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DETERMINATION OF THE OPTIMUM LOCATION IN REVERSE LOGISTICS: AN APPLICATION

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Abstract

Determination of the optimum location has importance for recycling center because of increase the significance share of reverse logistics in the economy. This study unsues to develop a solution using the available data to the real problem and the main purposes of the study are;

* To evaluate the alternative plant location, according to the optimization criteria of plant location.

* To determine the optimum plant location with linear programming based on the data of distance and amount of waste.

*To determine to optimum plant location with Fuzzy TOPSİS model and to verify the results.

This study has uses linear programming analysis to determine location of optimum facility with waste amount and distance dataset. Also, site of optimum establishment has been examined by fuzzy TOPSIS method. This method includes distance, waste amount, alternatives of transportation and population data.

The amount of waste has been identified as the most important decision criteria of decisions makers. At the level of importance of the decision criteria, the distance is the second, the transportation facilities are the third and the forth is the population.

The same alternative was determined to be optimum location in the light of the finding obtained from both linear programming and the optimization solution by fuzzy TOPSIS.

The order of plant location obtained by linear programming which was (KY1 > KY2 > KY3 > KY4) has changed partially in fuzzy TOPSIS to (KY1 > KY3 > KY2 > KY4) and optimum plant location which had been discovered with linear programing in numerical analysis has been verified with fuzzy logic as a linguistic and qualitative application. This result shows that two methods can be used in optimization problems.

Key Words: Reverse Logistics, Recycling, Optimization Problem, Fuzzy TOPSIS

Özet

Tersine lojistiğin öneminin ve ekonomideki payının artması ile birlikte, dönüşüm merkezinin optimum yerinin belirlenmesi önem kazanmıştır. Gerçek bir probleme, geçerli verileri kullanarak çözüm geliştirmek üzere yapılan bu çalışmanın temel amaçları şunlardır:

* Belirlenen kuruluş yeri optimizasyon kriterlerine göre alternatif kuruluş yerlerini değerlendirmek.

* Mesafe ve atık miktarlarına ait verilerden hareketle doğrusal programlama ile optimum kuruluş yerini belirlemek.

* Bulanık TOPSIS modeli ile optimum kuruluş yerini belirleyerek sonucu doğrulamak.

Bu amaç çerçevesinde atık miktarı ve mesafe verileri derlenerek doğrusal programlama ile analiz edilmiş ve optimum tesis yeri belirlenmiştir. Ayrıca Bulanık TOPSIS yöntemiyle optimum kuruluş yerinin doğruluğu test edilmiştir. Bu yöntemde mesafe ve atık miktarı ile birlikte ulaşım alternatifleri ve nüfus verileri de dikkate alınmıştır.

Karar vericilerin en önemli karar kriteri olarak atık miktarını gördükleri belirlenmiştir. Karar kriterlerinin önem düzeyinde ikinci sırada mesafe, üçüncü sırada ulaşım olanakları ve dördüncü sırada da nüfus yer almaktadır.

Çalışma sonucunda, hem doğrusal programlama hem de Bulanık TOPSIS yöntemiyle yapılan optimizasyon çözümünde, aynı alternatif, optimum kuruluş yeri olarak belirlenmiştir.

Doğrusal programlama ile elde edilen (KY1 > KY2 > KY3 > KY4) şeklindeki kuruluş yeri sıralaması, Bulanık TOPSIS'te (KY1 > KY3 > KY2 > KY4) biçiminde kısmi bir değişikliğe uğramakla birlikte, sayısal analiz olarak doğrusal programlama ile bulunan optimum kuruluş yeri, dilsel veya nitel bir uygulama olarak bulanık mantık ile de doğrulanmıştır. Bu sonuç, iki yöntemin de optimizasyon problemlerinde kullanılabileceğini de göstermiştir.

Anahtar Kelimeler: Tersine Lojistik, Geri Dönüşüm, Optimizasyon Problemi, Bulanık TOPSIS

Literature Review

Logistics , today, emerges as a business function that has taken the place of supply functions and that also gathers some applications of marketing and production functions. In this context, logistics, together with supply, is the management of the flow of all kinds of raw materials, products, information, and money, and is a set of activities related to keeping records at the production stage and at the delivery process of the finished product to the customer. Reverse Logistics is the type of logistics that is realized from consumer to producer in order to bring the products received by the customer back to the producer due to such reasons as maintenance and repair or re-filling, as well as to collect and recycle a number of wastes turning them into new products. (Küçük, 2013, p.26).

Reprocessing of waste material to contribute the economy and in order to refill the product packages or repair the detective parts or replacing them, their transportation to production units are applications that encompass reverse logistics. In this way, different reverse logistics practices becomes more and more important everyday in the total trade volume. Besides, for both of its usage and promotion function, an increase in the investment in packages, enhances the importance of contributing these products back to economy and all of these aspects eventually increase the importance of reverse logistics.

Along with increasing importance of reverse logistics, the localization of both the optimum capacity and optimum plant location has emerged as an application to improve logistic efficiency. Optimal or most suitable facility location is the location that provides minimum operating costs, and optimum capacity is the capacity that provides minimum unit logistics costs (Küçük, 2013, pp. 44-50)

The problem of facility locations for distribution centers, collection centers and recycling centers etc. in logistics and reverse logistics can be dealt with network design. Thus, within network design optimization; optimum establishment location for the related facilities will be determined.

Optimization studies conducted in different areas are included in the literature. Li, Zhu and Zhang (2013) have solved optimization models with the help of a genetic algorithm by taking into account the competitive relationship between the different load centers of the same company. Lee, Gen and Rhee (2009) have developed a network model that will minimize the logistics costs keeping in mind that reverse logistics has an increasing importance and reverse logistics network problems will be a powerful tool in gaining customers in the more competitive plane of the future and that it will offer a great potential.

Salema, Barbosa, and Novais (2007) have studied reverse distribution network design, and generalized a model overcoming the limitations. Sheu (2006) has revealed how total cost reduction in logistics can be achieved ensuring optimal placement of logistics resources. Mhlanga, Mbohwa, Pretorius and Gwangwava (2011) have studied on the deficiencies encountered in the optimization of South African rail transport, Qi (2013) has put emphasis on vehicle routing optimization and has revealed that route optimization not only cuts logistic costs but also provides a scientific logistics management.

Li and Lindu (2009) worked on logistics networks and solved network optimization problems using Genetic Algorithm. Demirel, Gökçen, Akçayol and Demirel (2011) studied logistics network optimization problem to design a distribution network in which customer requirements will be met at minimum cost by identifying the number and location of the facilities in forward and reverse network; Başlıgil, Kara, Alcan, Özkan and Çağlar (2011) also studied logistics network optimization, which 3rd party logistics enterprises take advantage of, for a minimum distribution distance.

Aydın (2009) made an optimization study to select a location for a hospital to be established in Ankara using a Fuzzy AHP. Eleren (2006) used AHP to select the location for an establishment in leather sector; and tested the applicability of this multiple decision-making process on optimization problems. Alp and Gündoğdu

(2012) determined the location of an establishment performing a garment manufacturing business, using AHP and Fuzzy AHP.

Küçük and Ecer (2007 and 2008) ,in their previous studies, used Fuzzy TOPSIS and AHP in the determination of the most appropriate suppliers for the retailers in manufacturing and trade sectors.

In this study, the plant location of optimum has been determined with linear programming using numeric data and the optimization problemhas been solved with Fuzzy TOPSIS which is a linguistic tool and the results has been verified. At the same time, the availability of the tool has been tested with judgment of decision makers.

With this study, the authorities will be guided in terms of the facility location to minimize the transportation costs, and the study will contribute to the strengthening of public awareness on the recycling of waste.

Objectives and Method

This study unsues to develop a solution using the available data to the real problem and the main purposes of the study are;

* To evaluate the alternative plant location, according to the optimization criteria of plant location.

* To determine the optimum plant location with linear programming based on the data of distance and amount of waste.

*To determine to optimum plant location with Fuzzy TOPSİS model and to verify the results.

*To test to what extent can the Fuzzy TOPSIS method give appropriate result or its usability in the solution of optimization problems.

*To identify scores of alternative plant location and put them in order.

The research has been carried out to include six settlements. First of all, distance between these settlements and their amount of waste have been acquired from the data of Turkish State Highways and municipalities involved. The data has been modeled in excel and optimum plant location which gives the most appropriate cost has been determined with linear programming.

Besides, in order to make an assessment with the method of Fuzzy TOPSIS and to simplify the process from these six centers, the first four are selected that are determined with linear programming. Face to face interview has been made with represantatives of four real sectors and they were required to evaluate these previously identified four alternative plant locations in terms of distance, amount of waste, means of transport and popuiuation. In the determination of performance criteria, the opinions of the represantatives of real sectors along with literature has been taken into account.

Thus, the four representatives have evaluated the four alternative plant location with regards to the four criteria alond with their significance. The obtained results have been analyzed by fuzzy TOPSIS model, scores of alternative plant location have been calculated and the most available location has been identified. Thus, accuracy of optimum plant location which is determined by linear programming has been tested.

Linear Programming Solution

The data on the distance and amount of waste belonging to alternative plant locations are given in Table 1.

Table 1. Distance and Amount of Waste (Tons) Belonging to Alternative Plant Locations

	Gumushane merkez (30 T)*	Torul (6 T)	Kurtun (8 T)	Kelkit (16 T)	Kose (6 T)	Siran (10 T)
Gumushane city centre	0	23	59	60	47	89
Torul	23	0	36	83	70	112
Kurtun	59	36	0	119	106	148
Kelkit	60	83	119	0	25	27
Kose	47	70	106	25	0	56
Siran	89	112	148	27	56	0

*: Amount of Waste (Tons)

According to these data; in accordance with the minimizing objective function, the constraints and notations are written as follows:

Notations

a_j: j. The amount of the city's waste

x_{ij}: Shipment from i to j (0-1 variables)

x_{ij}=	Shipment from i to j (No)
	Shipment from i to j (Yes)

c_{ij}: Load amount from i to j (aj*xij)

B : Total amount waste

yj=	Waste facility (in) j city
	Waste facility (out) j city

$$Min\ Z = \sum_{i=1}^{n}\sum_{j=1}^{n} c_{ij} * x_{ij}$$

Restricts:

$$\sum_{i=1}^{n} a_i * x_{ij} + B * y_j = B \qquad j=1,2,..,n$$

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad i=1,2,..,n$$

$$x_{ij} = 0-1\ , y_j = 0-1\ \ ;\ \ i = 1,2,\ldots,n \qquad j = 1,2,\ldots,n$$

Microsoft Excel 14.0 Response Report

Report created: 21.06.2013 09:55:41

Result: Solver found a solution. All restrictions and eligibility conditions were met/provided.

Solvent Infrastructure

Infrastructure: Simple LP

Solution time: 0,078 seconds
Repeats: 11 Old (Sub) problems: 8

Solver Options

Time limit no limit, repeats no limit, iterations no limit, Precision 0,000001

Assume; The most sub-problem no limit, the most integer solution un limit, integer of 1% tolerance and not negative.

Simple Linear Programming solution are given in Table 2.

Table 2. Cost Optimization Alternative Plant Locations

Target Cell (Min)		
Cell	**First Value**	**Final Value**
C48 (Gumushane city centre)	2742	2742

As can be seen in Table 2; the lowest factor load (2742) has been identified as central Gumushane. According to this, optimum plant location of the facility where waste will be collected for recycling is Gumushane centrum.

The results of linear programming solution, held in the Excel environment and containing the ranking between the score and alternative facility locations are given in Table 3.

Table 3. Alternative Facility Locations Score and Ranking

Alternative Facility Locations	Gumushane c. centre (30 T)*	Torul (6 T)	Kurtun (8 T)	Kelkit (16 T)	Kose (6 T)	Siran (10 T)	Total Load (76 T)	Ran-king
Gumush. c.	0	23	59	60	47	89	**2742**	**1**
Torul	23	0	36	83	70	112	3846	4
Kurtun	59	36	0	119	106	148	6006	6
Kelkit	60	83	119	0	25	27	3670	3
Kose	47	70	106	25	0	56	3638	2
Siran	89	112	148	27	56	0	5294	5

*: Waste amount (Tons)

As can be seen in Table 2; following the most available plant location which is the city center (2742), Kose (3638) and Kelkit (3670) districts have been identified. The district of Torul total load of which is 3847 has been determined in forth place as a suitable location.

Determination of Optimum Facility Location using Fuzzy TOPSIS Model

The stepwise algorithm of fuzzy TOPSIS model developed by Chen et al. (2006) can be summarized as follows:

Step 1: A jury composed of decision-makers is created and the decision criteria are determined.

Step 2: Decision criteria and alternatives are evaluated with linguistic variables.

Step 3: Following the evaluation, a fuzzy weights matrix consisting of the importance weights of criteria is obtained by converting linguistic variables to trapezoidal fuzzy numbers.

Step 4: A fuzzy decision matrix consisting of criteria values is obtained by converting the linguistic variables to trapezoidal fuzzy numbers.

Step 5: Normalized fuzzy decision matrix is obtained.

Step 6: Weighted normalized fuzzy decision matrix is obtained.

Step 7: Fuzzy positive optimum solution A* and fuzzy negative optimum solution A- (in other words; the most preferred and least preferred alternatives) are determined.

Step 8: The distance of each alternative from A* and A- is calculated.

Step 9: The proximity coefficients of the alternatives are calculated.

Step 10: Alternatives are ranked according to their proximity coefficients.

In the model, the decision-makers consisting of experts in their fields first evaluate the decision criteria, then the existing alternatives according to these criteria. The evaluations made by linguistic variables are converted to trapezoidal fuzzy numbers benefiting from Table 4 and Table 5.

Table 4. Linguistic Variables used in the Evaluation of Significance Levels of Decision Criteria and Their Provisions as Trapezoidal Fuzzy Numbers

Linguistic Variables	**Trapezoidal Fuzzy Numbers**
Very High (VH)	(0.8, 0.9, 0.9, 1.0)
High (H)	(0.7, 0.8, 0.8, 0.9)
Moderately High (MH)	(0.5, 0.6, 0.7, 0.8)
Quite a few (Q)	(0.4, 0.5, 0.5, 0.6)
Moderately Low (ML)	(0.2, 0.3, 0.4, 0.5)
Low (L)	(0.1, 0.2, 0.2, 0.3)
Very Low (VL)	(0.0, 0.1, 0.1, 0.2)

Reference: Chen vd., 2006: 293.

Table 5. Linguistic Variables Utilized in Evaluation of Alternatives and it's Provisions as Trapezoidal Fuzzy Numbers

Linguistic Variables	**Trapezoidal Fuzzy Numbers**
Very Good (VG)	(8, 9, 9, 10)
Good (G)	(7, 8, 8, 9)
A Little Good (LG)	(5, 6, 7, 8)
Quite a few (Q)	(4, 5, 5, 6)
A Little Bad (LB)	(2, 3, 4, 5)
Bad (B)	(1, 2, 2, 3)
Very Bad (VB)	(0, 1, 1, 2)

Reference: Chen vd., 2006: 293.

Fuzzy TOPSIS application has been carried out by discussing face to face with the four decision makers (D1, D2, D3 and D4) composed of representatives from the real sector in Gumushane and by determining the four alternative plant location (AL1, AL2, AL3 and AL4) according to the following four decision criterias (C1, C2, C3 and C4).

As alternatives of plant location, the first four alternatives in the rankings determined in the first solution have been selected.

These alternative locations are; .

(AL1) Gumushane city centre

(AL2) Kose

(AL3) Kelkit

(AL4) Torul

Decision criterias, linked from 1 to 4 are;

(C1) Distance

(C2) Amount Waste

(C3) Transportation Alternatives

(C4) Population

Decision-makers have evaluated the decision criteria using the linguistic variables in Table 4. Evaluations are shown in Table 6.

Table 6. Evaluation of Decision Criteria and Criteria Importance Weights

Decision criterias	D1	D2	D3	D4	Importance Weights
C1	VH	VH	H	VH	(0.70, 0.88, 0.88, 1.00)
C2	VH	VH	VH	VH	(0.80, 0.90, 0.90, 1.00)
C3	VH	VH	H	H	(0.70, 0.85, 0.85, 1.00)
C4	H	Q	H	H	(0.40, 0.73, 0.73, 0.90)

Very High (VH), High (H), Moderately High (MH), Quite a few (Q), Moderately Low (ML), Low (L), Very Low (VL) C: Decision Criteria

The amount of waste has been identified as the most important decision criteria of decisions makers, according to Table 6. At the level of importance of the decision criteria, the distance is the second, the transportation facilities are the third and the forth is the population.

Decision-makers, using the linguistic variables in Table 5, have evaluated the facility location according to the decision criteria. The linguistic evaluation of alternative facility locations is given in Table 7.

Table 7. The Evaluation of Suppliers According to the Decision Criteria with Linguistic Variables

Criteria	Alternative Locations	D1	D2	D3	D4
C1	AL1	VG	VG	VG	VG
	AL2	VG	VG	G	VG
	AL3	VG	VG	G	G
	AL4	G	G	G	G
C2	AL1	VG	VG	VG	VG
	AL2	VG	VG	G	G
	AL3	VG	VG	G	G

	AL4	G	G	G	G
C3	AL1	VG	VG	VG	VG
	AL2	VG	VG	G	G
	AL3	VG	VG	G	VG
	AL4	VG	VG	VG	VG
C4	AL1	VG	VG	VG	VG
	AL2	VG	VG	G	G
	AL3	VG	VG	G	VG
	AL4	G	G	G	G

Very Good (VG), Good (G), A Little Good (LG), Quite a few (Q), A Little Bad (LB), Bad (B), Very Bad (VB), C: Decision Criteria

The linguistic variables in Table 7 have been converted to trapezoidal fuzzy numbers; the fuzzy decision matrix has been normalized and thus fuzzy decision matrix and weighted normalized fuzzy decision matrix have been obtained. A* and A- i.e., positive and negative ideal solutions;

A^* =[(1,1,1,1), (1,1,1,1), (1,1,1,1), (.9,.9,.9,.9)],

and

A^- = [(.35,.35,.35,.35), (.07,.07,.07,.07), (.56,.56,.56,.56), (.28,.28,.28,.28)].

Distance from A* ve A− are given Table 8.

Table 8. Distance from A^*ve A^-, Proximity Coefficients and AL Ranking

Alternative Locations	Distance from A^* (a)	Distance from A^- (b)	Proximity Coefficients CCi (b/(a+b))	Ranking
AL1	3,83	4,39	0,5341	1
AL2	3,85	4,32	0,5288	3
AL3	3,85	4,35	0,5305	2
AL4	3,92	4,11	0,5118	4

The closeness coefficient (CCi or Vi) is between the values zero (0) and one (1). As an alternative gets closer to the ideal alternative, so does its value to 1. As the distance to the positive ideal solution grows smaller and the distance to the negative ideal solution grows bigger, the closeness coefficient will grow, otherwise it will shrink.

Analyzing Table 8, it is seen that the scores of the facility locations are very close together. Hence, it can be expressed that the four facility locations have values close to each other in terms of location suitability.

However, the optimum facility location is AL1 (0,5341) alternative, namely Gumushane city center. To make a ranking, they can be listed from the most suitable location towards the most unsuitable one as; AL1 (0,5341) > AL3 (0,5305) > AL2 (0,5288) > AL4 (0,5118).

RESULTS AND RECOMMENDATIONS

In this paper, logistics and reverse logistics concepts have been mentioned; the optimum installation location has been briefly expressed. In the study mentioning the importance of the optimum location for the collection/recycling center in reverse logistics, the literature on optimization problems has been shared and the importance of optimization in the reduction of logistics costs has been emphasized.

Optimum plant location has been determined fort he recycling center with linear programming solution which was made on the basis of distance and the amount of waste. Accordingly, total factor load of Gumushane (AL1) which is the best location has been calculated as 2742. Separately, the alternative sites of establishment were arranged respectively from the most convenient to the inconvenient.

Besides, alternative plant locations are sorted respectively from the most available to not available. The ranking of plant locations that had been enumerated according to this sorting, have been listed from the lowest costing alternative plant location to the highest one AL1 (2742) > AL2 (3638) > AL3 (3670) > AL4 (3846) > AL5 (5294) > AL6 (6006).

In addition to distance and waste data, taking into account transport facilities and population, optimum plant location has also been determined with the help of TOPSIS model. In the fuzzy analysis, the order of importance of the decision criteria has been evaluated as a first. According to decision maker, the amount of waste is the most important decision, distance is the second, transportation facilities are the third and the fourth is population.

As a result of evaluation which was made by decisions makers according to decision criteria, Gumushane has been determined as the optimum plant location. In the study in which the scores of alternative plant locations are calculated as well, plant locations have been put in order from the best to the worst AL1 (0,5341), AL3 (0,5305), AL2 (0,5288) ve AL4 (0,5118).

As a result of fuzzy analysis and linear programming solution, it has been determined that Gumushane will be optimum plant location of recycling center. The order of plant location obtained by linear programming which was (AL1 > AL2 > AL3 > AL4) has changed partially in fuzzy TOPSIS to (AL1 > AL3 > AL2 > AL4) and optimum plant location which had been discovered with linear programing in numerical analysis has been verified with fuzzy logic as a linguistic and qualitative application. This result shows that two methods can be used in optimization problems.

As a result of this study, the optimum installation location and the appropriateness ranking of the alternatives have been determined to minimize transportation costs, authorities have been guided in this respect and contribution has been made to create social awareness.

This study only focuses on the determination of the optimum plant location, distance, amount of waste, transportation alternatives, and the population have been taken as the decision criteria. In subsequent studies, analyses can be made considering such values as vehicle type, capacity and number of transportation; additionally, the scale of the facility and its optimum capacity can be specified.

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