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Full Length Research Paper

A method for transportation mode choice

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This paper deals with the problem of choosing the best possible shipping alternative among a set of transportation modes *(under)* with four considered decision criteria. An AHP-like model used to solve the problem. The developed model was run with rail-road-sea transportation combination for Turkey. The model is applied to rail-road-sea transportation combination in Turkey. Instead of considering different commodity types just textile sector modeled and studied for simplicity. It is shown that the proposed model is very flexible *(depending on)* with *(the)* considered criteria. A short poll was conducted to find out the most important decision criterion of shippers. Then the first four most preferred criteria of respondents chosen for embodying into the model. At the end the model validity has proven by almost eighty percent of accuracy along with the real life choices of the shippers.

Key words: Multimodal transportation, logistics, freight transportation, transportation planning.

AIM AND SCOPE

In most cases, shippers determine the mode by which they will have their freight transported, considering their corporate (and probably their personal priorities as well) priorities. There is no doubt that the economical reasons are dominant in these decisions. However the presence of other criteria can't be denied and therefore they should be stated somehow. In this study, a model, which 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 collected with surveys. Surveys are carried out with the corporations operating in various sectors, but the analysis is concentrated on the "textile" sector. The reason for this is that the textile sector is one of the leading sectors in Turkey's export. The general structure of the model is like $M = a.X + b.Y + c.Z + d.K$. After the model is run, the most suitable mode for shipping is 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 modes do you use for your shipments?" are compared with the model results.

First in the following sections, transportation planning and a short literature review will be mentioned. In the third section an application with model details is given. The paper is then completed with the conclusion section where findings are discussed and suggestions are made.

LITERATURE REVIEW

The Shortest Path Method is used for vehicle routing in Barnhart and Ratliff's (1993) study. In Sinclair and van Dyk's (1987) study the tractor and the fully loaded trailer problem which is placed under the routing and scheduling problems is analyzed. Bertazzi et al. (1997) intends to develop a method to lower the total cost (inventory and shipping) from an origin to multiple destinations by using different shipping frequencies. Crainic et al. (1984) analyzed the freight traffic routing problems and the assignment of the work of scheduling and classification of the train services, among the stations on the network.

The aim of the study of Blomenfeld (1985) is to determine the optimal shipping strategies by analyzing the interactions between shipping, inventory and production costs between O-D pairs. Burns (1985) developed an analytical method to minimize the cost of distribution of goods from one shipper to multiple buyers. With the help of this method, formulations about shipping and inventory costs are derived and the optimal trade-offs between them are determined. Benjamin's (1989) study focused on minimizing the costs of inventory, production and shipping. Beuthe et al. (2001) studied on the direct and cross elasticities of the freight transport demand. The model explained in this study minimizes the generalized cost of transport in assignments which is defined in O-D matrixes and assigns the flow to different modes and routes. The aim of Gao's (1997) thesis is to develop mathematical model to help determine places and capacities of the warehouses of maritime transporters.

The aim of the report prepared by Cambridge Systematics (Corsi and Grimm, 1995) is to suggest methods to conduct different types of analysis about freight demand to transportation planners and other relevants. Kim (1997) in his doctoral thesis, studied about solving design problems for large size service networks for transporters. Nozick and Morlok (1997) thinks that the multimode railway-truck systems have to be redesigned so as to operate safer, offer more service and equipment and facility efficiency to be raised. Crainic and Roy (1998) set up an algorithmic structure and a general model depending on mathematical programming techniques for medium term planning of freight transportation.

In a report prepared by Jack Faucett Corporation (1997), 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 is presented. In Cullaine and Toy's (2000) 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 (1997) suggests a structure that takes into consideration two conflicting objectives like transport cost minimization and transport time minimization to choose between transport modes. According to the findings in Boardman's (1997) 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 (1985)' in his paper, analyzes a problem that points the relationship between shipment size and mode.

Patterson et al. (2008) aimed at determining the potential of "premium intermodal services" for reduction of CO_2 emissions in their study. They have used 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. (2003) in their study seek a multi-modal supply-demand equilibrium model for predicting intercity freight flows. They have taken an equilibrium supply-demand modeling approach in order to simultaneously represent in a consistent way the decisions of shippers and carriers.

Eskigun et al. (2005) in their work, considers the design of an outbound supply chain network considering lead times, location of distribution facilities and choice of transportation mode. Their NDMC (capacitated network design model) is a large-scale integer linear programming (ILP) model. They have developed a Lagrangian heuristic to obtain near-optimal solutions in short computation times. Ham et al. (2005) tries to develop, a combined model of interregional, multimodal commodity shipments, incorporating regional input-output relationships, and the associated transportation network flows is formulated as an alternative to the traditional four-step travel forecasting procedure . The model is formulated as a constrained optimization problem, solved by the partial linearization algorithm of Evans (1976).

In this paper the transportation (shipping) issues before and after physical production phase are discussed. But taking only physical transportation (or shipping part) *(issues)* of whole process into consideration in freight transport can be compared to a building without a proper foundation. Therefore the topic should include business operations and management. When all these are taken into consideration "Logistics Process" or "Logistics Planning" concepts emerge. So its proper to begin with a description of "Logistics": "The process in which an efficient and effective flow and storage -when necessary- of the goods, services and related information is planned, controlled and performed to meet the customers needs is called logistics" (Bowersox and Closs, 1996). "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 the customer services, demand, product characteristics, costs and pricing policies (Kasilingram, 1999) On the other hand, LS analysis can be separated in four phases: Description of the problem, data collection, analysis of the problem, user test and real application. Simulation, operations research models and heuristic models are the most commonly used methods in LS analysis.

As it can easily be seen from the literature review, there are numerous works had been done for freight transportation mode choice which some of them used routing and scheduling approaches (Barnhart and Ratliff, 1993; Sinclair and van Dyk, 1987; Bertazzi, 1997) and some others preferred to find which parameters would have affect the actual mode choices (Cullinane and Toy, 2000), again there were mathematical and heuristical methods could be find in the literature to minimize freight transportation costs (Bertazzi, 1997; Blomenfeld, 1985; Burns, 1985; Srinivasan and Thompson, 1977). Besides some works that was focusing on location selection and capacity analysis (Gao, 1997), also other works which were concentrated on data collection methods for freight transportation (Faucett Assoc., 1997).

This model enables the users to make their mode choices with an innovative approach that is using a simple scoring system different from the works which were used difficult solution techniques (Barnhart and Ratliff, 1993; Sinclair and van Dyk, 1987; Crainic et al., 1984; Cullinane and Toy, 2000) and a generalized transportation cost phenomena instead of using only transportation costs as some other works e.g. (Bertazzi, 1997; Blomenfeld, 1985; Burns, 1985; Srinivasan and Thompson, 1977). The parameters which are believed to have effects on mode choice are taken from Cullaine and Toy (2000) and first four of them selected by testing their appropriateness for the model.

It will be useful to mention the analysis levels commonly used in transportation planning. Florian et al. (1988) suggests that 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 making in the following three groups: strategical level, tactical level, operational level. This study has been thought by the author, belongs to tactical level planning works. At the next section a mode choice model for freight transportation was described and introduced.

A MODE CHOICE MODEL FOR SHIPPING

In this part of the study, the origins of the model to be presented will be introduced and the model which is designed to determine the mode by which the freight would be shipped will be explained with a numerical application.

There is various decision support systems (DSS) (Blomenfeld, 1985; Burns, 1985; Srinivasan and Thompson, 1977; Hall, 1985; Fernandez et al., 2003; Eskigun et al., 2005; Ham et al., 2005) developed to help the ones in decision making positions to make their decisions on a rational basis. Although these have infinite variations according to the subject to be/will be analyzed, there are definite basic algorithms/methods they use. Analytic hierarchical processes, fuzzy logic, genetic algorithms can be given as examples. The “giving points to criteria” and the idea of producing a model from these points that are used in the presented shipping mode choice model (SMCM) are developed with the inspiration from the AHP method.

Describing the problem

Up to this point, general information about freight transportation and particular information about shipping mode choice are given and examples from recent studies and a literature review are presented. Here, a decision supportive method for mode choice in freight transportation will be presented.

What emerges from the previously mentioned studies is; a model that determines the proper shipping mode has to be developed using the shipper’s preferences and real data about financing, schedules and service levels (speed, accessibility) instead of using the difficult demand estimation methods and economic analyses. 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 (Gass, 1975).

The planning process presented here can be qualified as an example for descriptive approach. As stated in the studies of Beuthe et al. (2001), it is nearly impossible to obtain ready-to-use market data about freight transportation in Turkey. Therefore a necessity to collect our data by our own occurred. The best known way of collecting the needed data is to conduct surveys on the related sector. On the other hand the idea of conducting surveys depends on the following reasons:

One of the reasons can be stated as the lack of an appropriate and standardized data storage habit in most countries (Erel et al., 1995; Faucett, 1997; Fisher, 1996). In Turkey, data is generally stored in some way but it cannot be utilized for some reason when needed (it is hard to get data of any use from the private sector, and bureaucratic difficulties arise in the same case with the public sector). Errors made during the evaluation or the insensitive approach of the data collectors makes it hard to use the data for different purposes. Because of the stated reasons it is decided that the best way to collect object oriented data in this study is to conduct a carefully prepared survey.

As an example for the studies made with the help of surveys Regan and Golob’s (2000) paper can be given. Here, a survey on analyzing truck shipping that is part of a multimodal transportation (MMT) operation which one of its components is waterways, is conducted.

In the presented work, four criteria that are assumed to be effective in the shipping mode choices of shippers are determined depending on both the Culliane’s (2000) study and the survey conducted on the shippers cluster in the thesis’ scope in 2001. The chosen criteria are; shipping cost, shipping speed (time), shipping safety, accessibility of the shipping mode. In the mentioned paper and in our own survey, it is understood that more criteria like; shipping time reliability, frequency, loss and damage, freight traceability that affect “shipping mode choice” exist. But because of the constraints of this study, the criteria except the chosen ones above were left out of the scope of this study.

Other than the mentioned surveys above, 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 received answers and it is seen that the answers were consistent with each other. Also the railways performance model (it is assumed that shippers’ mode choices are determined with this model) that S. Strasser (1990) used in her doctoral thesis gives us light (affected the) to determination of the mode choice criteria.

In the literature review no other model like the suggested one is encountered. The most advantageous

Table 1. Textile sector grouping and the number of companies in each group.

	National	International
Apparel	18	42
Weaving	10	28
Yarn	6	17

feature of the presented model is its easiness. This model with its present content brings a new point of view to freight transportation planning. The data needed is collected with the help of the surveys that depend on the experiences of the related sector personnel and the experts (e.g. academics) in this sector in a country where it is hard to find data as frequently mentioned before.

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 up to the preferences, e.g. 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 are also determined arbitrarily) are used] to make up a "penalty point". This "penalty point" concept can be thought as 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 are; 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, "criteria weights matrix" made up of transportation experts' surveys, and the output of the model is given as the mode choice weight values.

The objective of the model which is designed as a decision support aid is to inform the decision makers confronting with shipping mode alternatives about the past preferences of people/institutions and let them know how they reacted in such a situation. In this way by staying inside the integrated system and assuming that the past applications were optimal, it is meant to clear the sights of the decision makers. 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 among the model's outputs.

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

It can be seen from the table that the total number of companies is larger than the total number of companies analyzed. The cause of this is that some companies declared that they serve both domestically and internationally. As a result of this these companies are evaluated in both groups.

Model and objective function

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

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 (or modes) choice that maximizes the total preference points according to the specified parameters. "j" represents shipping mode with A, B and C and "i" represents 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.

The conditions that the parameters should satisfy

Condition: The preference weight is between 0 and 1

$$0 < X_i < 1 \tag{2a}$$

And

$$\sum_{i=1}^{4} X_i = 1 \tag{2b}$$

Condition: The maximum distance only the A mode can be used

$L_A \leq 200$ km (can be varied arbitrarily) (3)

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

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

$L_B, L_C > 200$ Km, (can be varied arbitrarily) (4)

Condition of being positive

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

EXPLANATIONS AND FORMULATION

Distribution of shipping price weight among modes

By highway = Y_{A1}
By highway + railway = Y_{B1}
By highway + sea = Y_{C1} and $\sum_{j=A,B,C} Y_{j1} = 1$

Distribution of shipping time weight among modes

By highway = Y_{A2}
By highway + railway = Y_{B2}
By highway + sea = Y_{C2} and $\sum_{j=A,B,C} Y_{j2} = 1$

Distribution of shipping safety weight among modes

By highway = Y_{A3}
By highway + railway = Y_{B3}
By highway + sea = Y_{C3} and $\sum_{j=A,B,C} Y_{j3} = 1$

Distribution of accessibility weight among modes

By highway = Y_{A4}
By highway + railway = Y_{B4}
By highway + sea = Y_{C4} and

$\sum_{j=A,B,C} Y_{j4} = 1$

At the end the result that maximizes the value of the expression;

$$Z_j = (X_1.Y_{j1} + X_2.Y_{j2} + X_3.Y_{j3} + X_4 Y_{j4}) \qquad (j = A, B, C) \qquad (6)$$

Is chosen. This expression written in the form of an objective function and the conditions were given above (Expression 3.1)

Shipping price

The drayage shipping price, transshipping price and the 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 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 (+). But while the shipping price weight is being calculated, it is a logical necessity that the mode with a higher shipping price should be 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 like that, the model should be expressed as a utility function. However so as to stick to the "the mode with the maximum points is 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. These explanations can be clearly understood with the help of the given at the example in the Appendix.

The details of calculating the shipping price are given below. In this case;

Shipping price by A mode $= x_{1A}.L$ ($)
Shipping price by B mode $= x_{1A}.l' + x_{1tb} + x_{1b}.l''$ ($)
Shipping price by C mode $= x_{1A}.l' + x_{1tc} + x_{1c}.l''$ ($)
Here $l' + l'' = L$ is given in (km's).

The general expression for shipping price is given as;

$$SP_i = a x_{1A}.L + b.(x_{1A} l' + x_{1tb} + x_{1b} l'') + c.(x_{1A} l' + x_{1tc} + x_{1c} l'') \ (\$) \qquad (7)$$

Here it is assumed that;

$$a = \begin{cases} 1 & \text{If only highway} \\ 0 & \text{Otherwise} \end{cases} \qquad (8a)$$

$$b = \begin{cases} 1 & \text{If highway + railway} \\ 0 & \text{Otherwise} \end{cases} \qquad (8b)$$

$$c = \begin{cases} 1 & \text{If highway + seaway} \\ 0 & \text{Otherwise} \end{cases} \qquad (8c)$$

Shipping time

The explanations given in the calculation of shipping price are also valid here. (First the weights of not being preferred according to the shipping time criteria for the related mode with the given data 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 Y_{B2} and Y_{C2} values. (This even distribution process can be changed into an uneven distribution process arbitrarily).

The general expression for shipping time;

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

Here the values are chosen as;

$$a = \begin{cases} 1 & \text{If only highway} \\ 0 & \text{Otherwise} \end{cases} \quad (9a)$$

$$b = \begin{cases} 1 & \text{If highway + railway} \\ 0 & \text{Otherwise} \end{cases} \quad (9b)$$

$$c = \begin{cases} 1 & \text{If highway + seaway} \\ 0 & \text{Otherwise} \end{cases} \quad (9c)$$

The explanation about adding the penalty point to the shipping time (speed) weight for highway mode: If the shipping distance "L" (km) is greater than a previously determined "P" (km) threshold value; In the case where $L > P$, the calculated Y_{A2} value is multiplied by a M value $(0 < M < 1)$. The being-preferred priority for the shipping time of the highway mode becomes; $Y'_{A2} = M.Y_{A2}$ $(0 < M < 1)$. In that case; a $(Y_{A2} - M.Y_{A2}) = T$ value remains. This remaining amount is evenly distributed between Y_{B2}, Y_{C2}. At last the new weight (priority) values can be expressed as below:

$$Y'_{B2} = \left(Y_{B2} + \frac{T}{2}\right) \text{ And } Y'_{C2} = \left(Y_{C2} + \frac{T}{2}\right)$$

Shipping safety

The accident statistics are used in determining shipping safety. A safety value is found by proportioning the accidental numbers with each other.

To determine the ACCESIBILITY 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 "accessibility coefficients". But as there is no possibility to do the same for the seaway accessibility value, a rate is set up using the number of sea ports.

Determining the weights of shipping mode choice criteria

$$Y_{A1} = \frac{SP_A}{SP_A + SP_B + SP_C}$$
(10a)

$$SP_A + SP_B + SP_C = \sum_{i=A,B,C} SP_i \quad (11)$$

Are given. In that case the others take the forms below;

$$Y_{B1} = \frac{SP_B}{\sum_{i=A,B,C} SP_i} \quad (10b)$$

and

$$Y_{C1} = \frac{SP_C}{\sum_{i=A,B,C} SP_i} \quad (10c)$$

The weights of the other criteria are calculated in the same way. 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. In the following pages the real preferences of the shippers and the preferences according to the distance obtained from the model are presented graphically. It is possible to test the variations in rate of utilization for different scenarios by giving different values to the variables arbitrarily. One can see the flow chart of the employed model from Figure 1.

Some graphics related to the calculations done for the textile sector are presented in the Figures 2 - 3 as examples.

Modal split for all the subgroups given in Table 1 of the textile sector shipping are determined and plotted with respect to shipping distance (Gürsoy, 2003).

After all these, so as to be able to compare the presented model's choices with the shippers real mode choices, model's compatibility with the shippers mode choices is investigated. A flaw chart used in the mentioned study and a graphic showing the model's compatibility rates with respect to the shipping distance are given in Figures 4 and 5).

EVALUATION AND CONCLUSION

As stated before the aim of this study is to put forth the factors affecting the shipping mode choice in multimodal freight transportation and form a decision supportive

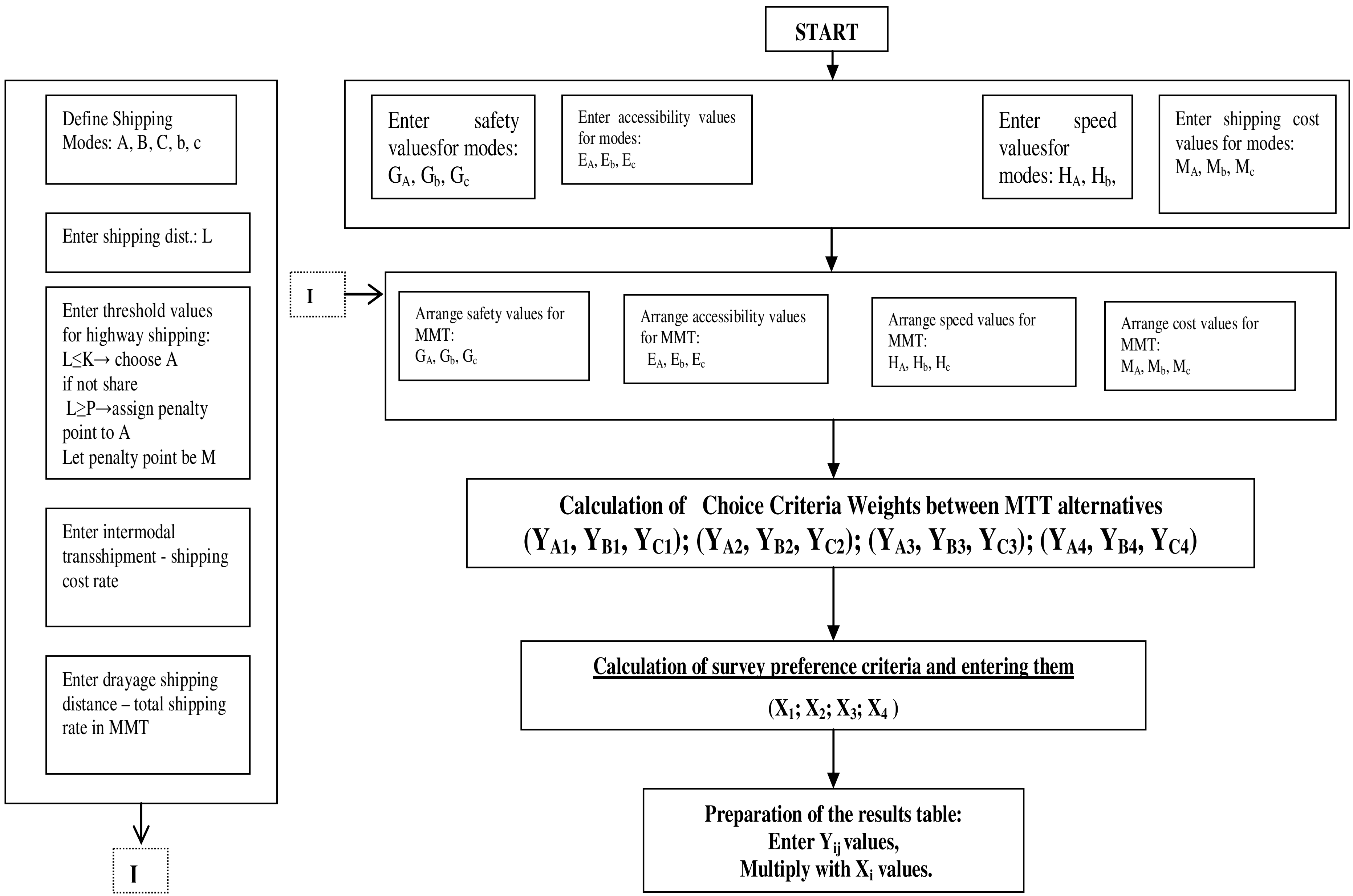

Figure 1. Flow chart of the model.

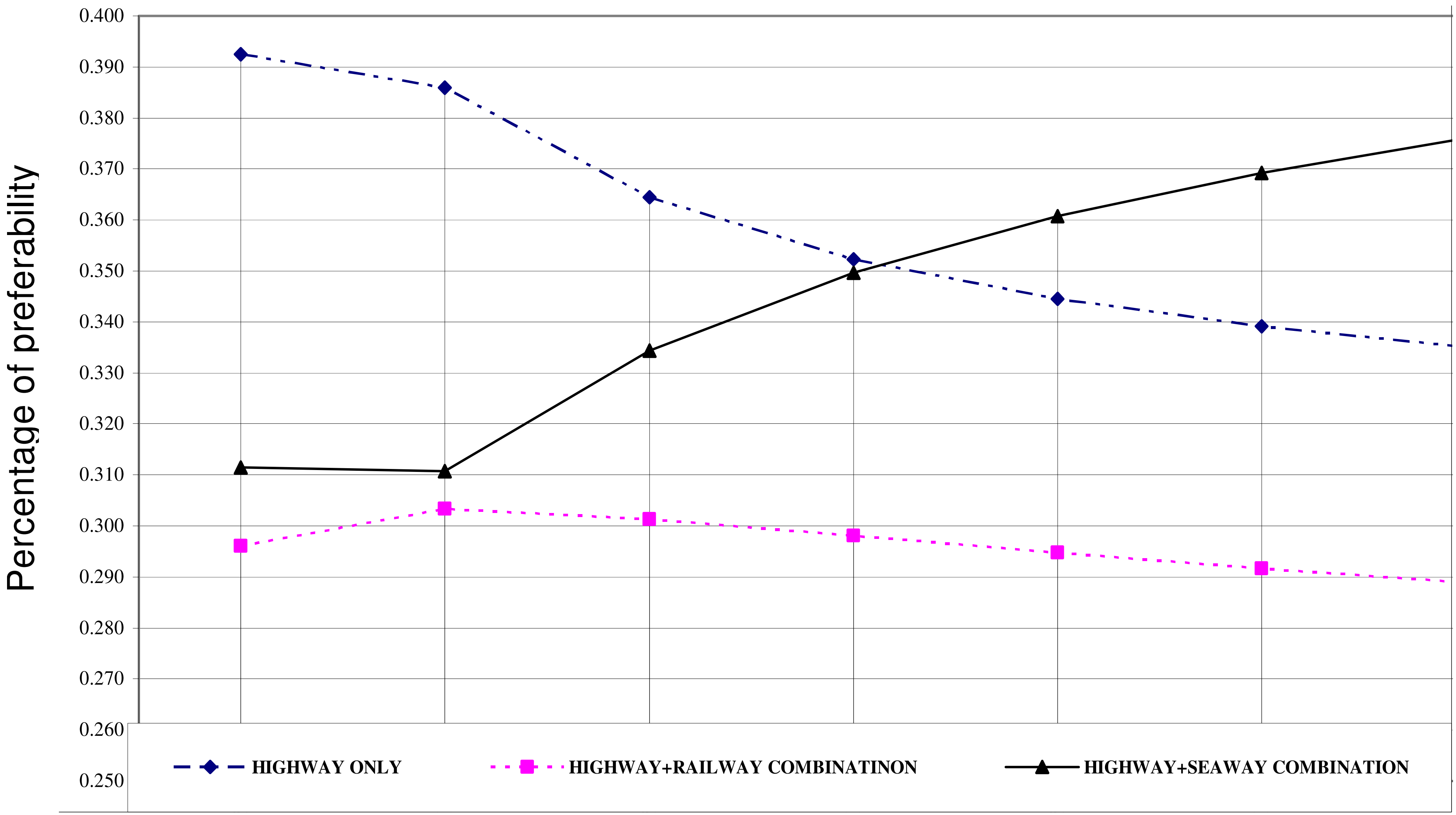

Figure 2. Preferability of three shipping alternatives with respect to distance(weaving-international) (Gursoy, 2003)

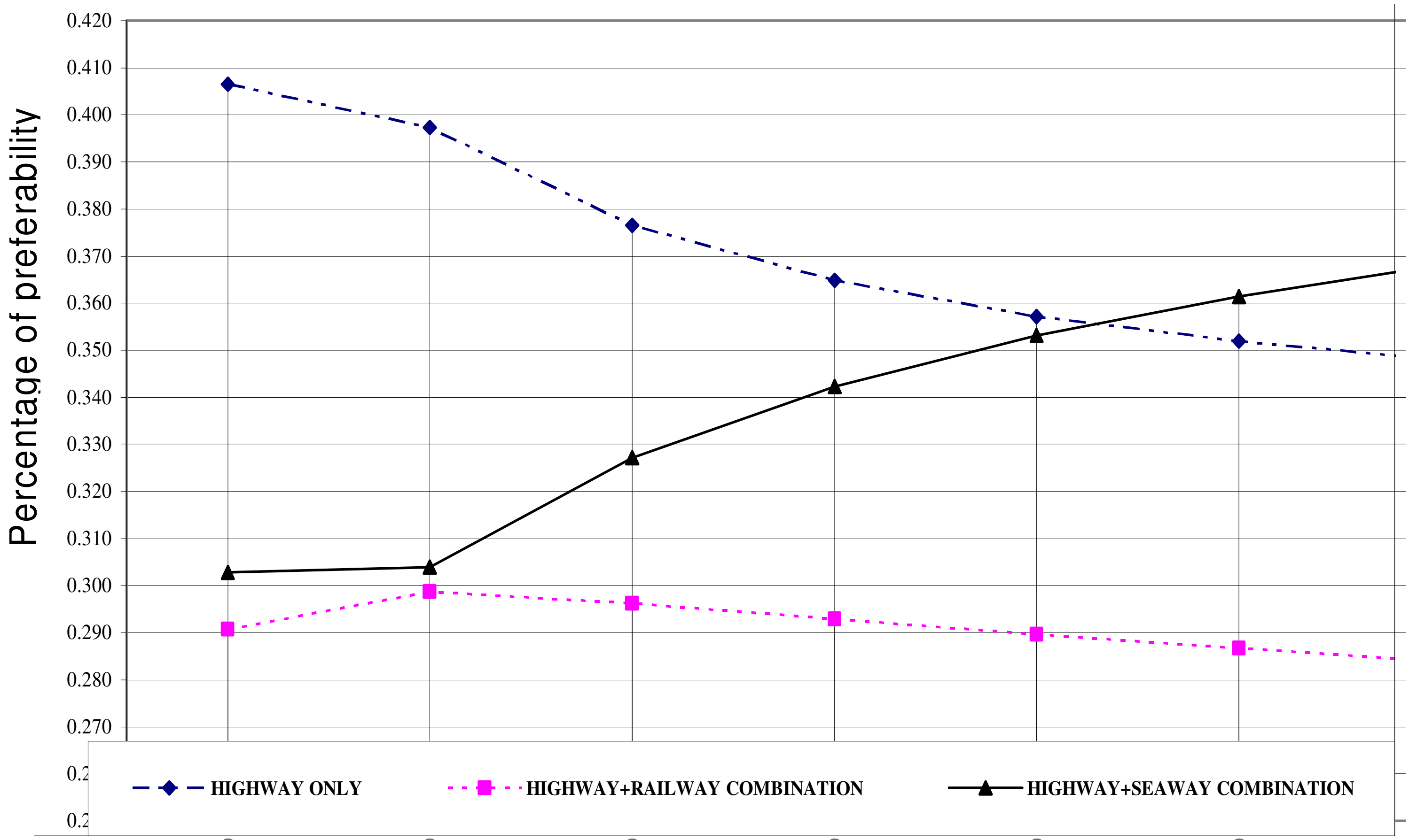

Figure 3. Preferability of three shipping alternatives with respect to distance (weaving-local) (Gursoy, 2003)

Figure 4. Model's compatibility rates with the real choice with respect to the shipping distance.

system using them. The textile sector is specially handled and modeled. During the literature review, many studies some using challenging mathematical methods and some only using simple field studies are confronted. While building a model, first realism then solution simplicity aresought for. To reach these twin goals, surveys are conducted to determine the sectors preferences and the judgments of the experts and these are assumed to reflect the reality. Then the first four criteria that are determined to be effective on mode choice are included

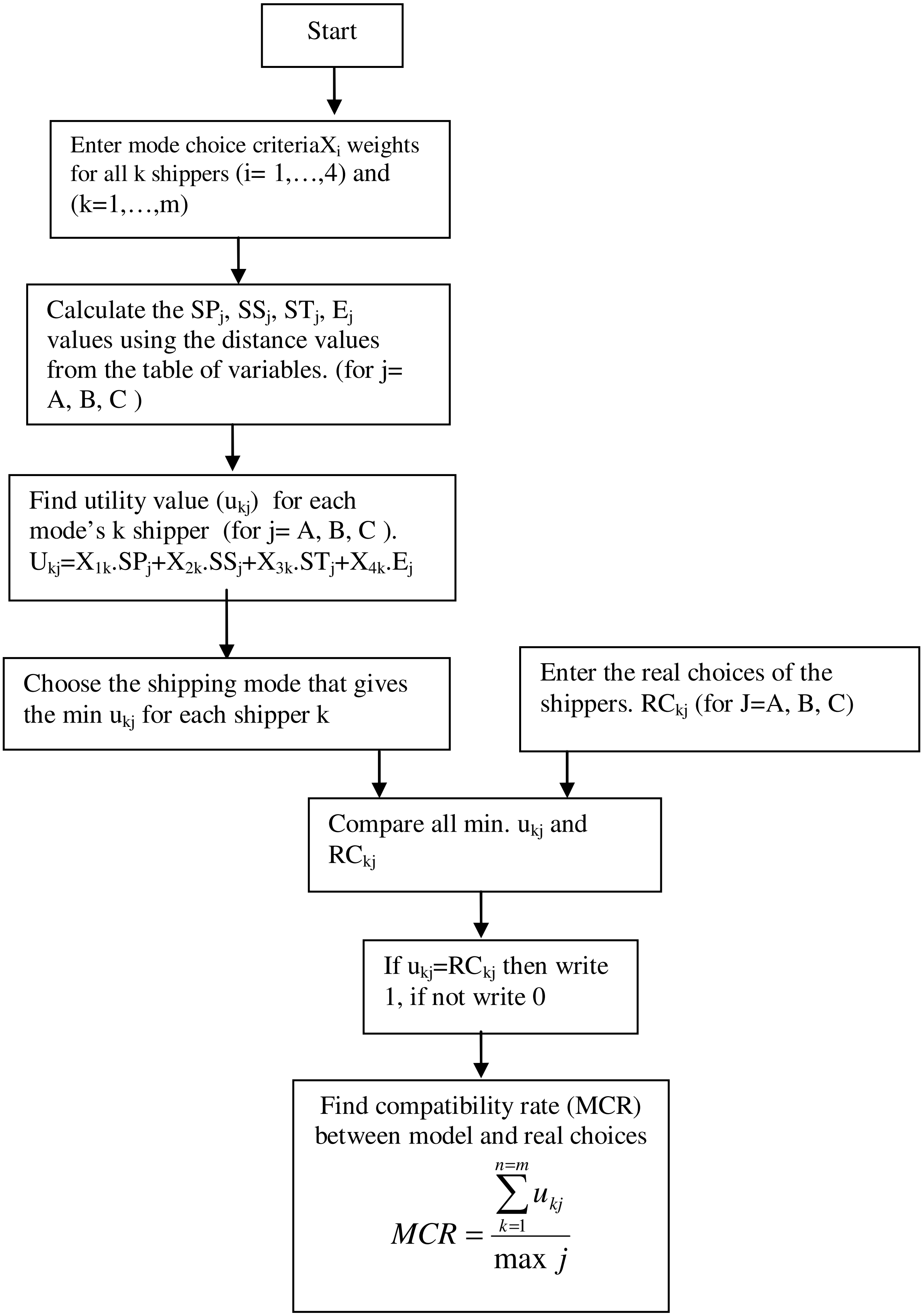

Figure 5. Flow chart formed to determine the model's compatibility rate (Gursoy, 2003).

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 decision 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 percent-tage of the total distance in MTT application where drayage is provided by highway shipping. The speeds of the shipping modes are proposed by getting information from the related institutes. As shipping costs, the mean value of the unit shipping prices obtained from various carrier companies is used. Random values are used for safety and accessibility issues. On the other hand while determining the safety coefficients, accident statistics are used at least for highways but assumptions are made for comparisons between modes as sufficient information was not available for other modes. Expert surveys are used along with sector surveys for accessibility issues.

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 is run for various shipping distances is found to be over 78% every time. This value may not seem adequate. This low compatibility rate value is reached for only very long distances. For shorter distance values, the compatibility rate is always found to be 85% or over. As a result; the preferred alternative with the highest probability for the given problem seems to be Highway + Sea + Highway. The results may change slightly if changes are made in the priority coefficients of the decision variables. Some additional suggestions can be stated like this: The surveys conducted are limited Istanbul City, Denizli City, Bursa City and Adana City. The foremost reason for that is these cities has the most of the textile production of whole country (almost 75 per cent of total). Face to face survey method is preferred as the reliability rates for the surveys made by fax or e-mail are assumed to be low. As an output of the model, there exists "mode choice weights with respect to shipping distance" which are a guide for shipping mode choice. Other than that, the accident probabilities for modes with respect to shipping distance can also be taken as an output. Additionally cost calculation and shipping time calculation can be made with respect to the distance (though it is linear). These can be defined as a side products cluster. Here the point that should be strongly stated is the highly flexible structure of the model as mentioned before. The variations of the results can easily be traced by assigning an arbitrary value to an arbitrary variable. Besides other variables can be added to the model as some existing ones can be excluded.

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APPENDIX

Explanation of shipping price usage in the model

Let the SP values be as,

$$SP_A = 80(\$/Km) \qquad SP_B = 30(\$/Km) \qquad SP_C = 20(\$/Km)$$

In this case,

$Y_{A1} = \dfrac{SP_A}{SP_A + SP_B + SP_C} = \dfrac{80}{(80+30+20)} = 0{,}62$ is the percentage of not being preferred?

Likewise; $Y_{B1} = 0{,}23$ ve $Y_{c1} = 0{,}15$ are the percentages of not being preferred. Inverse values of these not being preferred values are calculated;

$\dfrac{1}{0{,}62} = 1{,}61, \quad \dfrac{1}{0{,}23} = 4{,}35, \quad \dfrac{1}{0{,}15} = 6{,}67$ values are found. If these values are ordered by priority; $Y'_{A1} = \dfrac{1{,}61}{(1{,}61 + 4{,}35 + 6{,}67)} = 0{,}13$ is the value of preference. Other results will be found as $Y'_{B1} = 0{,}34$ and $Y'_{C1} = 0{,}53$. It can be seen that the negative (-) effect of the shipping price is eliminated.

List of symbols

X_1: The weight of shipping price among preference criteria.
X_2: The weight of shipping time among preference criteria.
X_3: The weight of shipping safety among preference criteria.
X_4: The weight of accessibility among preference criteria
A: Highway,
b: Railway,
c: Sea,
B: A+b (highway + railway)
x_{2b}: Railway mean shipping speed (km/hr),
C: A+c (highway + seaway)
L: Shipping distance, (km)
l': Drayage shipping distance, (km)
l'': Line haul shipping distance (km)
x_{1A}: Highway shipping price, ($/km)
x_{1tb}: Railway transshipment price, ($/km)
x_{1tc}: Sea transshipment price, ($/km)
x_{1b}: Railway shipping price, ($/km)
x_{1c}: Sea shipping price, ($/km).
x_{2A}: Highway mean shipping speed (km/hr),
x_{2c}: Seaway mean shipping speed (km/hr),
x_{2tb}: Transshipment time from highway to railway (hour.),
x_{2tc}: Transshipment time from highway to seaway (hour.),
x_{3A}: The probability of an accident in highway shipping (accident/total vehicle)
x_{3tb}: The probability of an accident during transshipment from highway to railway (assumed to be negligible),
x_{3tc}: The probability of an accident during transshipment from highway to seaway (assumed to be negligible),
x_{3b}: The probability of an accident in railway shipping (accident/total vehicle),
x_{3c}: The probability of an accident in seaway shipping (accident/total vehicle).
SP_j: Shipping charge of mode j ($)
SS_j: Shipping Safety of mode j
ST_j: Shipping Time of mode j (hr.)
E_j: Accessibility of mode j
k: Shipper code
i: Mode choice criteria
j: Available modes
RC_{kj}: Real mode choice of shipper k
u_{kj}: Utility amount of mode j for shipper k