A SYSTEM OF INTERMODAL TRANSPORTATION SYSTEM AND AN APPROACH MULTICRITERIA

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Abstract *— Istanbul is the most important city of Turkey, being the economic, social and cultural capital of the country. It spans two different continents: Europe and Asia. The city is established on the both sides of the Bosphorus, which collects the Black Sea and the Marmara Sea and joins these two continents. The Bosphorus is one of the bottlenecks in multimodal transport connection in Turkey This paper aims to evaluate the Bosphorus crossing alternatives that have a vital role in inner and outer-city transportation in Istanbul. Transportation via Bosphorus is actually realized by three alternatives: two Bosphorus bridges (Bogazici and Fatih Sultan Mehmet Bridges) and maritime transportation. In recent years, to solve the Bosphorus crossing problems three alternatives are taken into consideration and discussed In this study we compare these three alternatives by TOPSIS methodology that is one of the multi-criteria decision making techniques.*

Keywords — Bosphorus transportation, Bosphorus crossing alternatives, *multi-criteria decision making,* TOPSIS

INTRODUCTION

In the developed countries, the transportation statistics indicate that there is an increase in road transportation for passengers and freights [3]. Road transportation is generally preferred to the other modes of transportation since it provides rapid and continuous move of the products from the production point to the final consumers. In Turkey, part of the road transportation in total transportation is higher than that of the World average. This fact causes a lot of accidents, congestion and pollution, and limits the mobility for economic development. In European countries, new projects on maritime transportation are supported to diminish the part of the road transportation [5]. As a result, in these countries the part of the short distance maritime transportation increased, from 29 % to 32 %, since 1992. However in Turkey, although it has an advantage of being surrounded by seas on three sides, the part of maritime transportation was only 3.5 % in total freight transportation and less than 1 % in total passenger transportation in 2002. This study deals with the Bosphorus crossing and transportation in Istanbul. The Bosphorus is located on two continents, Europe and Asia. . Bosphorus crossing is actually realized by three alternatives: The Bogazici and Fatih Sultan Mehmet bridges, and the maritime transportation. Bosphorus transportation often causes important congestion which bring about many troubles, not only for inner-city but also for national and international transportations [7]. In this study, first of all three alternatives are taken into consideration to compare the modes of transportation for Bosphorus crossing. These alternatives are: construction of a third Bosphorus bridge, construction of a rail tunnel beneath the Bosphorus and improvement the existing maritime transportation system. In the second stage of the study, we will discuss about the existing Bosphorus crossing system, the alternatives and the criteria for making a choice between the alternatives. Furthermore, for making design alternatives decision, we applied the TOPSIS. (Technique for Order Performance by Similarity to Ideal Solution) method that is brought up by Yoon and Hwang. to establish a multiple object design decision making method. Finally, we ranked the Bosphorus crossing alternatives, and had a conclusion from the obtained results.

EXISTING MARITIME TRANSPORTATION SYSTEM

The boats and the buses of sea which form the base of maritime transport are used for two reasons: the walk and work. In the voyages having the goal of walk the planning of material does not pose a problem since speed is not important and the request is extended to various hours of the day. For the planning of urban transport, which forms the problem it is the request for accessibility of house - office which appears in the precise hours (peak hours) of the day. To satisfy this application for a job, one should have terrestrial urban transport which would make it possible to continue the way towards the points of arrivals of the travelers. In the event of lack of this coordination, the travelers who reached the landing stages would pose more problem of traffic to the research of the suitable means of transport like it is done now. Another means to solve this problem is to employ boats of low capacity but having a faster circulation between the starting point and of arrival to escape an accumulation from travellers.

BOSPHORUS CROSSING

Istanbul is located on the Asian and European coast of the Bosphorus. One of the bottlenecks in seamless intermodal transport connection in Turkey is the Bosphorus. According to the data of 2000, one makes 1,1 million voyage per day, between the two sides of the Bosphorus. The 20%. from that only passes by the maritime transport. The first bridge of the Bosphorus being built in 1973 between Ortaköy and Beylerbeyi, had a traffic of 27,000 vehicles per day at these days. With the second Bridge (the Bridge De Fatih Mehmet Sultan) built in 1985 between Kavacik and Rumeli Hisarüstü, 185,000 of vehicles passed by the 1st Bridge and 171,000 of vehicles by the Bridge of Fatih Sultan Mehmet. 84 % of these vehicles is the car in the Bridge of the Bosphorus and 67 % in the Bridge of Fatih Sultan Mehmet [11]. The year 2000 considered, 46% of the voyages (500 miles of voyage) passing by the Bosphorus are done by the cars which form 76% of adulterates of vehicle.

The creation of the new possibilities of transport for the crossing of the Bosphorus, will increase the number of travellers passing by the Bosphorus. In the case of improvement of the maritime transport with the new lines, in 2010 one awaits 1,5 million crossings day labourers of the Bosphorus, in the case of to make the connection of way of the Railway Tunnel one awaits this number to rise to 1,8 million and in the case of to build the Third Bridge (Route+Le Ferroviaire system) one awaits this number to rise to 2,4 million [12]. With the development of the possibility of collective transport between the two sides of the city, the percentage of crossing the Bosphorus with the private vehicles decreases to 29%. The percentage of maritime transport, in the case of the development of the new lines increases to 24%, and in the case of to make the crossing with the Railway Tunnel, this percentage decreases with 4-6%. In the case of to connect the two coasts of the Bosphorus with the Railway Tunnel, by increasing the number of suburban line to 3, one awaits 600 miles of people per day to be used Railway Tunnel A side of the Railway Tunnel, between the two existing bridges, in the case of to build the Third Bridge relating to the system with rail, one awaits 1 million people to be used the Railway Tunnel and the railway systems in the Third Bridge.

The congestion is actually a major problem for Bosphorus traffic. The congestion has many reasons. First of all the population in Istanbul has an increasing trend with a significance rate, not only because of the new births but also because of the immigration. It is estimated that the population of the city will attend to 15 millions in 2010 [5]. The second major problem concerning the Bosphorus crossing is that the most of the working places are in the European part of Istanbul. This fact causes an unbalanced traffic circulation from the Asian to the European side of the city. The third problem is the complexity of the transportation administration. Seventeen public authorities control transportation activities in Istanbul, and this fact Is the main reason for the complexity of decision-making.

In this study we are concentrated on three alternatives to determine the best solution to the transport problems in Bosphorus

crossing. These alternatives are the construction a 3rd Bosphorus bridge, construction a rail tunnel beneath the Marmara Sea (Marmaray) that was already begun and the improvement of the existing maritime transportation system that is shown in figure 1 [6]. The cost of constructing a new Bosphorus bridge is estimated to be 300 millions [8], and that of the project of the rail tunnel is 3 billions USD [8]. Especially the rail tunnel project is a long-standing and very expensive one, and it will also have negative effects on the Bosphorus traffic during its construction period. The third alternative is different from the first two, and only aims to improve the existing maritime transportation system.

Figure1: Existing and proposed transportation modes in Bosphorus

The comparison of these alternative transportation modes depends on many criteria. Hence we have determined five main criteria in the frame of this study. These are economic, environmental, social,

cultural criteria, and the criteria associated with the transportation policies and with transportation system. Each criterion has seventeen sub-criteria and they are shown in Table 1.

Table 1 : Types of Criteria

MAIN CRITERIA	SUB-CRITERIA
Economical (C1)	Investment cost (SC11)
	Management and maintenance costs (SC12)
	Impact on the economical development of the region and the country (SC13)
	Impact on the employment (SC14)
Environmental (C2)	Visual pollution (SC21)
	Impact on ecosystem during construction (SC22)
	Impact on ecosystem during management (SC23)
Social and cultural (C3)	Displacement of the population to the region (SC31)
	Comfort (SC32)
	Danger during the construction
	Accessibility (SC33)
Transportation Policies (C4)	Convenience to the Transportation Master Plan (SC41)
	Economical dependency to other countries (SC42)
Transportation system (C5)	Price (SC51)
	Time programming (SC52)
	Created capacity (SC53)
	Traffic of transportation (SC54)

CHOICE OF DECISION MAKING METHODS

The Multi Criteria Decision Making (MCDM) problems are widespread in the field of the theory of the decision [10]. According to Hwang and Yoon the problems of MCDM are commonly categorized into two groups [11], as Multiple Attribute Decision Making (MADM) and Multiple Objectify Decision Making (MODM). MADM, defined as a technique of assistance, has the decision to evaluate and to choose the alternatives which are characterized with several attributes of criteria. In this study, we have chosen TOPSIS which is one of the methods of MADM developped by Hwang and Yoon [12]. Although the other methods (AHP, ELECTRE...etc.) have many advantages, TOPSIS is the best method for our study since it has an appropriate structure decreasing the response time for the information obtained from the experts who contributed to our research. TOPSIS uses the following six steps:

i. **Standardization of the data**: The standardization of vector is employed to calculate the normal data:

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^{\,2}}} \quad i = 1,2,...m;\ j = 1,2,...n \quad (1)$$

where x_{ij} indicates the effective output of the i^{th} alternative with regard to j^{th} criterion.

ii. **Calculation of the weighed normal data:** The weighted normal data are calculated as follows:

$$v_{ij} = w_j r_{ij} \quad i = 1,2,...m;\ j = 1,2,...n \quad (2)$$

where w_j is the weight of j^{th} criterion.

iii. **Determination of the ideal and anti-ideal solutions:** The ideal solution (A *) and the anti-ideal solution (A -) are defined in terms of weighed normal values as follows:

$$A^* = \left\{ (\max_i v_{ij} \mid j \in J), (\min_i v_{ij} \mid j \in J'),\ i = 1,2,\ldots m \right\}$$
$$= \left\{ v_{j^*},\ j = 1,2,\ldots,n \right\}$$
$$A^- = \left\{ (\min_i v_{ij} \mid j \in J), (\max_i v_{ij} \mid j \in J'),\ i = 1,2,\ldots m \right\}$$
$$= \left\{ v_{j^-},\ j = 1,2,\ldots,n \right\}$$

where *j* is the whole of criteria of profit and *i* is the whole of criteria of cost.

iv. Calculation of measurements of distance: The distance between the alternative solutions can be measured by the Euclidean dimensional distance of n. The distance from each alternative ideal and anti-ideal solution are then indicated by:

$$D_i^* = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j^*})^2}\ ,i=1,\ 2,\ \ldots,m$$
$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_{j^-})^2}\ ,i=1,\ 2,\ \ldots,m \qquad (4)$$

v. Calculation of the proximity to the ideal solution:

$$C_i = \frac{D_i^-}{D_i^* + D_i^-},\ i = 1,2,\ldots,m \qquad (5)$$

Where C_i indicates the proximity of the i^{th} alternative to the ideal solution. Denote that $0 \le C_i \le 1$, where $C_i = 0$ when $A_i = A^-$ and $C_i = 1$ when $A_i = A^*$.

iv. Determination of the order of preference: The alternative solutions are arrenged in a descending order.

The first type of data are obtained and formed from the responses given by the experts to the questions of our survey questionnaire. The survey has been conducted for twenty-nine experts. These experts are from universities Ministry of Transportation, State Highway Autority, General Administration of State Airports and Harbours, Planning Organisation of the State, Istanbul City Maritime Transport. Administration and Directory of Istanbul Seabus Entreprise. The second group of data are obtained from the official statistics of the Statistical Institut of the State. First of all, we converted the answers of the surveys from the qualitative form to the quantitative form.

Depending on the TOPSIS, we found the degrees of importance of the main criteria by taking the average of the given responses. The answers have been taken the values from 1 to 5; 1 y for the answer “much less important”,” 2 for “less important”, 3 for”quite important”, 4 for ” important” and 5 for “very important”. Using these data we formed table below:

Table 2
Results concerning the degrees of importance of the criteria

Criteria	Degrees of Importance
C1	0,24
C2	0,19
C3	0,19
C4	0,19
C5	0,19

In the same way we get the degrees of importance of the sub-criteria depending on the main criteria shown in table 3. Then, we used the steps of the TOPSIS method and we obtained the ideal and non-ideal solutions for each sub-criterion that are given in Table 4. Finally Table 5 shows the ranking of the possible alternatives for the Bosphorus crossing:

Table 3
Results of the degrees of importance of the criteria

Sub-Criteria	Degrees of Importance
SC11	0,0564
SC12	0,0564
SC13	0,0708

SC14	0,0564
SC21	0,0633
SC22	0,0633
SC23	0,0633
SC31	0,0475
SC32	0,0475
SC33	0,0475
SC34	0,0475
SC41	0,1064
SC42	0,0836
SC51	0,04465
SC52	0,05605
SC53	0,04465
SC54	0,04465

Table 4
Results of the ideal and non-ideal solutions

Sub-Criteria	Ideal Solution	Non-Ideal Solution
SC11	0,0012	0,0561
SC12	0,0115	0,0529
SC13	0,0500	0,0300
SC14	0,0386	0,0290
SC21	0,0258	0,0517
SC22	0,0270	0,0405
SC23	0,0270	0,0405
SC31	0,0325	0,0244
SC32	0,0335	0,0201
SC33	0,0230	0,0345
SC34	0,0296	0,0222
SC41	0,0664	0,0498
SC42	0,0310	0,0620
SC51	0,0123	0,0411
SC52	0,0396	0,0237
SC53	0,0348	0,0098
SC54	0,0229	0,0306

Table5
Ranking of possible alternatives

	3rd Bosphorus bridge	Rail Tunnel Crossing	Improving the maritime transportation
Ideal Distance	0,0609	0,0645	0,0537
Anti-ideal Distance	0,0690	0,0721	0,0798
Proximity to the ideal solution	0,5313	0,5277	0,5977
Ranking	2	3	1

CONCLUSION

Istanbul the economical and social capital of turkey, plays a great role for domestic and international trade of the country. in spite of its importance, both the problem of transportation alternatives and the traffic congestion in istanbul remains still important problems. in this study, we focused on the bosphorus crossing that plays a very important role both in inner and outer-city transportation. we had taken into consideration three alternatives, which can reduce the traffic congestion on the bosphorus crossing: the construction of a new bosphorus bridge, the rail tunnel and the improvement of the existing maritime transportation. we compared these three alternatives using a madm method, topsis. first group of data has been collected from the survey results. the answers of the transportation authorities had been evaluated. we obtained another group of the data from the official documents and statistics. as the result, the improvement of the existing maritime transportation gave the best results. it is observed hat the improvement of the existing maritime transportation appears as the first alternative in the ranking of three alternatives of bosphorus crossing. this result confirms the new

transportation policies of EU that is currently supporting the maritime transportation.

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