of criterion *Cj* assessed by the committee of *k* DMs is computed as:

$$\widetilde{W_j} = (I_1 \otimes \widetilde{W_{j1}}) \oplus (I_2 \otimes \widetilde{W_{j2}}) \oplus \ldots \oplus (I_k \otimes \widetilde{W_{k1}}) \tag{2}$$

where $a_j = \sum_{t=1}^{k} I_t a_{jt}$, $b_j = \sum_{t=1}^{k} I_t b_{jt}$, $c_j = \sum_{t=1}^{k} I_t c_{jt}$.

Step 4. The fuzzy weights of criteria are defuzified. The defuzzification of $\widetilde{W_j}$ is denoted as $d(\widetilde{W_j})$ and computed as:

$$d(\widetilde{W_j}) = \frac{1}{3}\left(a_j + b_j + c_j\right), j = 1,2,\ldots,n \tag{3}$$

Step 5. Normalized weight of criterion *Cj* is denoted as W_j and computed as:

$$W_j = \frac{d(\widetilde{W_j})}{\sum_{j=1}^{n} d(\widetilde{W_j})}, j = 1,2,\ldots,n \tag{4}$$

where $\sum_{j=1}^{n} W_j = 1$ and the weight vector $W=(W_1, W_2, \ldots, W_n)$ is constructed.

APPLICATION

Step 1: Customer requirements of smart city logistics in House of Quality matrix are determined with a detailed literature survey and expert opinions.

Step 2: Technological requirements of smart city logistics in House of Quality components are determined with a detailed literature survey and expert opinions.

Step 3: DMs evaluated customer requirements using linguistic terms in Table 2 to calculate weights. These evaluations with linguistic expressions are shown in Table 3.

Table 3. DMs Evaluation for Customer Requirements

	DM1	DM2	DM3		DM1	DM2	DM3
CR1	M	H	VH	**CR5**	N	N	L
CR2	VL	M	L	**CR6**	H	H	H
CR3	L	L	VL	**CR7**	P	VH	VH
CR4	VH	M	L	**CR8**	M	L	M

Step 4: The equations (1) – (4) are applied and the weights of customer requirements are calculated as shown in Table 4.

Table 4. The Weights of Customer Requirements

	Aggregated Fuzzy Weights	Defuzzified Weights	Normalized Weights
CR1	(0.50,0.67,0.83)	0,667	0,168
CR2	(0.17,0.33,0.50)	0,333	0,084
CR3	(0.11,0.28,0.44)	0,278	0,070
CR4	(0.39,0.55,0.72)	0,556	0,140
CR5	(0.06,0.11,0.28)	0,149	0,038
CR6	(0.50,0.67,0.83)	0,667	0,168
CR7	(0.72,0.89,1)	0,870	0,220
CR8	(0.28,0.44,0.61)	0,444	0,112

Step 5: DMs made a collective decision and formed the relationship matrix. For each actor group such as customer requirements, technological requirements, comparison matrices between them, weights and relationship matrix are placed in the House of Quality as Table 5.

Table 5. House of Quality

			Technological Requirement										
			TR1	**TR2**	**TR3**	**TR4**	**TR5**	**TR6**	**TR7**	**TR8**	**TR9**	**TR10**	
Customer Requirements	**CR1**	0,168	9	3			3	1					
	CR2	0,084	9				3				1		
	CR3	0,070		3	3		3		9			3	
	CR4	0,140		3			9		3		1	1	
	CR5	0,038		1		3				9	3	1	
	CR6	0,168		3		9						3	
	CR7	0,220		3	9			3					
	CR8	0,112			3	3					3	9	Sum
			2,271	2,336	2,522	1,963	2,229	0,827	1,051	0,338	0,673	1,902	16,112
		Importance degree	0,141	0,145	0,157	0,122	0,138	0,051	0,065	0,021	0,042	0,118	1,000
		Ranking	3	2	1	5	4	8	7	10	9	6	

Step 6: The importance degree of each technological requirement, by multiplying the weight of the customer requirement and the relationship matrix values are found as follows:

Weight of TR1 = [(0,168×9) + (0,084×9)]/16,112 = 0,101

The final importance degrees are shown in Table 5. As a result of the evaluation, the priority order of the technical requirements is as follows: security and emergency systems (TR3), full adaptive traffic management system (TR2), demand and access management (TR1), intelligent public transport systems (TR5), variable message system (TR4), communication systems (TR10), lane control systems (TR7), road and meteorological observation sensors (TR6), electronic detection system (TR9) and parking guidance systems (TR8).

According to this result, the first issue to focus is on smart city logistics solutions is security and emergency systems. It is the most critical solution because it has the highest evaluation of the relationship between customer requirements and technological requirements. At all times, human safety is the key element. Thanks to smart systems in the case of emergency, fast and direct interventions protect passenger and driver's health. With the developed brake and speed control systems, a more secure logistics system will establish.

CONCLUSION

This study aims to identify and evaluate smart city logistics solutions with fuzzy analytic methods to decide where to start the development of a more sustainable, mobile and livable city. In this reason, a methodology is proposed; the components of the House of Quality determined by the literature survey and the expert opinions are prioritized by the proposed methodology. In this combined work, the priority ranking is made for all technologies without focusing on only one smart technology. According to the results obtained, safety and emergency systems has ranked first in importance.

In future studies, the number of customer and technological requirements can be increased and the problem can be solved using aggregation operators for group decision making to aggregate DMs' evaluations.

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DIGITAL TRANSFORMATION MATURITY ASSESSMENT FOR SUPPLY CHAINS

Gülçin Büyüközkan[1], Merve Güler[2], Esin Mukul[3]

Abstract − *Digital Transformation (DT) is one of the most discussed topics both on academia and business. DT aims to improve operational efficiency, create new customer experience and generate new revenue streams. DT affects the whole business and supply chains have been affected from this transformation. Leveraging the new emerging technologies with new business models makes widespread information available, enhances visibility of supply chain, creates high level collaboration and communication across digital platforms. However, the new digital business models should be systematically shaped. At this point, Digital Maturity Models (DMMs) help firms for analysing their current situation in terms of DT. This paper aims to develop a maturity model for supply chain DT assessment and proposes an original evaluation framework by integrating the model with an analytical method. The maturity dimensions and factors are determined by literature review, industry reports and experts' opinions. The factors' importance degrees are computed by using Fuzzy Analytic Hierarchy Process (AHP) method and the maturity score of the supply chains are calculated. The evaluations of experts are collected by using linguistic variables and fuzzy logic is preferred because of the uncertainty. At the end of study, an application is given and the future perspectives are presented.*

Keywords − *Digital transformation, Supply chain transformation, Maturity assessment*

INTRODUCTION

Over the past years, economy, business and society has been significantly affected from Digital Transformation (DT). The purpose of DT is improving operational efficiency, creating new customer experiences and generating new revenue streams while transforming the business conducting styles of companies. In firms that decide on beginning to DT journey, all of the business processes are reshaped by DT. From hiring processes to transportation processes, new business models are emerged. Supply chain processes have also been affected from DT. New business models of supply chains aim to create an intelligent, value driven network that leverages new approaches with new technology and analytics to create new revenue streams and business value in an efficient and effective way. Leveraging the new emerging technologies with new business models have potential to make widespread information available, to enhance transparency and visibility of supply chain, to create high level collaboration and communication across digital platforms, resulting in improved reliability, agility and effectiveness. However, to successfully implement the new business models, supply chains should be systematically designed. Firms need to know where to start to shape their supply chain's business model. At this point, Digital Maturity Models (DMMs) help firms for assessing their current maturity in terms of DT.

The aim of this paper developing a maturity model concerning the supply chains' DT and proposing a research methodology for their maturity assessment. Firstly, this paper develops a novel DT maturity model for supply chains. Secondly, this paper proposes a research methodology for calculating the maturity score of the supply chains. The research methodology consists of three phases. In the first phase, the maturity dimensions and factors are determined by literature review, industry reports and experts' opinions. In the second phase, the importance degrees of the maturity factors are calculated by using Fuzzy Analytic Hierarchy Process (AHP) method. AHP method is preferred because it builds alignment between criteria, it is intuitive, it is easy to use

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and it validates consistency. Fuzzy logic is preferred because of the uncertain and complex nature of the problem. Experts' evaluations about factors are collected with the aid of fuzzy linguistic variables. In the third phase, the maturity score of the companies are calculated by using maturity questionnaires. At the end of the study, an implementation of the methodology is provided and the future perspectives of the study are presented.

The remainder of the paper is as follows; after introducing the subject, the existing studies concerning DT in supply chains and maturity models are presented in the second section. The research methodology is introduced in the third section. The fourth section presents the supply chain DT maturity model of the study. An implementation of the proposed methodology is given in the fifth section. In the last section, the concluding remarks and the perspectives for future studies are provided.

LITERATURE REVIEW

Digital technologies are changing the world by changing the industries. The expectations for service, speed and quality of supply chains increase due to this change (URL1). DT of supply chains enables tracking and tracing the flow of goods, creating B2B networks and enhancing visibility of supply chains (URL2). Firms seek to transform their supply chains from traditional supply chains to digitally enabled supply chains. To meet the requirements of continuously changing business landscape, firms have to assess their current performance of supply chains in terms of DT. Maturity assessment helps firms the calculate the score of their supply chains in their DT journey (URL3).

In the literature, although many studies have been interested in DT of supply chains, there is not much study about the supply chain DT assessment through a maturity model utilization. Inversely, there are a variety of industry reports that investigates the supply chain maturity assessment (URL1, URL2, URL3, URL4, URL5).

McCormack and Kasper (2002) examined the utilization of digital technologies in supply chain. Plomp and Batenburg (2010) introduced a maturity framework for digitalization and realized a case study for Dutch retail branches. Schumacher et al. (2016) proposed a model to assess the maturity of manufacturing companies and the readiness for Industry 4.0. Gilbert et al. (2017) assessed the performance and stability of a digital supply chain by conducting a pilot study in India. Klötzer and Pflaum (2017) developed maturity model for the manufacturing industry's supply chain.

Bechtsis et al. (2018) developed a simulation software to track intelligent autonomous vehicles in supply chain. Büyüközkan and Göçer (2018a) reviewed the studies concerning digital supply chain and proposed a framework. In another study, Büyüközkan and Göçer (2018b) applied an integrated interval-valued intuitionistic fuzzy MCDM methodology for selecting supplier in digital supply chain. Canetta et al. (2018) proposed a digital maturity model for manufacturing industry. Ghobakhloo (2018) reviewed the studies concerning Industry 4.0 and proposed a strategic roadmap to guide companies.

PROPOSED RESEARCH METHODOLOGY

The proposed research methodology consists of three main stages. The overview of the study is illustrated in Figure 1. In the first stage, the maturity dimensions and the maturity factors for assessing company's supply chain DT maturity are determined based on literature review, industry reports and experts' reviews. The maturity dimensions and the maturity factors are detailed in the following section. In the second stage, the importance degrees of maturity factors are determined by using fuzzy AHP method. The computational steps of the fuzzy AHP method is explained in further section. In the last stage, the maturity score of the company is calculated based on a maturity questionnaire. At the end of the research methodology, the digital maturity score of a company can be found and the weaknesses of a company can be clearly seen.

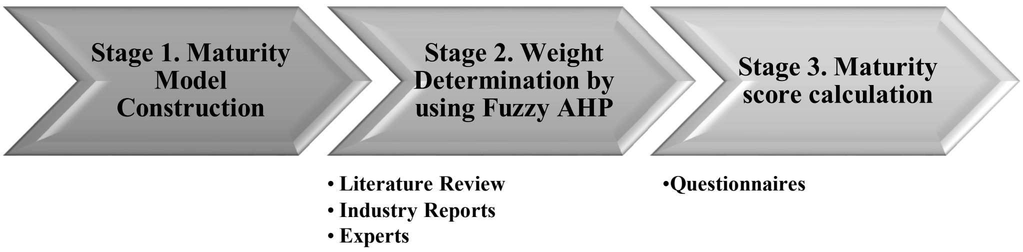

Figure 1. The stages of the proposed research methodology

Supply Chain Digital Transformation Maturity Model

DT of supply chains requires radical changes in areas such as human resources, process, technology, management and ecosystem. For this reason, DT Maturity Assessment follows these five essential dimensions.

For example, to achieve higher level of digital maturity in technology dimension, it is important to have an enhanced IT infrastructure, to utilize data analytics and to have automated decision-making. Table 1 summarizes the five dimensions and the maturity factors below these dimensions.

Table 1. Maturity model for supply chain

Dimensions	Digital Maturity Factors
Human Resources	Hiring digitally talented employees Having digital capability development programs Working with cross-functional teams
Processes	Having digital product and service offerings Integrated and connected supply networks Visible and traceable processes
Technology	Enhanced IT infrastructure Data analytics utilization Rapid/automated decision-making
Management	Supplier relationship management Risk management Agile project management
Ecosystem	Omni-channel order and distribution networks Direct to consumer and B2B commerce Identifying and mitigating supply risks

Human Resources: Digital workforce is one of the most important components of DT. With digitally talented employees, it is possible to achieve high level of digital maturity. After hiring digitally talented employees, they should be supported with digital capability development programs (URL1). On the other hand, the cross-functional teams should enable collaboration and communication among employees (URL4).

Processes: Integrated and end-to-end connected supply chains collaborate better with suppliers, identify areas to improve and react quickly to unexpected changes. A networked supply chain leads to more comprehensive data and it creates visible and traceable processes. As a result, supply chains improves their capabilities on planning, forecasting, and the movement of goods (URL1).

Technology: Companies should strategically utilize digital technologies for improving their supply chain performance. To have a mature organization in terms of DT, supply chains should have an enhanced IT infrastructure, utilize data analytics and have automated decision-making (URL3). To uncover hidden values from diverse, complex, and large-scale data sets, descriptive, diagnostic, predictive and prescriptive analytics should be performed between departments (URL4).

Management: A company-wide management with a focus on demand stimulation, supplier relationship management, risk management and agile project management is essential for supply chains (URL4, URL5). First, the suppliers and the company should trust each other. The business performance and compliance risk should be reduced through utilization of predictive analytics (URL3). Furthermore, company should response to changing conditions in an agile way with agile project management.

Ecosystem: Supply chains are collaborative networks and they continuously interact with their ecosystem. For this reason, ecosystem dimension is indispensable for DT of supply chains. To have a digitally enabled and mature organization, supply chains should contain Omni-channel order and distribution networks, direct to consumer and B2B commerce and mitigate supply risks (URL2, URL4).

Fuzzy AHP Method

The linguistic expressions that we used for fuzzy AHP method are given in Table 2. Experts use these linguistic expressions for evaluating the criteria.

Table 2. Fuzzy linguistic expressions (Büyüközkan and Çifçi, 2012)

Linguistic Expressions	Abb.	Triangular Fuzzy Numbers
Equal	E	(1,1,1)
Equal Importance	EI	(1,1,2)
Moderate Importance	MI	(2,3,4)
Strong Importance	SI	(4,5,6)
Very Strong Importance	VSI	(6,7,8)
Extremely More Importance	EMI	(8,9,10)

Fuzzy AHP-1st Stage. The first task of the fuzzy AHP method is to decide on the relative importance of each pair of factors in the same hierarchy. The evaluation matrix is constructed by binary comparison.

Fuzzy AHP-2nd Stage. Fuzzy linguistic expressions collected from experts are transformed into triangular fuzzy numbers. The membership function of the fuzzy number $\widetilde{A}=(l,m,u)$ is as follows: (Wu vd., 2009):

$$\mu_{\widetilde{A}}(x)=\begin{cases}\frac{(x-l)}{(m-l)} \text{ if } l\leq x\leq m ,\\ \frac{(u-x)}{(u-m)} \text{ if } m\leq x\leq u ,\\ 0 \text{ otherwise.}\end{cases} \quad (1)$$

Fuzzy AHP-3rd Stage. By using $\propto$*-cut* method, $\propto$*-cut* fuzzy pairwise comparison matrices are built ($\propto$=0.5; μ=0.5)

Fuzzy AHP-4th Stage. The optimality index is calculated for each factor (Lee, 1999):

$$\widetilde{a_{ij}^{\propto}} = \mu a_{ij}^{\alpha} + (1 - \mu)a_{ij}^{\alpha}, \quad \forall\alpha\epsilon[0,1] \quad (2)$$

Fuzzy AHP-5th Stage. Normalization process is performed and the local weight vector is calculated (Büyüközkan and Çifçi, 2012).

Fuzzy AHP-6th Stage. To test the evaluations, the consistency ratio is calculated using the following formulas. Firstly, to obtain single values from the triangular fuzzy numbers denoted as $\tilde{A} = (l, m, u)$ in the matrices, defuzzification operation is realized and the Best Nonfuzzy Performance Value (BNP) of each factor is calculated (Hsieh et al., 2004):

$$BNP_i=\frac{[(u_i-l_i)+(m_i-l_i)]}{3}+l_i, \quad \forall_i \quad (3)$$

Consistency ratio (*CR*) is computed by (Büyüközkan ve Çifçi, 2012):

$$CI = \frac{\lambda_{max}-n}{n-1} \quad (4)$$

$$CR = \frac{CI}{RI} \quad (5)$$

CI shows consistency ratio, λ_{max} shows the biggest eigenvector of the matrix. *n* is the number of factors and *RI* is the random index. RI changes according to dimension of the matrix. To agree the result as consistent, the CR value should be less than 0.1.

Fuzzy AHP-7th Stage. For sub-criteria, the same operations are performed in order to find local weights. Finally, the weights of the sub criteria are multiplied by the weights of the main criteria and the final weights are found.

Maturity Score Calculation Method

A digital maturity assessment questionnaire is prepared for assessing the companies' current situations. Experts evaluated their companies on a scale between 1-5 (1: the worst - 5: the best). After getting the responds from the questionnaire, the maturity score of the company's supply chain is calculated by (Schumacher et al., 2016):

$$M_D = \frac{\sum_{i=1}^{n} M_{DIi} * g_{DIi}}{\sum_{i=1}^{n} g_{DIi}} \quad (6)$$

M shows the maturity, *D* shows the dimension, *I* shows the item (factor), *g* shows the weighting factor and *n* is the number of the maturity factors.

IMPLEMENTATION OF THE PROPOSED METHODOLOGY

The proposed method will be implemented for a logistics company to verify its applicability. According to Capgemini Consulting's report, 49% of organizations feel pressure for the necessity of supply chain DT. On the other hand, 65% of organizations haven't started yet to DT or they only have a strategy and digital vision (URL6).

The name of the company is denoted as "XYZ". The company wants to digitally transform its supply chain for different reasons. These reasons can be summarized as:

— To make and to store just the necessity amount of inventory,

— To have supply chain that provides co-working across functions, integration of tasks and collaboration with partners,

— To have real-time data for processes that enhances the operational efficiency of supply chain,

— To manage cost effectively,

— To have exact forecasts that decreases the level of the safety stock,

— To have real-time information sharing with the customers, the suppliers and the third-party service providers.

To begin its DT journey, XYZ has to learn where to begin its journey and to analyze its current digital maturity. In this context, DT maturity assessment helps XYZ to find its current digital maturity score. The digital maturity assessment consists of three main stages. First of all, the maturity model is constructed. The maturity dimensions and factors are identified based on academic research and professional opinions of the industrial experts. They are provided in Table 1. In the second stage, the importance degrees of these factors are determined with the help of experts. The experts are the technology manager, technology expert and finance general manager. They have insights about supply chain operations, logistics processes and they have experience about DT projects. The fuzzy AHP method is used for determining the factors' importance degrees. In the last stage, the experts assessed the digital maturity of XYZ via a digital maturity assessment questionnaire.

Stage 1. Maturity Model Construction

The maturity dimensions and factors used in this study are:

- **Human Resources (F_1):** Hiring digitally talented employees (F_{11}), Having digital capability development programs (F_{12}), Working with cross-functional teams (F_{13});
- **Processes (F_2):** Having digital product and service offerings (F_{21}), Integrated and connected supply networks (F_{22}), Visible and traceable processes (F_{23});
- **Technology (F_3):** Enhanced IT infrastructure (F_{31}), Data analytics utilization (F_{32}), Rapid/automated decision-making (F_{33});
- **Management (F_4):** Supplier relationship management (F_{41}), Risk management (F_{42}), Agile project management (F_{43});
- **Ecosystem (F_5):** Omni-channel order and distribution networks (F_{51}), Direct to consumer and B2B commerce (F_{52}), Identifying and mitigating supply risks (F_{53}).

Stage 2. Weight Determination by using Fuzzy AHP

First, experts compared the maturity dimensions and maturity factors using the expressions given in Table 2. Table 3 shows the experts' assessment for the Human Resources factor (F_1).

Table 3. Experts' assessment for F_1

	Linguistic Expressions			Fuzzy Numbers		
Criteria	F_{11}	F_{12}	F_{13}	F_{11}	F_{12}	F_{13}
F_{11}	-	WMI	EI	1	(2,3,4)	(1,1,2)
F_{12}		-		(1/4,1/3,1/2)	1	(1/2,1,2)
F_{13}		EI	-	(1/2,1,1)	(1,1,2)	1

The steps of the fuzzy AHP method are applied responsively and the weights of the criteria are found using (1), (2), (3), (4), (5). The result of the method is given in Table 4. Consistency ratios of the assessments are found as: CR_{main}=0.0013; CR_{F1}=0.026; CR_{F2}=0.0062; CR_{F3}=0.0026; CR_{F4}=0.0033; CR_{F5}=0.005).

Table 4. The result of fuzzy AHP method

Dimensions	Weights	Factors	Local Weights	Weights	Ranking
F_1	0.135	F_{11}	0.493	0.066	5
		F_{12}	0.196	0.027	12
		F_{13}	0.311	0.042	8
F_2	0.060	F_{21}	0.453	0.027	11
		F_{22}	0.122	0.007	15
		F_{23}	0.426	0.026	13
F_3	0.099	F_{31}	0.493	0.049	7
		F_{32}	0.311	0.031	10
		F_{33}	0.196	0.019	14
F_4	0.337	F_{41}	0.266	0.090	3
		F_{42}	0.109	0.037	9
		F_{43}	0.624	0.210	2
F_5	0.368	F_{51}	0.643	0.237	1
		F_{51}	0.216	0.079	4
		F_{53}	0.141	0.052	6

The most important maturity factor is found as Omni-channel order and distribution networks (F_{51}); the second important factor is found as Agile project management (F_{43}) and the third important factor is found as Supplier relationship management (F_{41}).

Stage 3. Maturity score calculation

The questionnaire about maturity factors is sent by e-mail to experts and they evaluated the XYZ. By using (6), the maturity score of the company is calculated. The overall maturity score of the company is provided in Table 5 and the maturity scores are visualized by the radar chart in Figure 2.

Table 5. The digital maturity scores

Dimensions	Score
Human Resources	2.493
Processes	3.122
Technology	2.804
Management	3.266
Ecosystem	2.643
Total Score	14.328

Total digital maturity score of the XYZ is calculated as 14.328 where the maximum maturity score is 25 (5 dimensions*5 maximum score). Therefore, the digital maturity point of XYZ is (14.328/25) *100= 57.

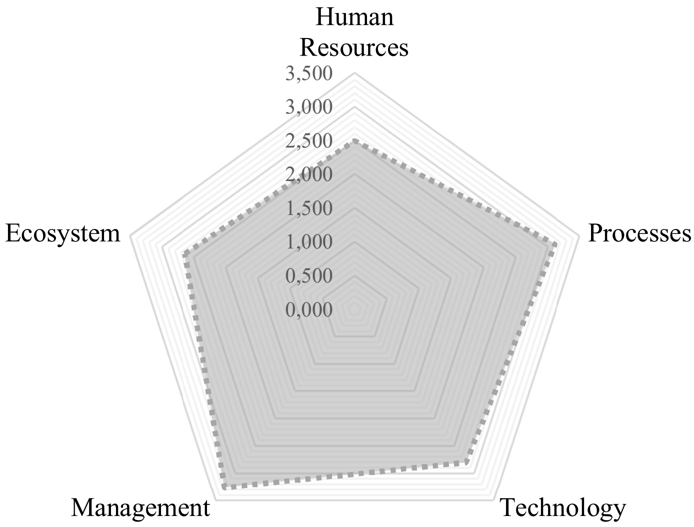

Figure 2. The maturity scores of XYZ

As seen in Figure 2, XYZ has weaknesses in Human Resources and Ecosystem dimensions. XYZ should mainly focus on these dimensions while transforming its supply chain.

CONCLUSION AND PERSPECTIVES

The aim of this study was to develop a maturity model concerning the DT of supply chains and to propose a research methodology for their maturity assessment. In this context, a novel DT maturity model for supply chains is proposed. Then, a research methodology for calculating the digital maturity score of the supply chains is presented. The research methodology is composed from model construction stage, weight calculation stage and score calculation stage. The fuzzy AHP method is utilized in the weight calculation stage. Fuzzy logic is preferred to overcome uncertainty in decision-making process and to facilitate experts' evaluation phase by the utilization of linguistic expressions. AHP method is preferred because it builds alignment between criteria, it is intuitive and it validates consistency. To prove the applicability of the proposed methodology, implementation of the model is realized for a company and the results of the study is given.

In future studies, it can be interesting to consider the interaction between maturity factors and calculate the factors' weights by utilizing fuzzy Analytic Network Process (ANP) method and to compare the results with the current method.

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A MATHEMATICAL MODEL FOR THE MILK COLLECTION PROBLEM WITH VARIOUS MILK TYPES

Olcay Polat[1], Can Berk Kalaycı[2], Bilge Bilgen[3], Duygu Topaloğlu[4]

Abstract *– Milk collection problem (MCP) is concerned with the collection of raw milk with different qualities from dairy factories via tankers under problem specific constraints. During this process, collection of milk without mixing is at least as critically important as production quality since final milk quality is accepted to be equal to the quality of the milk with the worst quality when milk of different qualities is mixed. MCP is concerned with decisions of selecting farms/milk collection centers to be visited, milk quality to be selected, type of tanker to be used; tanks to be stored; and finally, the visiting sequence to be optimized. MCP is a rich variant of vehicle routing problem that additionally considers incompatibility and loading constraints, critical in practice, specific to MCP. In this study, an integrated mathematical model that aims to minimize total distance for tanker assignment and routing problems is proposed. Results show that developed mixed integer linear programing model is promising on efficiently solving small sized instances.*

Keywords: Logistics, Milk collection problem, Mathematical modelling, Vehicle routing problem

INTRODUCTION

Milk collection problem (MCP) is concerned with the collection of raw milk with different qualities from dairy factories via tankers under problem specific constraints. MCP is concerned with decisions of selecting farms/milk collection centers to be visited, milk quality to be selected, type of tanker to be used; tanks to be stored; and finally, the visiting sequence to be optimized. For this reason, MCP has two kinds of sub problems. These problems are Vehicle Assignment Problem (VAP) and Vehicle Routing Problem (VRP).

MCP is a rich variant of vehicle routing problem that additionally considers incompatibility and loading constraints, critical in practice, specific to MCP. In the scientific literature of MCP, there are studies that solve small sized problems sequentially or by simplifying. However, any study that is directed to the simultaneous solution of these decision problems is not yet available. In a few studies in the literature that considers MCP as a rich variant of vehicle routing problem, incompatibility and loading constraints specific to MCP which are critical in practice are ignored.

In the literature, Caramia and Guerriero (2010) solved the MCP problem in two stage. Firstly, they assigned tanks, after that they find these tanks' route. Tarantilis and Kiranoudis (2007) and Dayarian et al. (2015) considered the problem as heterogeneous VRP. The assignment and routing problem is solved simultaneously. However, in these studies, incompatibility constraints and loading constraints were not taken into consideration. Therefore, while these studies produce better results in terms of solution quality, the results are not applicable due to the problem-specific constraints are not handled.

In this study, it is aimed to consider problem specific constraints such as different tank capacity, time limit, divisible demand, fixed fleet, multi-tank transport and different milk types constraints. For this aim, an integrated mathematical model that aims to minimize total distance and total networks costs for tanker assignment and routing problems is proposed in the literature for the first time.

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MATHEMATICAL MODEL

Core MCP model is modelled as **multi compartment vehicle routing problem with split deliveries (MC-VRP-SD)**. Mathematical model assumptions for basic problem are;

- To be collected raw milk amounts are known and deterministic.
- Raw milk types are predetermined and categorized by experts.
- There is no blending in tankers for different type of raw milks.
- There is blending for same type of raw milk from different farms.
- Farms may provide each type of raw milk.
- Each tanker must start and end its route at the dairy factory.
- Farms/collection centers are contracted which means all raw milk in the farms/collection centers have to be collected.
- Split collection allowed which means each of tankers may visit farms/collection centers.
- The collected amount of raw milk cannot exceed related tanks capacities.
- Collected raw milks have to be delivered to dairy factory under a certain time limit.

The objective is to minimize the total distance travelled by the tankers in the network.

Indices

$i, j, p \in N$	set of nodes (0: dairy factory, 1..N: farms/collection centers)
$k \in K$	set of tankers
$t \in T$	set of tanks on a tanker
$m \in M$	raw milk types in the collection area

Parameters

Q_{kt}	capacity of tank *t* on tanker *k*
C_{ij}	distance between node *i* an *j*
D_{im}	to be collected amount of type *m* raw milk from farm/collection center *i*
S_i	service time at farm/collection center *i*
V	average speed of tankers
L	maximum route duration for delivering collected raw milk to the dairy factory

Decision variables

x_{ijk}	1: if the arc between the node *i* and *j* is served by tanker *k*; 0: otherwise
z_k	1: if the tanker *k* is used in the network; 0: otherwise
h_{ktm}	1: if the tank *t* on the tanker *k* is assigned to the milk type *m*; 0: otherwise
y_{ik}	Fulfillment ratio for farm/collection center *i by using tanker k*
π_i	Subtour elimination variable

$$minimize\ Z = \sum_{i \in N} \sum_{j \in N} \sum_{k \in k} C_{ij} x_{ijk} \qquad (1)$$

s.t.

$$\sum_{i \in N} \sum_{k \in K} x_{ijk} \geq 1 \qquad \forall j \in N \qquad (2)$$

$$\sum_{i\in N} x_{ijk} - \sum_{i\in N} x_{jik} = 0 \qquad \forall j \in N, k \in K \qquad (3)$$

$$\sum_{j\in N/\{0\}} x_{0jk} \leq 1 \qquad \forall k \in K \qquad (4)$$

$$\sum_{i\in N/\{0\}} x_{i0k} \leq 1 \qquad \forall k \in K \qquad (5)$$

$$\sum_{i\in N/\{0\}} \sum_{j\in N/\{0\}} x_{ijk} \leq |N| z_k \qquad \forall k \in K \qquad (6)$$

$$\sum_{m\in M} h_{ktm} \leq z_k \qquad \forall k \in K, t \in T \qquad (7)$$

$$y_{ik} \leq \sum_{j\in N} x_{ijk} \qquad \forall i \in N/\{0\}, k \in K \qquad (8)$$

$$\sum_{m\in M} \sum_{k\in K} y_{ik} = 1 \qquad \forall i \in N/\{0\} \qquad (9)$$

$$\sum_{i\in N/\{0\}} D_{im}\, y_{ik} \leq \sum_{t\in T} Q_{kt}\, h_{ktm} \qquad \forall k \in K \qquad (10)$$

$$\sum_{i\in N/\{0\}} \sum_{j\in N} \frac{C_{ij}}{V} x_{ijk} + \sum_{i\in N/\{0\}} \sum_{j\in N} S_i x_{ijk} \leq L \qquad \forall k \in K \qquad (11)$$

$$\pi_i \geq \pi_j + 1 - N * (1 - \sum_{k\in K} x_{ijk}) \qquad \forall i, j \in N, i \neq j \qquad (12)$$

$$y_{ik}, \pi_i \geq 0 \qquad \forall i \in N, k \in K \qquad (13)$$

$$x_{ijk}, z_k, h_{ktm} \in \{0,1\} \qquad \forall i, j \in N, k \in K, t \in T, m \in M \qquad (14)$$

Objective function (1) aims to minimize traveled total distance in the network. (2) Constraint ensures that each node is visited at least once. Constraint (3) are the flow conservation constraints. Constraint 4-5 Each vehicle k starts its route from depot 0 and ends it at depot 0. Constraint (6) guarantees that a tanker can be served as long as it is in use. Constraint (7) impose that only one type of raw milk can be assigned to a single tank. Constraint (8)-(9) ensures that to be collected amount of a farm/collection centers may satisfied by several visit. In each visit, a certain percentage of demand is collected. Constraint (10) guarantees that the amount of raw milks assigned to a tank cannot exceed related tank's capacity. Constraint (11) represent the maximum duration limit for collected raw milks in a tanker. Constraint (12) are the subtours elimination constraints. Finally, Constraint (13)-(14) define the variable domains.

HYPOTHETICAL CASE STUDY

A real life hypothetical case study is designed to the measure mathematical model problem performance. The hypothetical case study has 16 clients as shown in Figure 1. For this problem, the first node is taken as a dairy processing firm, and the other nodes are taken as a milk collection centers. Some of milk collection centers can collect two kinds of milk while some of them collect just one type of milk.

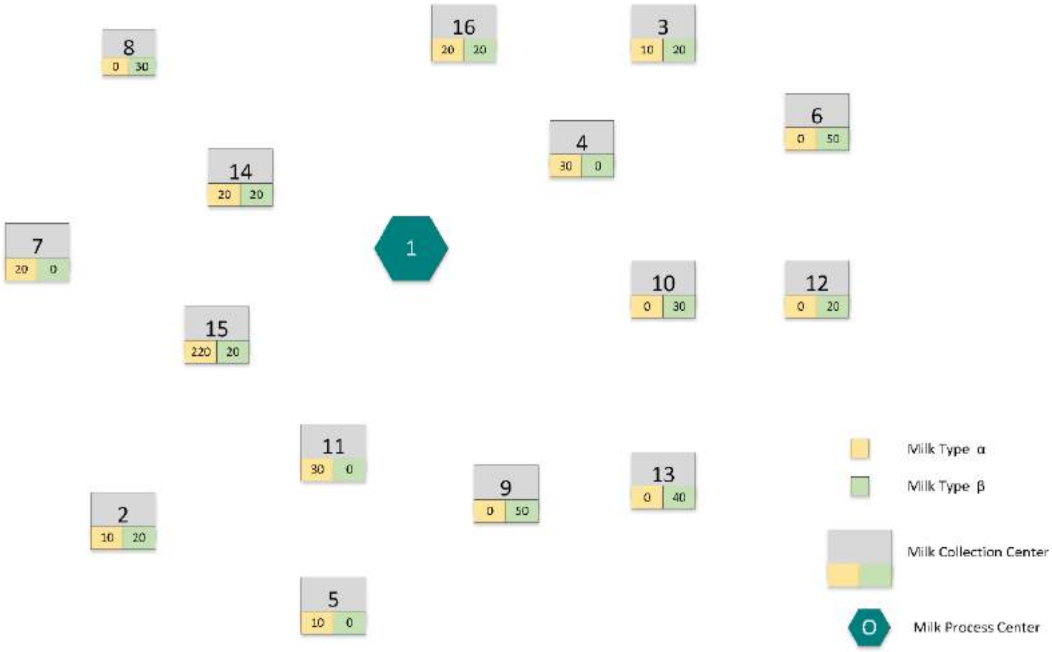

Figure 6. Milk Collection Centers & Dairy Firm Map

Each milk collection center has own service duration time. Service duration time important for the milk quality. As we introduce at the introduction part milk producing has a specific time limit constraints. For this reason, within the defined time limit milk should be collected from the milk collection centers and delivered to the dairy firm. The time windows limit for this problem determined as 3000 minutes for each vehicle total route time. Problem data sets show in Table 1.

Table 1. Hypothetical Case Study Data Set

Client	Milk Type		Service Duration	Location	
	α	β		X	Y
1	0	0	1	0	0
2	10	20	15	975.690	411.985
3	10	20	20	457.692	977.378
4	30	0	15	336.499	148.107
5	10	0	25	867.212	241.269
6	0	50	25	919.882	547.194
7	20	0	10	766.775	360.531
8	0	30	15	376.221	264.250
9	0	50	25	998.429	979.084
10	0	30	15	574.582	240.938
11	30	0	15	900.367	860.861
12	0	20	35	678.493	560.583
13	0	40	35	606.304	601.788
14	20	20	20	72.657	869.263
15	220	20	45	355.443	872.139
16	20	20	50	359.834	974.215

The dairy firm has three tankers from two types of tankers. Both tanker types have two tanks and different amount of capacities that shown in Table 2.

Table 2. Tanker & Tank Capacities

Tankers	Tanks	
	1	2
1	100	100
2	100	100
3	200	200

The hypothetical case study solved in Gams 23.5.1 version by using BONMIN solver. The solution is illustrated in Figure 2 as service network map.

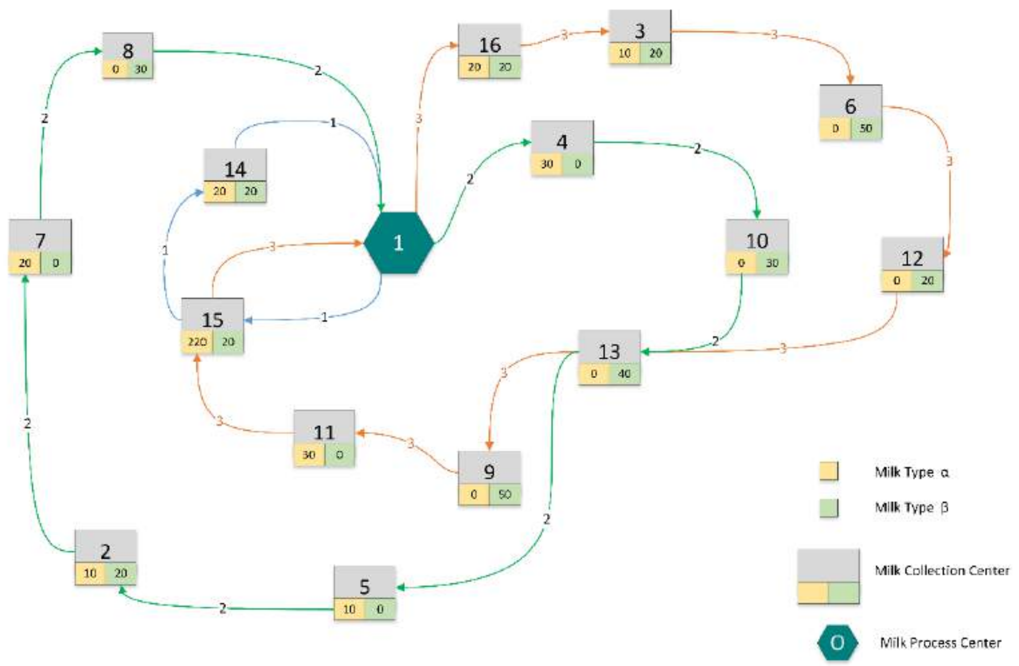

Figure 7. Service Network Map

When the mathematical model solution examined, it is observed that the model split the amount of milk collected by tanks in two clients. The first of these clients is 13th milk collection center. The mathematical model divided the amount of milk to equal amounts to the second tank and the third tank. Another client, which is the amount of the milk split two parts, is the 15th milk collection center. The mathematical model has assigned two tanks to collect the milk of this milk collection center. These are first and third tanks. The first tank will receive 36.4 percent of the total amount of milk, while the third tank will receive the remaining 63.6 percent.

Table 3. Conclusion of the Hypothetical Case Study

Tanker Number	Milk Collection Center Sequence	Route Distance (km)	Route Duration (m)	Tank Usage (lt/capacity)	
				1st Tank	2nd Tank
1	1-15-14-1	209,69	37,38	100%	27%
2	1-4-10-13-5-2-7-8-1	270,993	113,5	70%	100%
3	1-16-3-6-12-13-9-11-15-1	427,738	217,12	100%	96%
Total		908,421			

CONCLUSION

MCP is known to be NP-Hard when problem complexity is considered. CPLEX solver can be utilized in order to obtain exact solutions on small sized data sets while heuristic approaches would be more suitable for rapidly reaching near-optimal solutions on bigger sized problems. In this context, efficient solution approaches that are known to be successful in solving vehicle routing problems should be developed.

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DETERMINING TIME WINDOW SOLUTIONS IN CITY DISTRIBUTION

Derya Eren Akyol[1], Rene De Koster[2]

Abstract *–To lessen the negative effects of urban freight transport, local governments in many cities have implemented time windows for freight vehicles to limit the time vehicles are allowed to enter city centers. The delivery time windows for each city is determined by the city authority itself and the retailers have to comply with the restrictions imposed. However, the time window restrictions that a particular city applies affect not only store deliveries in that city, but also the store deliveries in neighbouring cities, since retailers try to make combined trips. In this paper, we use a game theoretic method to find time windows that improve on the currently used time windows, by cooperation between the cities. Using the municipal time preferences for truck deliveries, mathematical models are developed to represent the city satisfaction functions which take into consideration the interaction with the time windows of the neighbouring cities. Joint optimal time windows can be determined resulting from the possible city coalitions. A case study is presented to illustrate the approach and the results.*

Keywords –City distribution, game theory, time windows, truck deliveries

INTRODUCTION

Governments of Western European and some Asian countries try to solve urban freight problems by some measures such as access-restricting delivery time windows for trucks, vehicle size and weight restrictions, noise regulations and environmental zones. Time window measures are probably the most commonly used (Quak, 2008). They limit the periods during which freight vehicles are allowed to enter city centers (usually outside shopping hours). The objective is to reduce inconvenience for residents and the shopping public, to increase accessibility (reduce congestion) during shopping hours and thereby make the city more attractive for the shopping public (Quak and De Koster, 2007).

As mentioned in OECD (2003), in most countries, urban freight transport is considered as a local problem and local authorities are responsible to establish transport regulations including time windows. Since the local authorities determine time window restrictions without considering other cities' objectives, time window restrictions in a country may vary from city to city and even within the cities from area to area, it is possible to have different time window restrictions. As the time window pressure increases, the number of store deliveries that can be combined in one roundtrip decreases, i.e., the retailer is forced to use extra number of trucks and cover longer distances to accomplish the store deliveries which results an enourmous increase in the retailer's cost. Furthermore, time windows change over time and for the retailer, it is not possible to accommodate to all these changes. For this reason, many retailers consider time window policies as one of the major problems in urban freight transport.

In this study, we try to find the time window restrictions that might be bettter than the current time window restrictions, considering both the objectives of the retailers and the city municipalities. In practice, the retailers comply with the restrictions applied, however, local authorities create some incentives for the retailers to increase the efficiency of transport operations. In some cities, large retailers that use less polluting and/or low noise trucks can obtain exemptions so that they are allowed to enter the central areas in an extended time window period or they pay a small penalty for violating the time window restrictions. These penalties can be enforced through movable bollards placed under the ground which go down when the time windows start and go up when the time windows end, and the retailers with a chip-card can enter and leave the city centers outside time windows for allowed extended hours.

In determining the time windows, a game theoretic approach is used where a coalition of the cities cooperate to determine their time windows together. Cooperation between the cities brings advantages to both the cities

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and the retailers. Since the time windows of the cities will be determined in accordance with each other, it might lead to lower cost for the retailer which results an increase in the city attractiveness. Furthermore, since the retailers can easily combine trips, it might lead to less violation and therefore, a higher satisfaction for the cities.

LITERATURE REVIEW

Despite a set of measures, in recent years, several researchers have studied time windows which are among the most common actions taken by local authorities in order to control or reduce the negative sustainable impacts of freight transport (Quak & de Koster, 2006). Allen et al. (2003) test the effect of different measures including time window restrictions, low emission zones, congestion charging and vehicle weight restrictions on the financial and operational costs and the environment. The relationship between these policy measures and the reaction of the companies in different areas to the measures were also analyzed. Groothedde and Uil (2004) analyze the impacts of time windows and vehicle restrictions and find that estimate that these measures result in a great increase in the Dutch retailer distribution costs. Quak and De Koster (2007) examine the impact of time window pressure on the distribution performance of retailers. They show that as time window restrictions become tighter, emissions and retailer distribution cost increase in a nonlinear manner. In another study, Quak and De Koster (2009) consider the effect of the retailer's distribution choices on his cost sensitivity to combined time window and vehicle restrictions.

In the literature various studies have been conducted to increase the effectiveness of freight transportation operations through cooperation. According to Cruijssen et al. (2007), horizontal cooperation is perceived to be an interesting approach by logistic service providers to decrease cost, improve service, or protect market positions. As a result, in recent years, literature on horizontal cooperation in transportation and logistics has also increased. For a detailed overview of earlier works, see Cruijssen et al., (2007).

Different than the horizontal cooperation examples in the literature, in this paper, we consider cooperation between neighboring cities, in an attempt to jointly determine their time windows. We then evaluate the city satisfactions, resulting from the optimal retailers' delivery routes, based on these time windows.

METHODOLOGY

The first step involves the development of the scenarios in order to generate the data for the regression models to approximate the city satisfaction scores. These scenarios have random time window medians and lengths at the different cities involved, representing different degrees of time window pressure. The problem for each retailer can be modeled as a vehicle routing problem with time windows (VRPTW). The deliveries start from one depot (i.e. a distribution center) and the objective is to serve the customers at minimum cost. The municipal time preferences for truck deliveries are obtained from the study of Eren Akyol and De Koster (2013) and the satisfaction score of each city is calculated. Then, the satisfaction score functions are obtained using regression analysis. Through the help of mathematical models, city cooperation is modeled.

We consider the collaboration between n municipalities and introduce models where the cities can get a higher satisfaction by determining their time windows together. After that, we determine time windows from these models.

CASE STUDY AND RESULTS

The model and framework is tested for three retail chains in the Netherlands which try to combine multiple deliveries in a truck route and, as a result, the truck routes are sensitive to time window policies in different cities (see Quak and De Koster, 2009).

Since the urban freight policies of the local authorities usually are implemented in city center shopping areas, our focus is on retail chains whose stores are mostly located in city centers. Detailed flow data were collected on each retailer's secondary distribution. The retailers were asked to provide information of the vehicle types used, capacity of the vehicles, the loading and unloading process, etc.

For the comply option of each retailer, a VRPTW problem is solved for each time window scenario. The results are obtained for a minimum number of vehicles. After obtaining the routes of each retailer, for each scenario, the satisfaction score of each city is computed resulting from the routes of three retailers. After solving the collaborative models, time window solutions are obtained through a numerical procedure (See Table 1). A statistical software is used to approximate the city satisfaction score functions. From the results obtained, we see that by determining the time windows using the proposed approach, we obtain higher satisfaction values for all the cities compared to the current situation.

Table1. Time window solutions

Time windows	*Comply option*
TW_city1	07:45-09:45
TW_city1	08:00-10:00
TW_city2	08:30-10:30
TW_city2	18:30-20:30
TW_city3	07:00-09:00
TW_city3	09:00-11:00

CONCLUSIONS

We develop a framework to determine the time windows that maximize the city satisfaction at minimum costs for the retailers involved in a cooperative environment. A game theoretic collaborative approach is proposed where the cities cooperate to determine their time windows together.

Cooperation between the cities brings advantages to both the cities and the retailers. The cities benefit, as the satisfaction obtained by cooperation is larger than or equal to the current satisfaction. Since the time windows of the cities will be determined jointly, cooperation can also lead to lower costs for the retailers, which in its turn might result in an increase in the city attractiveness. Furthermore, since the retailers can easily combine trips, it might lead to less time-window violation and therefore, a higher satisfaction for the cities. Municipality decision makers can use the proposed framework to organize their time windows in cooperation with other cities.

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A MODEL FOR DETERMINING THE LOCATIONS OF ELECTRIC CHARGE STATIONS IN ISTANBUL

Büşra Gülnihan Daşcıoğlu[1], Gülfem Tuzkaya[2], Hüseyin Selçuk Kılıç[3]

Abstract *– Regarding the environmental concerns of the classic transportation systems, the studies about hybrid vehicles have become more important and increased in the last years. One of the problems to consider at this point is to determine the proper locations of recharging stations for hybrid and electric vehicles (EV). The aim of this paper is to determine the optimum locations of charging stations in Istanbul considering the existing number of EVs and hybrid vehicles (HV). The locations of charging stations are determined by using a mathematical model based on the p-median model with the aim of minimizing the total distance traversed.*

Keywords – Assignment problem, Electric vehicles, Electric Stations, Hybrid vehicles, P-Median model.

INTRODUCTION

In recent years, electric and hybrid vehicles are getting attention because it is a good solution for liquid fossil fuel problems. CO_2 emission consumption increased by almost 4% between the years of 2014-2016 according to EDGAR (Emission Database for Global Atmospheric Research) survey. In land use with the decline in the tilth rate, in 2017 it reached almost 41 billion metric tons. According to survey of Global Carbon Project Figure 1 shows CO_2 emission from fossil fuels over the past 59 years (Olivier et. al, 2017). The energy sector predicts that future estimates will be a serious loss of energy systems by 2040 (Nakata, 2000). This loss is mainly caused by the damage caused by man-made energy resources, and to prevent these damages by reducing the damage caused by fuel consumption of technological developments. Researchers aim to reduce carbon emissions by using hybrid and electric vehicles to regulate the roots of normal vehicles.

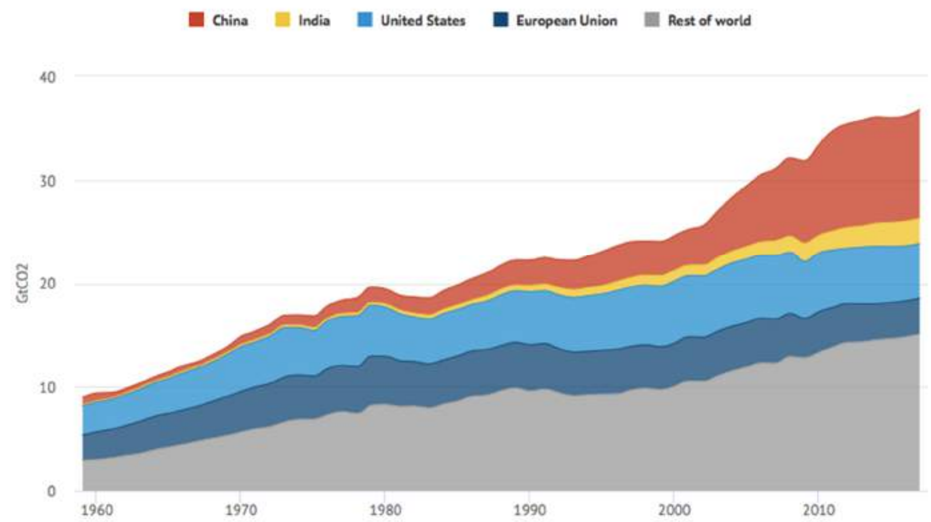

Figure 1. The amount of CO2 emissions of countries from using fossil fuels, 1959-2017 (Olivier et. al, 2017)

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Usage of the battery directly affects the electric and hybrid vehicles' driving performance and cost of the path (Rahman et. al, 2016). Researchers have been examining these special types of vehicles since it is important for reducing the environmental damage even though the hybrid and regular vehicle types are not fully exploited (Iwata and Matsumoto, 2016). Since the existing infrastructure is not sufficient and the infrastructure of installing electric charge stations is expensive; development in electric and hybrid vehicles in developing countries is moderate. Turkey is one of these countries that alternative fuel technology develops slowly. Table 1 shows electric and hybrid automobile sales volume by years, according to the report made by Turkey Electric Vehicle and Hybrid Vehicles Association (http://tehad.org).

Table 1. Electric And Hybrid Automobile Sales Volume By Years

Year	**Sales Volume**	**Cumulative Sales Volume**
2012	184	184
2013	31	215
2014	47	262
2015	120	382
2016	44	426
2017	49	475

Due to increase in the usage of electric vehicles, demand on the charging stations increase respectively (Gavranovic et. al, 2014). The primary challenge of EV charging technology industry is to determine optimal capacitated and located charging stations (Awasthi et. al, 2017). There are four presumptions made for EVs charging necessities in Lee and Han's research (2017): driver selects the shortest route, at the beginning of the route half of the battery is full, at the end of the route, the battery must not be less than half of the battery and finally the travel range is constant and deterministic.

Charging station infrastructures are divided into two groups; intra-city developments use node-based approach (Hakimi, 1964), this type of charging stations meets the demand when the vehicle is in the parking. Intercity developers on the other hand, considers usually use flow-based development approach (Hodgson, 1990), demands of vehicles during long journeys. In intra-city charging demand, the charging process is carried out at the end of the trip of vehicle; in intercity, the process interrupts the trip of the vehicle (Csonka and Csiszar, 2017).

There are 3 types of electric charging station. Type 1 and type 2 are supplied via AC charging infrastructure and type 3 is a DC charging station which is also called as "fast charging station". Table 2. shows the properties of station types.

Table 2. Properties of the Stations

Type No	Supply Power	Charging Time
1	220-240 V/ 16 A	6-8 Hours
2	380 V/16 A	2-4 Hours
3	380 V/32 A	30 Min. - 1 Hour

This study emphasizes the authorized electric charge station problem for electric and hybrid vehicles in Istanbul. By determining the potential station locations with capacitated p-median model, the objective function aims to minimize distance between connected location and station's location. After selecting the district of the station; type of station is assigned by the need of the connected districts.

The first part of the article deals with the fundamentals of the methods, in the second part, a case study is given to illustrate the effectiveness of the proposed approach. In the last part, the results and conclusions are presented.

METHODS

In this section, mathematical representation of p-median model (Heragu, 2016) is explained.

The p-median problem is originally designed and used for facility location and it is one of the most important discrete location theory problems. Either capacitated or un-capacitated, the p-median model aims to decide locations of the facilities or stations in our situation and allocate the demand points to one or more stations.

i: demand district's index
j: station district's index
N: number of districts in Istanbul
p: total number of stations
d_{ij}: distance between i[th] demand district and j[th] station district

$$x_{ij} = \begin{cases} 1, & \text{if } j \text{ candidate district is connected to the station} \\ 0, & \text{otherwise} \end{cases}$$

$$a_{ij} = \begin{cases} 1, & \text{if } d_{ij} \leq 15\ km \\ 0, & \text{otherwise} \end{cases}$$

$$\min Z = \sum_i \sum_j d_{ij} x_{ij} \qquad \forall i \in N, \forall j \in N, i \neq j \qquad (1)$$
$$\sum_{j=1} x_{ij} = 1 \qquad \forall i \in N \qquad (2)$$
$$\sum_{j=1} x_{jj} = p \qquad \forall j \in N \qquad (3)$$
$$x_{ij} \leq a_{ij} x_{jj} \qquad \forall i \in N, \forall j \in N \qquad (4)$$
$$x_{ij} \leq x_{jj} \qquad \forall i \in N, \forall j \in N \qquad (5)$$
$$x_{ij} \in \{0,1\} \qquad \forall (i,j) \in N \qquad (6)$$

Objective function (1) aims to determine optimum locations of stations while minimizing the total distance of the connection. Constraint (2) ensures that each district belongs to one station only, and constraint (3) determines the number of stations. Constraint (4) guarantees that each district is connected to a station with less than 15 km and (6) ensure that no other district can be assigned to the selected station. Constraint (6) is binary constraint.

RESULTS

The objective of the article is to determine the locations of electric charge stations. Optimum locations of cities are obtained by a p median method based on the distances between locations and electric stations. The method is applied and results are summarized in Table 3. Electric stations were installed in shopping malls in each district based on the distance between center of selected districts to shopping mall.

Table 3. Results

Station	Connected Locations
Ataşehir	Kadıköy, Maltepe, Ümraniye
Bahçelievler	Avcılar, Bağcılar, Bakırköy, Beylükdüzü, Esenyurt, Fatih, Güngören, Küçükçekmece, Zeytinburnu
Beşiktaş	Başakşehir, Beykoz, Beyoğlu, Kağıthane, Sarıyer, Şişli, Üsküdar
Çatalca	Arnavutköy, Büyükçekmece, Silivri
Gaziosmanpaşa	Bayrampaşa, Esenler, Eyüpsultan, Sultangazi
Pendik	Kartal, Tuzla
Sancaktepe	Çekmeköy, Sultanbeyli, Şile

Although the station types are not provided in the mathematical model, they are determined regarding the population density of the locations that are allocated to the stations. Hence, Table 4. shows the list of shopping malls and the type of the stations.

Table 4. Capacity of shopping malls

District	Shopping Mall	Station Type
Ataşehir	Palladium Shopping Mall	3
Bahçelievler	MetroPort Shopping Mall	3
Beşiktaş	Akmerkez	3
Çatalca	Cine My	1
Gaziosmanpaşa	Venezia Mega Outlet	3
Pendik	Neomarin Shopping Mall	3
Sancaktepe	Rings Shopping Mall	2

Figure 2 shows map of the connection.

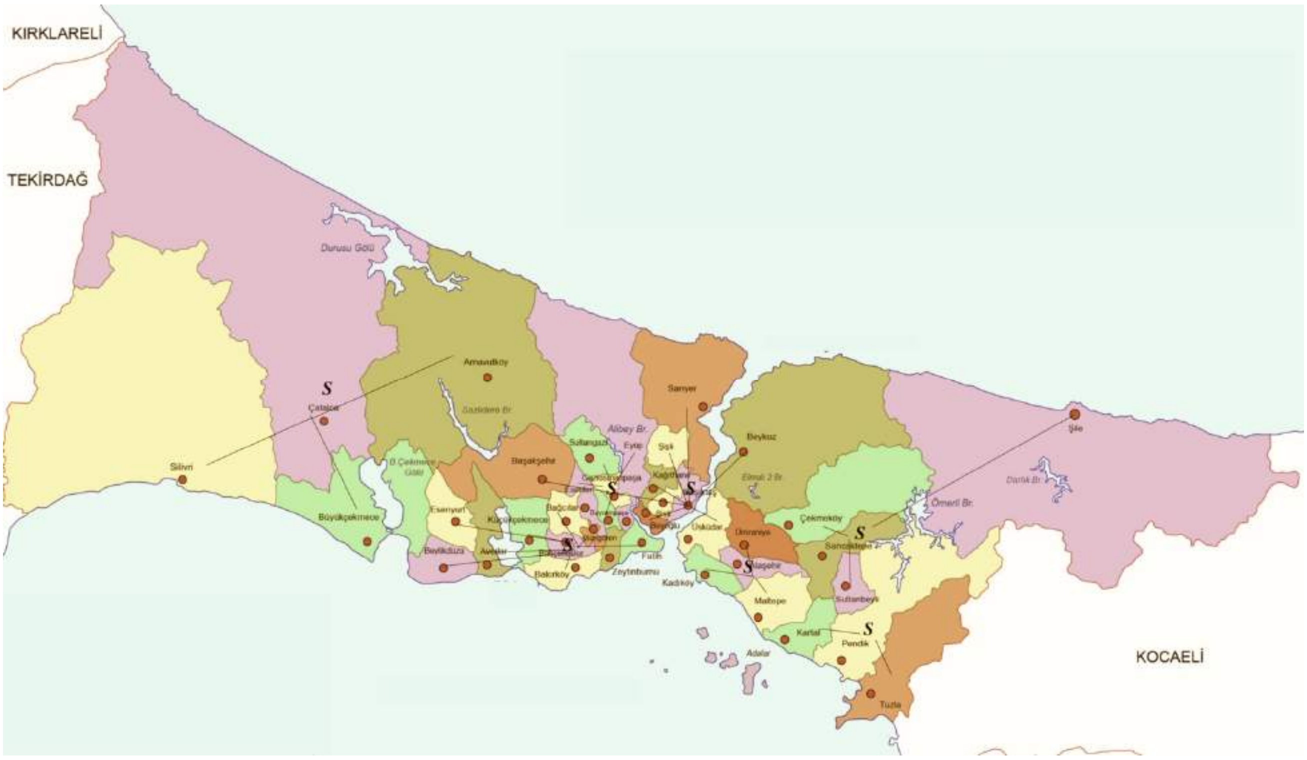

Figure 2. Connection map

CONCLUSION

With the increase in global warming, green awareness come to the agenda by focusing an ecological value in a stage not only producing a product, but also its service processes. In this article, we studied the problem of determining charging stations in Istanbul by p-median clustering approach. The stations and locations connected to stations are found by p median method and summarized. Type of the stations are determined by the need of the cities from the results of p median method and assigned by the need. It will be more comfortable to travel in Istanbul with electric vehicles when the stations are established by the obtained results.

In this research this problem was considered generally. For further studies, other integrated methodologies may be developed and applied to the same problem and results may be compared by proposed methodology. Additional constraints may be considered such as the capacity of stations, detailed parameters, etc. Also, different station types may be considered by adding more constraints.

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