

“Research Note”

A DECISION SUPPORTIVE METHOD FOR MULTIMODAL FREIGHT TRANSPORT MODE CHOICE: AN EXAMPLE FROM TURKEY*

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Abstract– This article deals with the problem of choosing the best possible shipping alternative among a set of transportation modes based on four decision criteria. An Analytic Hierarchy Process (AHP)-like model was used to solve the problem. The developed model was run on a combination of rail–road–sea transportation, for Turkey. Instead of considering different commodity types, just the textile sector was modeled and studied for simplicity. The proposed model was shown to be very flexible with the considered criteria. Because of time and financial limitations the study area was restricted to Istanbul city. A short poll was conducted to find out the most important decision criterion for shippers. Subsequently, the first four most preferred criteria of the respondents were chosen to be embodied into the model. Finally, the model validity was proven by almost seventy percent accuracy along with the real life choices of the shippers.

Keywords– Multimodal transportation, logistics, freight transportation, transportation planning

1. AIM AND SCOPE

In most cases, the shippers determine the mode by which they will have their freight transported, considering their corporate (and probably their personal) priorities. There is no doubt that the economical reasons are dominant in these decisions. However, the presence of other criteria cannot be denied, and therefore they must be confirmed in some way. In this study, a model that enables the shippers to choose the most economic shipping mode, with respect to the criteria derived from the knowledge obtained from shippers, transportation experts, and recent studies, is proposed.

The data was collected through surveys. Surveys were carried out with the corporations operating in various sectors, but the analysis concentrated on the “textile” sector. The reason for this was that the textile sector was one of the leading sectors in Turkey’s exports. After the model was run, the most suitable mode for shipping was determined with respect to the values of the criteria (shipping distance, time, safety, accessibility of the mode). To control this, the answers of the shippers to the question, “which mode do you use for your shipments?” were compared with the model results.

2. A SHORT LITERATURE REVIEW

The Shortest Path Method is used for vehicle routing in Barnhart and Ratliff’s [1] study. In Sinclair and van Dyk’s [2] study the tractor and the fully loaded trailer problem, which is placed under routing and scheduling problems, is analyzed. Bertazzi et al. [3] intends to develop a method to lower the total cost (inventory and shipping) from the origin to multiple destinations, by using different shipping frequencies.

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Crainic et al. [4] has analyzed the freight traffic routing problems and the assignment of the work with regard to the scheduling and classification of train services, among the stations on the network.

The aim of the study of Blomenfeld [5] is to determine the optimal shipping strategies by analyzing the interactions between shipping, inventory and production costs between the origin-destination (OD) pairs. Burns [6] developed an analytical method to minimize the cost of distribution of goods from one shipper to multiple buyers. Benjamin's [7] study focused on minimizing the costs of inventory, production, and shipping. Beuthe et al. [8] studied the direct and cross elasticities of the freight transport demand. The aim of Gao's [9] thesis was to develop a mathematical model to help determine places and capacities of the warehouses of maritime transporters.

The aim of the report prepared by Cambridge Systematics [10](Corsi and Grimm, 1995) was to suggest methods to conduct different types of analysis on freight demand for transportation planners and other relevant people. Kim [11], in his doctoral thesis, studied about solving design problems for large size service networks for transporters. Nozick and Morlok [12] feel that the multimode railway-truck systems have to be redesigned to operate safely, offer more service and equipment, and to facilitate an increase in efficiency. Crainic and Roy [13] set up an algorithmic structure and a general model, depending on mathematical programming techniques, for medium term planning of freight transportation. A report prepared by the Jack Faucett Corporation [14] presents the substructure of a method that directs attention to the evaluation of data needs in transportation planning and the need for data collection and combination among planning institutions, and performs all these tasks together. In Cullaine and Toy's [15] study, the past studies are analyzed and the results are evaluated to determine the criteria that are effective in freight transport route / mode choice.

Srinivasan and Thompson [16] suggest a structure that takes into consideration two conflicting objectives, such as, transport cost minimization and transport time minimization, to choose between transport modes. According to the findings in Boardman's [17] doctoral thesis "The gigantic marketing advantages of the large corporations, the global transportation associations and the general marketing and distribution strategies are directing the freight transportation sector to a multimodal concept". Hall [18], in his article, analyzes a problem that points to the relationship between shipment size and mode.

Patterson [19] et al., in their study, aimed at determining the potential of "premium intermodal services" for the reduction of CO₂ emissions. They have considered cost, on-time reliability, damage risk, security risk, and whether the carrier would send the shipment by rail for a portion of the journey, as the carrier attributes. Enrique Fernandez et al. [20], in their study seek a multimodal supply-demand equilibrium model for predicting inter-city freight flows. They have taken an equilibrium supply-demand modeling approach in order to simultaneously represent, in a consistent manner, the decisions of shippers and carriers.

Eskigun et al. [21], in their study, consider the design of an outbound supply chain network considering lead times, location of distribution facilities, and choice of transportation mode. Ham, et al. [22] tries to develop a combined model of inter-regional, multimodal commodity shipments, incorporating regional input-output relationships, and the associated transportation network flow is formulated as an alternative to the traditional four-step travel forecasting procedure. The model is formulated as a constrained optimization problem.

Taking only the physical transportation part of the whole process into consideration in freight transport can lead to flaws in the decisions of planning and management. At this point, the concepts of "Logistics Process" or "Logistics Planning" emerge. Therefore, it seems proper to begin with the description of "Logistics": "The process in which an efficient and effective flow and storage — when necessary — of goods, services, and related information is planned, controlled, and performed to meet the customer's needs, is called logistics" [23]. The "Logistics System" design problems emerge under two

conditions: When a new system is designed or when the present logistics system is rearranged to meet some new requirements. The mentioned requirements can be: Customer services, demand, product characteristics, costs or pricing policies [24]

It can be clearly seen from the literature review that numerous works had been done for freight transportation mode choice, some of which used routing and scheduling approaches [1-3], while some others preferred to find out which parameters would affect the actual mode choices [15]. Again there were mathematical and heuristic methods that were found in the literature to minimize freight transportation costs [3], [5], [6], [16]. In addition, some works focused on location selection and capacity analysis [9], while others concentrated on data collection methods for freight transportation [14].

Our model enables users to make their mode choices with an innovative approach, that is, using a simple scoring system, different from the studies that used difficult solution techniques [1], [2], [4], [15], with a generalized transportation cost phenomenon instead of using only the transportation costs, as in some other studies, for example, [3], [5], [6], and [16]. The parameters that are believed to affect mode choice are taken from Cullaine and Toy [15], and to begin with, four of them are selected by testing their appropriateness for the model. It would be useful to mention the analysis levels commonly used in transportation planning. Also, in some works, as in Arabani and Amani, the rough set approach was used as a modern mathematical model for reducing the number of parameters used in the modeling [32]. Florian et al. [25] suggest that the transportation planning steps should be handled according to their scope, level of detail, constant and variable factors, time dimensions, financial costs, and level of decision, and subsequently they should be placed in the following three groups: strategic level, tactical level, and operational level. The author is of the opinion that this study belongs to the tactical level of planning works. In the next section a mode choice model for freight transportation is described and introduced.

3. A MODE CHOICE MODEL FOR SHIPPING

There are various decision support systems (DSS) [5, 6, 16, 18, 20, 21, 22] that have been developed to help people in decision-making positions make their decisions on a rational basis. Although these have infinite variations according to the subject to be analyzed, there are definite basic algorithms / methods they use; analytic hierarchical processes, fuzzy logic, and genetic algorithms can be given as examples. "Giving points to any criteria" and the idea of producing a model from the points that are used in the presented Shipping Mode Choice Model (SMCM) have been developed with inspiration from the AHP method.

a) Describing the problem

Here, a Decision Support Method for mode choice in freight transportation will be presented. An important step in developing a realistic model is obtaining valid and reliable numerical data for the parameters to be used in the model. In some cases only estimations or mean values can be found for coefficients [26]. The planning process presented here can be qualified as an example of a descriptive approach. As stated in the studies of Beuthe et al. [8], it is nearly impossible to obtain ready-to-use market data about freight transportation in Turkey. Therefore, it was necessary to collect the data on our own. On the other hand, the idea of conducting surveys depends on the following:

One of the reasons can be stated as lack of appropriate and standardized data storage habits in most countries [24, 27, 14]. In Turkey, data is generally stored in some manner, but it cannot be utilized for some reason when needed (it is difficult to get data of any use from the private sector, and bureaucratic difficulties arise in the same case in the public sector). Errors made during the evaluation, or the insensitive approach of the data collectors, makes it difficult to use the data for different purposes. As an

example for the studies made with the help of surveys, Regan and Golob's [29] article can be given. Here, a survey of the analysis on truck shipping that is part of the multimodal transportation (MMT) operation, in which one of its components is waterways, is conducted.

In the present study, four criteria that are assumed to be effective in the shipping mode choices of shippers are determined based on both Culliane's [15] study and the survey conducted on the shippers cluster in the thesis' scope (Gursoy [31]). The chosen criteria are: shipping cost, shipping speed (time), shipping safety, and accessibility of the shipping mode. In the mentioned article [29] and in our own survey, it is understood that more criteria, such as shipping time reliability frequency loss and damage, and freight traceability that affect "shipping mode choice" exist. However, because of the constraints of this study the criteria, except for those chosen earlier, have been left out.

Other than the surveys previously mentioned, the same criteria were used in another survey named "transportation experts survey" for expert academicians in transportation to evaluate and give points to different modes. A correlation analysis was carried out between the answers received and it was observed that the answers were consistent with each other. Also, the railways performance model (it was assumed that the shippers' mode choices were determined with this model) that S. Strasser [30] used in her doctoral thesis sheds light on the determination of the mode choice criteria. In the literature review no other model such as the one suggested was encountered. The most advantageous feature of the present model is that it is easy to use. This model with its present form gives a new point of view to freight transportation planning.

As an addition, the survey results were brought together in an object-oriented function to maximize the total benefits. With the simple addition method the pro rata weights of the related criteria are determined. When a determined distance is exceeded (this determined distance may vary according to the preferences, for example, taking into consideration the environmental and economic negative effects of the shipping modes for the country, a decrement factor for the mode with the most negative effects), decrement factors to decrease the probability of the desired mode (the values of these factors can be given by the model users) are used to make up a "penalty point". This concept of "penalty point" refers to various tax exemptions and abatements, station-port price abatements, or incentives on vehicle purchase, as long as it is used in favor of other alternatives.

Inputs of the presented model can be seen in shipping mode costs, shipping mode accessibility values, shipping mode safety values, shipping mode speed values, "criteria weights matrix," made up of mode choice survey answers, and "criteria weights matrix," made up of transportation experts' surveys. The main output of the model is specified to be the mode choice weight values.

The objective of the model, which is designed as a decision-support aid, is to inform the decision-makers confronted with shipping mode alternatives about the past preferences of people and/or institutions and let them know how they had reacted in such a situation. On the other hand, the variations of the accident risk of the shipping mode and the cost by distance (therefore the shipping price), according to the shipping distance, can be determined, and these can be considered as the model's side outputs.

The outputs of the constructed model are compared with the real life preferences of the shippers and an 85% match is observed. The textile sector, which is analyzed thoroughly, is basically grouped into domestic and foreign trading companies and is divided into subgroups such as, apparel, yarn, and weaving industries. As domestic trading companies mostly have their shipping done through highways, their consistency with the model seems low (around 75%). The textile sector groups and the number of companies found in each group are given in Table 1.

Table 1. Textile sector groups and the number of companies in each group [31]

	National	International
Apparel	16	35
Weaving	6	23
Yarn	4	18

It can be seen from the table that the total number of companies is larger than the total number of companies analyzed. This is because some companies declared that they serve both domestic and international markets. As a result, these companies are evaluated in both groups.

b) Model and objective function

$$Z = \max_j \left[\sum_{i=1}^n X_i \cdot Y_{ji} \right] \quad , j = A, B, C \quad \text{and} \quad (i = 1, \dots, 4) \quad (1)$$

Here;

X_i represents the weights of the mode choice criteria according to the surveys

Y_{ji} represents the distributed value of the “mode choice criterion” among the shipping modes

The objective of the presented model is to determine the mode choice that maximizes the total preference points according to the specified parameters. “j” represents shipping mode with A, B, and C and “i” represents the preference criteria with 1, 2, 3, 4 (1 = Price, 2 = Time, 3 = Safety, 4 = Accessibility). After these explanations the conditions that the parameters should satisfy can be given as follows.

- Condition: The preference weight is between 0 and 1

$$0 < X_i < 1 \quad (2.1)$$

and

$$\sum_{i=1}^4 X_i = 1 \quad (2.2)$$

- Condition : For the maximum distance only the A mode can be used

$$L_A \leq 200 \text{ Km (can be varied arbitrarily)} \quad (3)$$

This constraint is added to the solution method arbitrarily. The aim is to obtain the use of highways without MMT and to eliminate unnecessary calculations and the cost of transshipment between modes.

- Condition: The minimum distance that combinations of B and C modes use

$$L_B, L_C > 200 \text{ Km, (can be varied arbitrarily)} \quad (4)$$

- Condition of being positive

$$X_i, Y_{ji} > 0 \quad (5)$$

Distribution of Shipping Price Weight among Modes

By highway = Y_{AI}

By highway + railway = Y_{BI}

By highway + sea = Y_{CI} and

$$\sum_{j=A,B,C} Y_{j1} = 1$$

Shipping time weights, shipping safety weights, and accessibility weights are calculated as mentioned above.

Shipping price- The drayage shipping price, transshipping price, and line-haul shipping price are accepted as the components that make up the shipping price. At this point, a short explanation about the effect of the shipping price on the model will be useful: As the presented model is in a form where the alternative with maximum points is preferred, all the preference criteria weights are marked positive (+). However, while the shipping price weight is being calculated, it is a logical necessity that the mode with a higher shipping price is disadvantageous. Therefore, the weights obtained from the shipping price values essentially give the “percentage (weight) of not being preferred” of that mode. In order to use the effect of shipping price in this manner, the model should be expressed as a utility function. However, to adhere to the “the mode with the maximum points” is the chosen principle, the inverse values of the — not being preferred — weights are calculated and ordered by priority to determine the — being preferred — priorities of the modes in the given price levels. The details of calculating the shipping price can be found in [31]. In this case, the general equation for shipping price is given as:

$$SP_i = a.x_{1A}.L + b.(x_{1A}.l' + x_{1tb} + x_{1b}.l'') + c.(x_{1A}.l' + x_{1tc} + x_{1c}.l'') \quad (\$) \quad (6)$$

Here the “a”, “b,” and “c” factors can only be “0” or “1” depending on the mode chosen (“a” for highway mode; “b” for highway + railway mode; “c” for highway + seaway mode).

Shipping time- The explanations given in the calculation of shipping price are also valid here. First, the weights for not being preferred according to the shipping time criteria for the related mode with the given data are found, and then the inverse values are found to reach the weights of being preferred for the related mode.

On the other hand, a “penalty grade coefficient” having the value of M ($0 < M < 1$) is added to the weight of the highway alternative if the line-haul shipping distance is greater than a previously determined P (km) value. The decreased amount ($(Y_{A2} - M.Y_{A2}) = T$) is distributed evenly between the Y_{B2} and Y_{C2} values. (This even distribution process can be changed into an uneven distribution process if so desired).

The general equation for shipping time;

$$ST_i = a.L/x_{2A} + b.((l'/x_{2A}) + x_{2tb} + (l''/x_{2b})) + c.((l'/x_{2A}) + x_{2tc} + (l''/x_{2c})) \quad (\text{hours}) \quad (7)$$

Here the “a”, “b,” and “c” factors can only be “0” or “1” depending on the chosen mode (“a” for highway mode; “b” for highway + railway mode; “c” for highway + seaway mode). The explanation about adding the penalty point to the shipping time (speed) weight for highway mode is given detail in [31].

Shipping safety- Highway freight transportation traffic accident statistics, railway freight transportation traffic accident statistics, and marine freight transportation traffic accident statistics (data of the year of 2001 from Turkish Statistical Institute) have been used to determine shipment safety. These figures are then proportioned to every mode’s ton-km shipments to reach the mode specific shipment safety values.

Accessibility- To determine the ACCESSIBILITY values of shipping modes, a rate between the area of the country and the lengths of the highway and railway networks is calculated to find the “accessibility coefficients”. For marine accessibility coefficients a numerical relationship has been set between ports and the distances of major production sites. Therefore, the proportion between the other two modes’ and the marine accessibility has been set and evaluated in this context.

c) Determining the weights of shipping mode choice criteria

$$Y_{AI} = \frac{SP_A}{SP_A + SP_B + SP_C} \tag{8}$$

$$SP_A + SP_B + SP_C = \sum_{i=A,B,C} SP_i \tag{9}$$

are given. In this case the others take similar forms.

The weights of the other criteria are calculated in a similar manner. The model is run by entering all these formulations in the related cells in a workbook prepared with Microsoft Excel and the graphical outputs are given. It is possible to test the variations in the rate of utilization for different scenarios by giving different values to the variables. Some graphics related to the calculations done for the textile sector are presented in Fig. 1 as examples (all details can be found in Gursoy [31]):

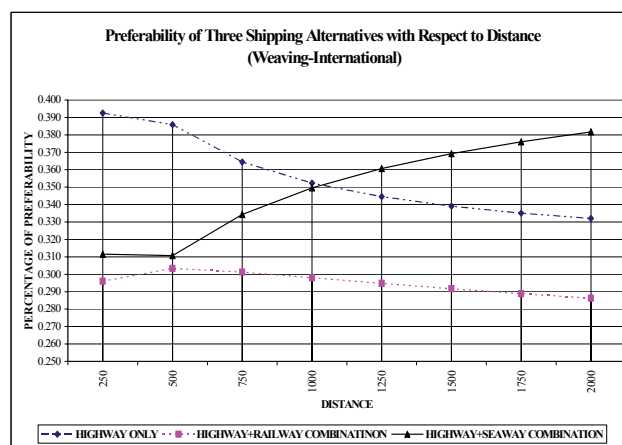


Fig. 1. Preferability of three shipping alternatives with respect to distance(weaving-international) (Gursoy [31])

The modal split for all the subgroups given in Table 1 of the textile sector shipping are determined and plotted with respect to shipping distance [31].

After all this, to compare the presented model’s choices with the shippers’ real mode choices, the model’s compatibility with the shippers’ mode choices is investigated. A flow chart used in the mentioned study and a graphic showing the model’s compatibility rates with respect to the shipping distance are given herewith (Fig. 2).

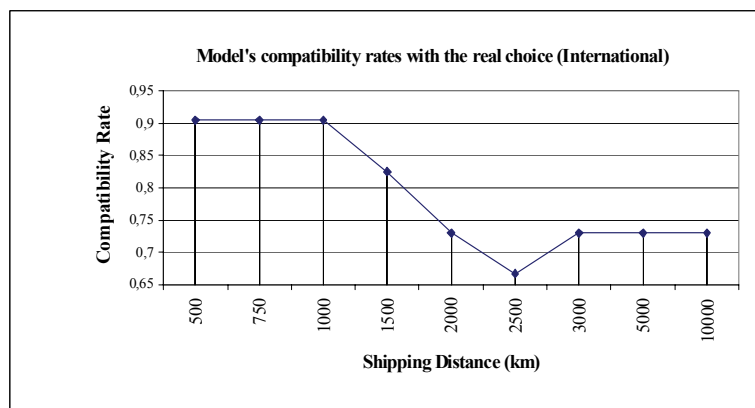


Fig. 2. Model’s compatibility rates with the real choice, with respect to the shipping distance (Gursoy [31])

4. CONCLUSIONS AND EVALUATION

As stated earlier, the aim of this study is to put forth the factors affecting the shipping mode choice in multimodal freight transportation and to form a decision-supportive system by using them. The textile sector is specially handled and modeled. During the literature review, many studies, some using challenging mathematical methods and some using only simple field studies have been confronted. Surveys have been conducted to determine the sector's preferences as also the judgments of the experts, and these are assumed to reflect their reality. Subsequently, the first four criteria, determined to be effective on mode choice, are included in the model for solution simplicity. Shipping price, shipping time, safety, and accessibility (ability to offer door to door shipping services) are included as primary decisive criteria. Transshipment cost is assumed to be a definite percentage of the physical shipping cost. Also, the highway shipping distance is assumed to be a percentage of the total distance in MTT application, where drayage is provided by highway shipping. The speeds of the shipping modes have been proposed after getting information from the related institutes. As for shipping costs, the mean value of the unit shipping prices obtained from various carrier companies is used. Values used for safety and accessibility have been obtained from government documents. Also, expert surveys and sector surveys have been used for accessibility criteria.

A verification process was performed by comparing the model's results with the real choices of the shippers. The compatibility rate with the real choice for the model, which was run for various shipping distances was found to be 73% or over, except for one distance level. As a result; the preferred alternative with the highest probability for the given problem seemed to be Highway + Sea + Highway. The results might change slightly if changes were made in the priority coefficients of the decision variables. Some additional suggestions could be stated, as follows: The surveys conducted were limited to the Istanbul area. The foremost reason for this was the difficulty in accessing other cities. A face to face survey method was preferred, as the reliability rates for the surveys made by fax or e-mail were assumed to be low. As an output of the model, there were "mode choice weights with respect to shipping distance," which were a guide for shipping mode choice. Other than that, the accident probabilities for modes with respect to shipping distance could also be taken as an output. Additionally, cost calculation and shipping time calculation could be made with respect to the distance (though it was linear). These could be defined as a cluster of side products.

Here, the point that should be strongly stated is the highly flexible structure of the model as mentioned earlier. The variations of the results can easily be observed by assigning an arbitrary value to any variable. Besides, other variables can be added to the model and some existing ones can be excluded.

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