

Optimization Models Performances for Transportation Cost Minimization

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Abstract

Transportation is the foremost activity at every stage of logistics (supply, production and distribution stages). It constitutes the huge part of logistics, because of its relative size in total logistics costs. The rate of the transportation in all logistics activities is approximately around 50-65 percent, however, that might be different sector by sector. Transportation is a term which can be defined as the physical movement of inventories such as raw materials, semi-finished goods and finished goods from one location to another. Shipping of products into firm storage after they have bought from suppliers, carrying of the storage items to manufacturing, and delivery of the manufactured items to warehouses or dealers to be sold, and delivery of the sold products to customers are some sub-activities of transportation. In order to achieve transportation with minimal cost, first of all the optimal transportation alternatives should be implied. In the literature there are many researches which confirm this statement. But the applied technique for decision problem is as important as transportation alternatives. For determining of optimal solution there are certain models. The aim of this study is comparing the performances (possible cost savings) of employed models (linear programming [LP], goal programming [GP], and fuzzy logic based integer linear programming [FLIP]) in the case analyses.

Keywords: Optimization models, optimization of transportation activities, integer linear programming, goal programming, fuzzy logic.

Introduction

Due to the fact that developing communication facilities, rapidly changing technologies and constantly increasing competitive pressure in the economy have encouraged the managers to be in the triangle of short time, high quality and low cost. Managers have had to search possible solutions which could provide higher added value. Also there has been a decrease in the numbers of current alternatives for the firm value maximization which is the prior aim for the businesses because of the changing environmental conditions. Providing higher added value has started not to be managers' price and selling policies any more. It makes managers to be more concentrated on their production and cost policies. Controlling the costs of value drivers, and removing the ones which don't create value become the basic principle for the managers, whom search for optimal solutions for certain decision problems. In this context, transportation costs (especially with respect to physical distribution) have begun to be prominent inception for the managers.

In order to obtain cost minimization for transportation, optimum decision alternative should be taken. In other words the question of "what should be the proportional rate of

using internal and external sources for transportation to make the cost minimum?" can be answered by only optimization.

In literature there are many case studies which prove that using quantitative and non-quantitative optimization techniques provide increase of efficiency in the conducted activities (Chen and Wang (1997); Shih (1997); Ulucan and Tarım (1997); Kim and Kim (2000); Balakrishnan, Natarajan and Pangburn (2000); Ruiz et al. (2003); Ergülen, Kazan and Kaplan (2005); Chu (2005); Ergülen (2005); Olsson and Lohmander (2005); Gül and Elevation (2006); Ergülen and Kazan (2007); Özdemir (2007); Özdemir and Ergülen (2012).

The aim of this study is not only comparing the performances (possible cost savings) of employed models (linear programming [LP], goal programming [GP], and fuzzy logic based integer linear programming [FLIP]) in the case analysis.

Transportation & Decision Alternatives

Transportation consists of fetching the products to company warehouses after being purchased from its suppliers, from warehouses to production phase, dispatching finished goods to the distributors or vendors for sale, or delivery of them to the customers. Moreover transporting of the consumed products for recycling should be also considered as a transportation activity. From this point of view, transportation is an immense activity distresses the managers about finding effective solution to transport the products from one location to another rapidly and safely with regards to following parameters: "via which vehicles?", "how?", "by whom?" and "for how much?"

Since these parameters are important in determining the transportation cost (Kobu, 2003, p. 237), the managers deal with evaluating the available options and choosing the most appropriate alternative or combination. The main objective of managers is transporting the right products to the market at the right time, at the right place. Otherwise customer dissatisfaction and increasing of transportation costs are become inevitable. But, the more transporting service is fast, the more transportation cost must be faced.

Basically, transportation costs consist of expenses related to the product transferred between the points of supply and demand. And in order to obtain efficient transportation results, managers should determine an optimal solution among the parameters such as the size and/or weight of the transported products, the capacity of the transportation vehicle under the given set of conditions (Gökçen, 2003, p. 66-67).

Transporting activity is divided into two as inbound and outbound transportation, in terms of place it is held. Inbound transportation; implies transporting the products from suppliers to storage. Outbound transportation; implies transporting the finished products from storages to distributors, vendors, or to the customers. And there may be three options available for both transportation phases. These are as follows (Özdemir, 2007, p. 41):

First option is using rented vehicles as well as performing transporting activities through a unit which formed within the organization and a fleet of vehicles which are bought by the firm. In that case it is obvious that costs which arise as depreciation or rent expenses due to this option can ratherly be qualified as fixed costs.

The other option is procurement of transportation service from third parties such as courier companies, subcontractor firms or transporting cooperatives. The firm contacts with them when service demand occurs. This demand can be covered by one of them which meet the

firm's requirements related to intended level of speed and quality with a favorable price. In that case a particular transportation cost cannot be expressed. But they can usually know what transporting rate for per unit (e.g. km.kg/TL or etc.) is, and it allows the firm to determine the costs of transportation depending on amount of freight to be transported. As the firm chose this option instead of the first option, depreciation and/or rent expenses become qualified as variable costs.

The final option is procurement of transportation service from the organizations which are specialized in transportation. This is called as "Outsourcing" in the literature. Outsourcing is a good way for achieving resource efficiency through having required activities performed by experts in a "*strategic partnership*". Moreover the firm that demand logistics support can focus more on its core business activities when it uses outsources rather than insources. As the firm chose third option, like in the second, expenses such as depreciation and/or rent become qualified as variable costs too. But it affects the behaviors of transportation cost. It means when transporting activities are held by the firm's own vehicles, the proportion of the fixed cost -like depreciation- in total cost would be high. On the contrary, when transporting activities are held by rented vehicles from the suppliers, courier companies or expert organizations, this makes the proportion of variable costs in total cost would be higher. Nutshell, whatever the transporting choice is, it is certain that the firm bears cost.

Firms, which use their own resources for transportation, bear 15-20 % higher costs than firms which perform transportation activities through outsourcing (Hacırustemoğlu and Şakrak, 2002, p. 96). Also managing of outsourcing variable costs is more rational rather than managing of fixed investment costs of the resources when transportation has been held by the firm itself.

Actually the relevant variable costs are manageable, while the fixed costs are accepted unmanageable due to the fact that they are also sunk costs. This means from the point of managerial accounting view that managers have a chance for decision making for transporting alternatives, it is really important to decide on whether using the firm's own vehicles or making a deal with courier firms or outsourcers. Procuring of transporting services from expert organization gives the firm an opportunity to dedicate their available funds and time for their core business activity. Secondly it also gives the firm another opportunity to focus its own activities and become more productive and profitable.

Additionally for estimating transportation cost of the product being transported, the qualitative attributes (whether hazardous, or not etc.) is as important as the quantitative attributes (its weight, dimensions, etc.). In this context, even if raw materials are less valuable than the goods, due to their dimensions, weights, variety, and so forth, their transportation cost per unit may have a significant proportion in total cost of the final product.

How Transportation Activities to Be Optimized

In terms of outputs, optimization is a practice which attempt to reach the most favorable and the best results under the given set of conditions (Bal, 1995, p. 1). In terms of inputs, optimization means finding the most effective alternative which makes the cost minimum or the profit maximum by making the idle capacity useable under the given constraints.

From the perspective of management, optimization is a technique which helps the managers to determine and select the most appropriate component(s) and to act on the purpose of profit maximization or cost minimization while they need to make decision. In this context, the optimization facilitates to determine the best plan related with a decision problem or constructed model.

Optimization of transporting is also a type of decision problem which helps to reach the lowest transporting costs through making idle transporting capacity usable under the given constraints. This can be also used for reaching the best solutions for these problems followings: How will transportation be held? Whether by vehicles belongs to company or procurement of third parties, or etc.? Which combination of the vehicles and the size of the fleet should be used for transportation? How many hours at least are required to transport products? How many times transporting should be done to the regions? Which route should be followed? And which combination of the load capacity of the vehicles should be employed? The main determinants of decisional these decisions are the qualification of the product, anticipated speed, service quality of transporting and the balance between the load and the vehicles. Thus the logistic managers may apply optimization techniques in order to minimize the transportation costs considering these issues.

The possible decision problems for the managers to decrease transportation cost through optimization can be listed as followings (Özdemir, 2007, p. 101):

- *Choosing the most appropriate transporting alternative,*
- *Determining the most appropriate storages (choosing the site of establishment in asense),*
- *Determining the most appropriate route,*
- *Minimizing vehicle usage inside the storage and the activities non-vehicle,*
- *Improving the loading durations and decreasing the labor usage on loading,*
- *Choosing the most appropriate packaging alternative with regard to storing and transportation.*

The number of the decision problems listed above can be increased. However the firm would try to optimize transportation can use one or more of them, it can be expressed that the most commonly used of them is the *choosing the most appropriate transporting alternative*.

Mathematically reaching a solution on transportation problem within a potential solution interval should not mean that this problem has been solved ideally. Even though transporting the whole product within a given time with different transporting combinations in different ways represents possible solutions, ideal solution is one of them makes the firm or activity efficient. This is called as optimal solution for the decision problem. And when the optimal solution is obtained, it can be expressed that maximum products are transported within the shortest time and by the lowest cost by means of the chosen combinations of the sources.

The optimal combination for transporting is determined according to past experiences, but conditions which are determined under given variables and data may change over time and optimum solution is needed to be revised. From the point of considering the effects of the developments on the solution sets, optimization is not a permanent situation.

Literature Review of Optimization Techniques for Transportation

The positive effect of optimization on transportation cost can be revealed by comparing transportation costs and the freight counts to the regions before and after optimization. And it shows that if the firm could have applied the optimal distribution plan ex-ante, the transportation cost would be less than actual transportation cost.

There are many empirical studies related to minimization of transportation costs which have employed various operational research techniques and/or computer software based on these techniques. These studies have been evaluating transportation problems which have different requirements and assumptions related to various subjects such as timing, distance, number of the transporter and the quantity of the product to be transported. In the most of these studies decision problems and the objectives have been modeled by using LP, integer linear programming [ILP] and complex integer linear programming, GP, and fuzzy logic based programming. Chen and Wang (1997), Shih (1997), Ulucan and Tarım (1997), Kim and Kim (2000), Balakrishnan et. al (2000), Ruiz et. al (2003), Ergülen et. al (2005), Chu (2005), Ergülen (2005), Olsson and Lohmander (2005), Gül and Elevation (2006), Ergülen and Kazan (2007), Özdemir (2007), Özdemir and Ergülen (2012) can be listed as the instances of these studies in literature.

LP is a mathematical modeling developed by the Russian economist Leonid Kantorovich and the US economist C. Koopmans, on the basis of the work of the Russian mathematician Andrei Nikolaevich Kolmogorov (Tamiz and Jones, 1997, p. 29). LP is a specific case of mathematical programming used for determining a way to achieve the best outcome (such as maximum profit or lowest cost) in a given mathematical model for some list of requirements represented as linear relationships ("Linear Programming", 2013).

There are many academicians who were rather attracted by LP. They have used it successfully for many industries such as transportation, energy, telecommunication, communication (Stapleton et al. 2003, p. 54).

Sometimes decision problems require integer solutions. In that case in order to create optimum integer solutions to decision problems, a special form of LP should be employed which is called as ILP (Lee, 1988, p. 174). In these models the entire or some of the variables are integer values and the limiters of those consist of linear inequalities, and objective functions consist of linear equations.

GP is a different technique used for minimizing transportation cost. In the cases that there are many goals under certain conditions, this technique used for decision making (Levin et al, 1989, p. 631). The algorithm of goal programming does not endeavor to optimize a certain goal as LP. Instead of this it endeavors to minimize the deviations from the goals (Tamiz and Jones, 1997, p. 29). There are certain studies which employed GP for different decisions. Lee and Roy (1974) exploit GP for doing a case analysis for marketing decisions. Chen and Wang (1997) employ it for integrated steel production and distribution planning, and Balakrishnan et. al (2000) use it for optimizing delivery fees for a network of distributors.

Another important technique for minimizing transportation costs is FLIP. Theoretically FLIP model provides the best solution the highest amount of savings among all other models due to usage of values not only (0) and (1) values like under classical logic, but also values between (0) and (1). For example in fuzzy logic, distance as a variable is not addressed only far and close, but also how far and how close. There are not many

examples that FLIP model is used for optimization. Therefore beside the studies used FLIP models, the studies about only fuzzy logic are also as followings: Teodorovic and Vukadinovic (1998) use fuzzy logic rules for vehicle guidance, and to control signalized intersections, and urban highways. Kelsey and Bissets (1993) use fuzzy sets in many classic operational research problems in mathematical models. Chanas (1982) use fuzzy sets in most of classic mathematical models for operational research. Gazdik (1983) do a network planning with fuzzy sets and minimizing the costs by the help of network usage. Kamburowski (1983) use fuzzy sets for activity timing restraint in critical road analysis. Kelley (1961) use fuzzy as a mathematical based approach in critical road planning and programming. Lootsma (1989) use fuzzy models for network-planning based on stochastic and fuzzy models of the activity durations. There are some other studies such as: fuzzy distribution application based project management (Mon et. al, 1995), range of activity durations at PERT (Golenko-Ginsburg, 1988), describing expected values (Shiple et. al, 1996) and analyzing the change of cost via fuzzy set theory (Zebda, 1984). Özdemir and Ergülen (2012) have compared the ILP and FLIP models performances by using income statements. They have also evaluated the impacts of these two models on the firm's financial ratios which are specified as a tool of measuring performance of the case firm in terms of financial ratios¹.

Case Analysis

The firm on the case analysis is from Turkey and it is running in food sector. It distributes the products from the city of Adana, where manufacturing is done, to the dealers in the certain cities of Turkey. These are as followings: Diyarbakır, Erzurum, Hatay, Kastamonu, Malatya, Mardin, Mersin, Samsun, Sivas, Tokat and Trabzon.

In determining the actual distribution cost, actual transporting costs of per unit weight (kilograms) are used. Actual transporting costs of per unit kilograms are fixed by the agreement between the firm and the sub-contractors. According to agreement, prices start with January prices but the sub-contractors give a 7.5 % rise to the agreement prices at the following months March, June, July, August and November. This shows that actual transporting prices are fixed.

The case firm distributes its products by using only 13 tones-capacity vehicles, and the total amount of loading is 26,165 tones which have been transported through 2,218 trips. The actual cost can be calculated by multiplying the load amounts delivered to the regions with actual freight counts. In that case the total actual distribution cost of the firm has been calculated as 447,547,099-TL.

Table 1: Available vehicle types, numbers and capacities

Vehicles types	I. Type	II. Type	III. Type
Carrying Capacity	13 Tonnes	20 Tonnes	25 Tonnes
Number of Vehicles	42 Unit	24 Unit	9 Unit

¹ Özdemir and Ergülen (2012) have used the rest part of the same firm's data and they have compared just ILP and FLIP models. Moreover the cities from Turkey the case firm transport its products are as followings; Afyon, Ankara, Antalya, Balıkesir, Burdur, Bursa, Edirne, Eskişehir, İstanbul, İzmir, Kayseri, Kırşehir, Konya.

Typically if the firm had had different loaded vehicle capacities as 20 and 25 tones besides 13 tones ex-ante, actual transportation costs could have been less than the cost under the given actual conditions. Therefore the case analysis has been designed to search in the case of the firm could run 24 unit 20 tones, and 9 unit 25 tones vehicles as well as 42 unit 13 tones capacity vehicles in the actual distribution plan, and has been intended to reveal how much savings could be provided by the certain models below.

Naive integer linear programming (ILP) model

The ILP model is a mathematical optimization or feasibility program in which some or all of the variables are restricted to be integers. ILP model is a kind of decision model which has decision variables, parameters, limiters and objective functions.

Symbols which are used in a naive ILP model are given below:

- i Type of vehicles which are used in distribution ($i = 1, 2, \dots, m$)
- m Number of the usable vehicle types
- J Distribution to the region ($j = 1, 2, \dots, n$)
- n Number of the regions

The identified objective function for ILP model is given below:

$$Z_{m \ i \ n} = \sum_{i=1}^m \sum_{j=1}^n (d_{ij} X_{ij}) \quad (1)$$

The decision variable at the canonical form of ILP models can be expressed as followings:

- X_{1j} : Essential trip count to the j-th region with the first type of vehicle,
- X_{2j} : Essential trip count to the j-th region with the second type of vehicle,
- X_{3j} : Essential trip count to the j-th region with the third type of vehicle.

ILP decision models also have the parameters in the objective function called as coefficient. It is symbolized as d_{ij} and represents the unit cost of one trip which is done by the i-th type vehicle to the j-th one.

Also there are other parameters which do not exist in the general pattern of the ILP model. They exist in limits and they should be identified also. They can be divided into two groups: I) Parameters for time limiters and II) Parameters for load limiters.

Parameters for time limiters are represented as a_{ij} and b_i . The a_{ij} parameter represents the time of the trip which is done by the i-th type of vehicle to the j-th one. And the b_i parameter represents the total essential trip time which is done by the i-th type vehicle in one year².

² For determining the trip time, there are two important drivers. One of them is the distance of regions to city of Adana in where the headquarters running and second one is the time limit in a day for drivers in Turkey. That might be different country by country but in Turkey legal arrangements says "drivers can drive five hours continuously in one day and after 5 hours they have to have a rest. By this way the total driving time must not exceed 9 hours according to current Highway Traffic Law in Turkey. Therefore while the estimates are calculated, it is assumed that there is enough number of drivers on the vehicles.

In that case the limiter of trip time is as below:

$$\sum_{j=1}^n (a_{ij} X_{ij}) \leq b_i \quad (2)$$

Parameters in load limit are represented as f_{ij} and h_j . The f_{ij} parameter represents the load of the trip which is done by the i -th type vehicle to the j -th one. And the h_j parameter represents the total amount of the load demand from the regions. In the formulation of load limits, the trips of the i -th type vehicle to the j -th region is guaranteed sufficient counts of trips which should meet the total amount of the load demand from the regions. In that case limiter of load is as below:

$$\sum_{i=1}^m f_{ij} X_{ij} \geq h_j \quad (3)$$

Finally the *limit of being positive and integer* means that decision parameters must be greater than zero and must be an integer in integer linear programming models. For this reason the limit of being positive and integer is integrated in model also as following:

$$X_{ij} \geq 0 \text{ and } X_{ij} \in \mathbb{Z} \quad (4)$$

Goal programming (GP) model

The identified objective function for GP model is given below:

$$Z_{\min} = \sum_{i=1}^n W_j P_k (d_i^- + d_i^+) \quad (5)$$

- i Type of vehicles which are used in distribution ($i = 1, 2, \dots, n$)
- k Distribution to the region ($k = 1, 2, \dots, m$)
- j Number of vehicles types ($j = 1, 2, \dots, t$)

Limits;

$$\sum_{i=1}^n a_i x_i + e_i y_i + d_1^- - d_1^+ = b_i \quad (6)$$

$$\sum_{i=1}^n c_i x_i + f_i y_i + d_1^- - d_1^+ \leq b_j \quad (7)$$

$$\sum_{i=1}^n h_i x_i + d_1^- - d_1^+ \geq b_k \quad (8)$$

Limit of being positive;

$$x_i, y_i, d_1^-, d_1^+ \geq 0 \quad (9)$$

And the other important compulsory issue in the same legal arrangement is that heavy vehicles can have a maximum speed of 80 km/h apart from the residential unit.

The used variables for objective function are given below:

- W_j : The value of its own weight in the same priority objectives
- P_k : The primary objective of the deviation of each variable
- d_i^- : Negative deviation variable of the i-th objective
- d_i^+ : Positive deviation variable of the i-th objective

The used variables for goal function are given below:

- Variables in first limit
 - x_i : Trip count of the i-th vehicle
 - y_i : Trip count of the i-th rented vehicle
 - a_i : Trip cost of the i-th vehicle
 - e_i : Trip cost of the i-th rented vehicle
 - b_i : Goal level of the i-th
- Variables in second limit:
 - c_i : Duration of a trip with the i-th vehicle
 - f_i : Duration of a trip with the i-th rented vehicle
 - b_j : The obtainable maximum trip time of the i-th vehicle
- Variables in third limit:
 - h_i : The loadings value of the i-th vehicle
 - b_k : Total loadings need to transport to the k-th region

Fuzzy logic based integer linear programming (FLIP) model

The general ILP model of fuzzy distribution problem is different from naive ILP model. For this reason general form of model, decision parameters, and parameters related to model, limits and symbols used in model are re-identified as below.

Objective function identified for FLIP model is given below:

$$Z_{\min} = \sum_{j=1}^n \alpha_j + \sum_{i=1}^m \sum_{j=1}^n c_{ij} X_{ij} + \sum_{i=1}^n g_i Y_i \quad (10)$$

$i = 1, 2, \dots, m$ (m: number of vehicle type)

$j = 1, 2, \dots, n$ (n: region number)

In fuzzy logic based distribution model, parameters which “*i*” shows vehicle type and “*j*” shows regions to the vehicle trip in objective function are identified below:

α_j : *j* interval usage rate stated in the *j*-th region request

c_{ij} : Trip cost to the *j*-th region with the type of the *i*-th vehicle

g_i : 10-days rent amount of the *i*-th type rental vehicle

Decision parameters are identified below;

X_{ij} : Trip count to the *j*-th region with the type of the *i*-th type of vehicle

Y_i : The *i*-th type of vehicle which is included in vehicle fleet of company

In the present instance parameters in time limit are identified as a_{ij} , b_i and h_i . a_{ij} and b_i have same meanings as ILP model; but the h_i parameter should need to re-identify. It represents obtainable running time within 10-days with the *i*-th type of rented vehicle (in hours). In that case the time limiters can be expressed as below:

$$\sum_{j=1}^n (a_{ij} X_{ij} - h_i Y_i) \leq b_i \quad (11)$$

$j = 1, 2, \dots, n$ (n: the number of regions)

The parameters in load limits are considerably different than in ILP model. The parameters in this model are symbolized as f_i , Q_j and d_j . The f_{ij} parameter represents load amount in tones of the *i*-th type vehicle to the *j*-th one in one trip.

Load limits of the distribution of goods;

$$\sum_{i=1}^m f_i X_{ij} + d_j \alpha_j + w_{kj} - u_{jt} \geq Q_j \quad (12)$$

$i = 1, 2, \dots, m$ (m: The number of vehicle type)

$$(j \neq k) \quad (j \neq t) \quad (13)$$

$J = 1, 2, \dots, n$ (n: region number)

$k = 1, 2, \dots, n$ (n: region number)

$t = 1, 2, \dots, n$ (n: region number)

f_i : Tonnage value of the *i*-th capacity vehicle in trip

Q_j : Load amount requested by the *j*-th one (in kg)

d_j : Negative deviation value in the *j*-th one request

W_{kj} : Load amount (in kg) which is allowed by one vehicle in the *k*-th region to the *j*-th region where is on the road of this vehicle

U_{jt} : Load amount (in kg) which is allowed by one vehicle in the j-th region to the t-th region where is on the road of this vehicle

In addition, if necessary, it is accepted that the demand amount of the j-th region can be decreased as d_j , which is identified as the fuzzy part of the demand, is equal to allowed negative deviation in demand amount. The value of α_j variable represents the usage rate of deviation. In order that α_j variable take the value between 0 and 1, load limits have been set up.

Mentioned aims below are located in this model in order of their priority.

1. **Aim:** Minimization of total transportation cost,
2. **Aim:** Minimization of used part of allowed negative deviation for demand capacity.

The coefficients in objective function of variables that related the second priority objective is very lower value than coefficients in objective function of variables that related the first priority objective so coefficients of (α_j) parameters is accepted as 1.

Another limit is related to usage rate of fuzzy interval.

$$\alpha_j \leq 1 \quad (14)$$

$$j = 1, 2, \dots, n \quad (n: \text{region number})$$

α_j : Usage rate of fuzzy interval of the j-th region's request.

Finally "*The limit of being positive and integer*" is valid limit in FLIP model. Decision parameters must be greater than (0) and must be an integer. For this reason, this limiter is included in model as mentioned below.

$$\begin{aligned} X_{ij} &\geq 0 \text{ and integer,} \\ (15) \quad Y_i &\geq 0 \text{ and integer} \end{aligned}$$

$$(16)$$

$$\begin{aligned} W_{kj} &\geq 0, W_{jt} \geq 0 \\ (17) \end{aligned}$$

$$0 \leq \alpha_j \leq 1 \quad (18)$$

The Assumptions and the Limitations of the Case Analysis

This study aims to compare the employed mathematical models (ILP, GP, and FLIP) in terms of optimization performances on a real case hypothetically. But naturally, this study has a few limitations. The main limitation of this study is that only distribution process has been focused on, since there is no possibility to determine transporting costs during pre-manufacturing and manufacturing processes separately. Therefore while decision problem is stated, both processes costs' have been assumed as fixed and just distribution process cost could be minimized through optimization. The other limitation is related with data of the analysis. The case firm actually has more cities to distribute its products than the areas

in analysis have been evaluated. Therefore some part of data from the case has been excluded for the analysis.

There are some other assumptions and limitations stated in this research. In actual distribution, only 13 tonnage vehicles of sub-contractor employed for the firm and these vehicles are considered as they are homogenous in terms of their engines and models.

In identifying actual costs, the agreement between the firm and sub-contractor has been considered and the statements reported by means of accounting information and documents have been utilized.

In estimating of the achievable total trip times with the vehicles in a year, trips from region to headquarters of the firm is not important for the analysis due to the fact that transporting is run by sub-contractor. In taking into account of times of the trip for returning the vehicles to the headquarters, those are subtracted from the achievable total trip times. That is, in time limits not only trip time to the headquarters to the regions, but also the trip time from the regions to the headquarters is considered.

Another limitation is related with the demand of the firms' product. Typically demand is not fixed during the year, but in this kind of analysis the demand should be fixed for a particular duration. In this analysis the fixed demand duration is accepted 10-days. Therefore by performing optimization models, the optimization period has considered as every 10-days period of every month and 36 times optimization has been done. This means that accepted fix demand period is in the analysis is 10 days.

Findings

Transportation costs after cost savings which are obtained according to actual distribution costs and optimum distribution plans of business in application example are given in Table 2.

Table 2. Actual and Programmed Distribution Costs and Provided Savings

	<i>Actual</i>	<i>ILP Based</i>	<i>GP Based</i>	<i>FLIP Based</i>
Estimated Total Cost	447,547,099	416,560,712	398,317,012	374,627,403
Estimated Trip Count (<i>Amount</i>)	2,218	1,505	1,340	1,055
Cost Savings	---	30,986,387	49,230,087	72,919,696
Cost Savings (<i>Percent</i>)	---	6.92	11.00	16.29
Trip Count Difference	---	713	878	1,163
Trip Count Savings (<i>Percent</i>)	---	32.15	39.59	52.43

According to Table-2, the followings findings can be expressed:

- Estimated total cost could be minimum, if the firm had applied FLIP based optimization models. The estimated cost of transportation in this model is 374.6 million Turkish Liras and the estimated trip counts are 1,055. This means that this model provides 72.9 million Turkish Liras savings and this amount of savings is equal to 16.29% according to actual cost, however the rate of decreasing trip counts is 52.43%.

- In GP model the estimated cost of transportation is 398.3 million Turkish Liras and the estimated trip counts are 1,340. This means that this model provides 49.2 million Turkish Liras savings and this amount of savings is equal to 11.00% according to actual cost, however the rate of decreasing trip counts is 39.59%.
- The model which ensures the least savings is ILP model. In this model the estimated cost of transportation is 416.6 million Turkish Liras and the estimated trip counts are 1,340. This means that this model provides 31.0 million Turkish Liras savings and this amount of savings is equal to 6.92% according to actual cost, however the rate of decreasing trip counts is 32.15%.

Summary and Conclusions

As a result of optimization, it is expected that the costs decrease or at least not to increase due to managers' decisions depending on various decision alternatives beyond the company. However additional costs occasionally become inevitable up to decisions taken. Anticipating the effects of the decision on the firm is important in terms of in which margin managers behave flexible. In this context optimization models enable managers to determine this margin can be reached by various decision alternatives.

In this hypothetical case analysis, it is determined to what extent transportation costs can be minimized through optimization models employed. According to findings, FLIP model is observed as the model provides the best solution and the highest amount of savings due to usage of values not only (0) and (1) values like under classical logic, but also values between (0) and (1). Despite that ILP, which can be referred to the most primitive optimization technique, is observed as it provides the least savings. And it is expressed that the GP model results are in the middle of these two models' results.

Additionally there is another important issue observed in the results. The rate of decreasing trip counts and the rate of cost savings are not the same in these three models. Actually when optimization models are set up perfectly, these rates might decrease parallel in each model. But for this, first of all, every way of the problem about the case should be able to formalize mathematically as limiters. It is theatrically possible, but also expensive and exhausting. Therefore, it should not miss out that it is normal due to the employed models' superior and inferior attributes.

It is concluded that the turnout between the rates of decreasing trip counts and the rates of cost savings have become bigger in order of the employed models (ILP, GP, and FLIP). In ILP model, the rate of decreasing trip counts is 32.15%, while the rate of cost savings is 6.92%, on the other hand the rate of decreasing trip counts in GP model is 39.59%, while the rate of cost savings is 11.00%. Also in FLIP model the rate of decreasing trip counts is 52.43%, while the rate of cost savings is 16.29%.

Nevertheless these models show to what extent transportation costs can be minimized through for the managers and indicate their flexibility while they need to make any decision related to improve their transportation activity.

References

- Akdoğan, N., & Tenker, N. (2007). *Finansal Tablolar ve Mali Analiz Teknikleri* (11th ed.) [Financial Statements and Financial Analysis Techniques]. Ankara: Gazi Kitabevi.
- Bal, H. (1995). *Optimizasyon Teknikleri* [Optimization Techniques]. Ankara: Gazi Üniversitesi Fen Edebiyat Fakültesi, İstatistik Bölümü.
- Balakrishnan, A., Natarajan, H. P., & Pangburn, M. S. (2000). Optimizing Delivery Fees For a Network of Distributors. *Manufacturing and Service Operations Management*, 2(3), 297-316.
- Chanas, S. (1982). Fuzzy sets in few classical operational research problems. In M. M. Gupta & E. Sanchez (Eds.), *Approximate Reasoning in Decision Analysis* (pp.351-363). New York: North-Holland Publishing Company.
- Chen, M. & Wang, W. (1997). A Linear Programming Model for Integrated Steel Production and Distribution Planning. *International Journal of Operations and Production Management*, 17(6), 592-610.
- Chu, C-W. (2005). A Heuristic Algorithm for the Truckload and Less-Than-Truckload Problem. *European Journal of Operational Research*, 165(3), 657-667.
- Çancı, M., & Erdal, M. (2003). *Lojistik Yönetimi* [Logistic Management]. İstanbul: UTİKAD.
- Ergülen, A. (2005). İşletmelerin Dağıtım Stratejilerinin Oluşturulması Modeli: Dağıtım Koşullarının Ağır Olduğu Türkiye'deki Doğu ve Kuzey İlleri Üzerine Örnek Bir Uygulama. *Atatürk Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 19(1), 325-342.
- Ergülen, A., Kazan, H., & Kaplan, M. (2005). İşletmelerde Dağıtım Sistemi Maliyetleri Minimasyonu İçin Çözüm Modeli: Bir Firma Uygulaması. *Selçuk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi*, 13, 163-172.
- Ergülen, A., & Kazan, H. (2007). Taşımacılık Sektörünün İşleyiş Süreci, Bulanık Dağıtım Probleminin Tamsayı Doğrusal Programlama Model Denemesi. *Zonguldak Karaelmas Üniversitesi Sosyal Bilimler Dergisi*, 3(6), 109-125.
- Gazdik, I. (1983). Fuzzy Network Planning-FNET. *IEEE Transactions on Reliability*, 32(3), 304-313.
- Golenko-Ginzburg, D. (1988). On the Distribution of Activity Time in PERT. *The Journal of Operational Research Society*, 39(8), 767-771.
- Gökçen, G. (2003). *Lojistik Maliyetler*. Muhasebe Öğretim Üyeleri Bilim ve Dayanışma Vakfı Dergisi, 5(3), 63-74.

- Gül, M. L., & Elevli, S. (2006). Tamsayılı Doğrusal Programlama ile Bir Çimento Fabrikasının Nakliye Probleminin Çözümü. *Erciyes Üniversitesi Fen Bilimleri Enstitüsü Dergisi*, 22(1), 229-241.
- Hacırüstemoğlu, R., & Şakrak, M. (2002). *Maliyet Muhasebesinde Güncel Yaklaşımlar [Contemporary Approaches in Cost Accounting]*. İstanbul: Türkmen Kitabevi.
- İslamoğlu, A. H. (2000). *Pazarlama Yönetimi (2nd ed.) [Marketing management]*. İstanbul: Beta Yayınevi.
- Kamburowski, J. (1983). Fuzzy Activity Duration Times In Critical Path Analyses, *International Symposium on Project Management (pp.194-199)*. New Delhi.
- Kelley, J. E. (1961). Critical Path Planning and Scheduling: Mathematical Basis. *Operational Research*, 9(3), 296-320.
- Kelsey, R. L., & Bisset, K. R. (1993). Simulation of traffic flow and control using fuzzy and conventional methods. In M. Jamshidi, N. Vadiie & T. J. Ross (Eds.), *Fuzzy Logic and Control: Software and Hardware Applications (pp.262-278)*. New Jersey: Prentice Hall.
- Kim, J-U., & Kim, Y-D. (2000). A Lagrangian Relaxation Approach to Multi-Period Inventory / Distribution Planning. *Journal of the Operational Research Society*, 51(3), 364-370.
- Kobu, B. (2003). *Üretim Yönetimi (11th ed.) [Production Management]*. İstanbul: Avcıol Basım Yayın.
- Koç Yalkın, Y. (1988). *İşletmelerde Mali Analiz Teknikleri (6th ed.) [Financial Analysis Techniques for Businesses]*. Ankara: Siyasal Bilgiler Fakültesi Yayınları.
- Lee, S. M. (1988). *Introduction to Management Science (2nd ed.)*. New York: Saunders College Publishing.
- Lee, S. M., & Nicely, R. E. (1974). Goal Programming for Marketing Decisions: A Case Study. *Journal of Marketing*, 38(1), 24-32.
- Levin, R. I., Rubin, D. S., Stinson, J. P., & Gardner, E. S. (1989). *Quantitative Approaches to Management (7th ed.)*. New York: McGraw-Hill Publishing Company.
- Linear Programming. (n.d.). Retrieved from the Wikipedia website: http://en.wikipedia.org/wiki/Linear_programming
- Lootsma, F. A. (1989). Stochastic and fuzzy Pert. *European Journal of Operational Research*, 43(2), 174-183.
- Mon, D. L., Cheng, C. H., & Lu, H. C. (1995). Application of Fuzzy Distributions on Project Management. *Fuzzy Sets and Systems*, 73(2), 227-234.

- Olsson, L., & Lohmander P. (2005). Optimal forest transportation with respect to road investments. *Forest Policy and Economics*, 7(3), 369-379.
- Örten, R., & Özdemir, F.S. (2006). Eczane İşletmelerinde Stokların Değerlemesi ve Dönem Karının Belirlenmesi. *Vergi Sorunları Dergisi*, 29(211), 7-18.
- Özdemir, F. S. (2007). Lojistik Maliyet Yönetiminde Optimizasyonla Sağlanan Etkinlik Artışının İşletmelerin Finansal Yapısı Üzerindeki Etkisinin Taşıma Maliyetleri Yönünden İncelenmesi.
- Özdemir, F. S., & Ergülen, A. (2012). Doğrusal ve Bulanık Mantık Temelli Doğrusal Programlama Modellerinin Dağıtım Lojistiği Maliyetlerinin Minimizasyonu Amacıyla Kullanımı: Karşılaştırmalı Bir İnceleme, *Dayanışma Dergisi* 117, 63-81.
- Ruiz, R., Maroto, C., & Alcaraz, J. (2003). A Decision Support System for a Real Vehicle Routing Problem. *European Journal of Operational Research*, 153(3), 593-606.
- Shih, L. H. (1997). Planning of Fuel Coal Imports Using Mixed Integer Programming Method. *International Journal of Production Economics*, 51(3), 243-249.
- Shipley, M., De Korvin, A., & Omer, K. (1996). A Fuzzy Logic Approach for Determining Expected Values: A Project Management Application. *Journal of Operational Research Society*, 47(4) 562-569.
- Stapleton, D.M., Hanna, J. B., & Markussen, D. (2003). Marketing Strategy Optimization: Using Linear Programming to Establish an Optimal Marketing Mixture. *American Business Review*, 21(2), 54-62.
- Şen, E. (2006). Kobi'lerin Uluslararası Rekabet Güçlerini Artırmada Tedarik Zinciri Yönetiminin Önemi. Unpublished internal document, Başbakanlık Dış Ticaret Müsteşarlığı İhracatı Geliştirme Etüd Merkezi.
- Tamiz, M., & Jones, D. F. (1997). An Example of Good Modelling Practice in Goal Programming: Means for Overcoming Incommensurability. *Lecture Notes in Economics and Mathematical Systems* 455, 29-37.
- Teodorovic, D. and Vukadinovic, K. (1998). *Traffic Control And Transport Planning: A Fuzzy Sets And Neural Networks Approach*, Massachusetts: Kluwer Academic Publishers.
- Ulucan, A., & Tarım, Ş. A. (1997). Petrol Ürünlerinin Deniz Yolu ile Taşınmasında Maliyet Minimizasyonu: Petrol Ofisi A.Ş. İçin Karışık Tamsayı Programlama Uygulaması. *Hacettepe Üniversitesi İktisadi ve İdari Bilimler Fakültesi Dergisi*, 15(1), 189-197.

- Ünalın, S.
(2006). Uluslararası Karayolu Yık Taşımacılığında Sefer Maliyetlerinin Oluşturulması, Yaklaşım Dergisi, 164.
- Zebda, A. (1984). The Investigation of Cost Variances: A Fuzzy Set Theory Approach, Decision Science, 15(3), 359-388.