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AN APPLICATION OF THE ANALYTIC HIERARCHY PROCESS FOR THE BOSPHORUS CROSSING IN ISTANBUL

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Abstract. In this paper, itineraries in a transport system will be investigated to help city authorities to prioritize alternative routes to improve them. In İstanbul, most commuters have to select a combination of transport modes for crossing the Bosphorus, these will be termed "itineraries" in the paper. Transport authorities who aim to provide the most efficient transportation system for commuters, have to consider passenger preferences as well as environmental pollutants of the different transport services. Thirty-four alternative itineraries are prioritized based on time, comfort, cost and pollution criteria, using Analytic Hierarchy Process(AHP) a multicriteria decision support system. Results indicate that itineraries which provide service frequency, with moderate comfort level and less environmental pollution have priorities.

1. Introduction

The city of İstanbul has witnessed a rapid growth in the past; the population increased from three million in 1970 to ten million in 1994. In addition to the population increase, the urban land use pattern has drastically changed (İstanbul Master Plan, 1995).

The problems became more complicated with the sudden growth of residential areas and new locations of industrial, commercial and financial centers. Istanbul was transformed from a monocentric to a polycentric city following the expansion of the city boundries and the development of communication systems . This transformation will continue in the future (Dökmeci and Berköz, 1994)

In İstanbul, the structure of the city fabric and the organization of urban transport are closely related. The expansion of the city in certain directions has dominated the extension of transport services to these areas and, in relation, the development of principal transport itineraries has accelerated urban growth around them. In the process of urban development which side of this interactive relationship will dominate over the other is determined to a great extent by the type and extent of capital entering into the transportation and the construction sector.

Nowadays, the transport system is inadequate to supply the existing travel demand. In order to increase the accessibility in the city , Light Rail Transport (LRT) facilities have been added to the system. Maritime transportion will be improved in the near future. An underground railway system (Metro) is under construction.

Construction project decisions are generally made by elected bodies. Municipalities have to decide how to allocate funds and to satisfy public expectations which is their main goal. At this stage, a quantitative method would be useful for decision makers.

In the paper, a quantitative method, *The Analytic Hierarchy Process (AHP)*, has been tested as a multicriteria decision approach on a specific problem. Cross-Bosphorus traffic is one of the major problems for which the municipalities have to bring urgent solutions. The existing commuting systems between the eastern and western sides of the city are currently inadequate due to the absence of effective transport services on the Bosphorus (Kılınçaslan, 1995).

In order to provide adequate transportation, central and local governments have made investments on several projects. The construction of the first Bosphorus Bridge was finalized in 1973 and the second bridge in 1984. Currently, local and central authorities are in the process of decision making for new infrastructure investments in order to improve the accessibility and thus to decrease the difficulties occured at the Bosphorus crossing. Local and central decision makers in government have to decide whether to build another bridge or construct a tunnel. Improvement of the existing transport facilities is yet another approach.

The city of İstanbul policy makers' approaches have been briefly explained in the Introduction. The available itineraries for first bridge Bosphorus-crossings are explained in the second section. The available alternatives of the first Bosphorus bridge have been examined by the AHP and brief description of the AHP is given in the third section. The goal, selected criteria and alternative itineraries have been structured in a hierarchical manner and explained in the fourth section.

Prioritization of the alternatives by selected criteria have been presented in the fifth section. Experts in the field of transportation and environmental pollution directed the study. Intensity levels and relative weights of the criteria were based on professional opinions. Results are presented in the sixth section The last part of the paper covers the conclusion and suggestions.

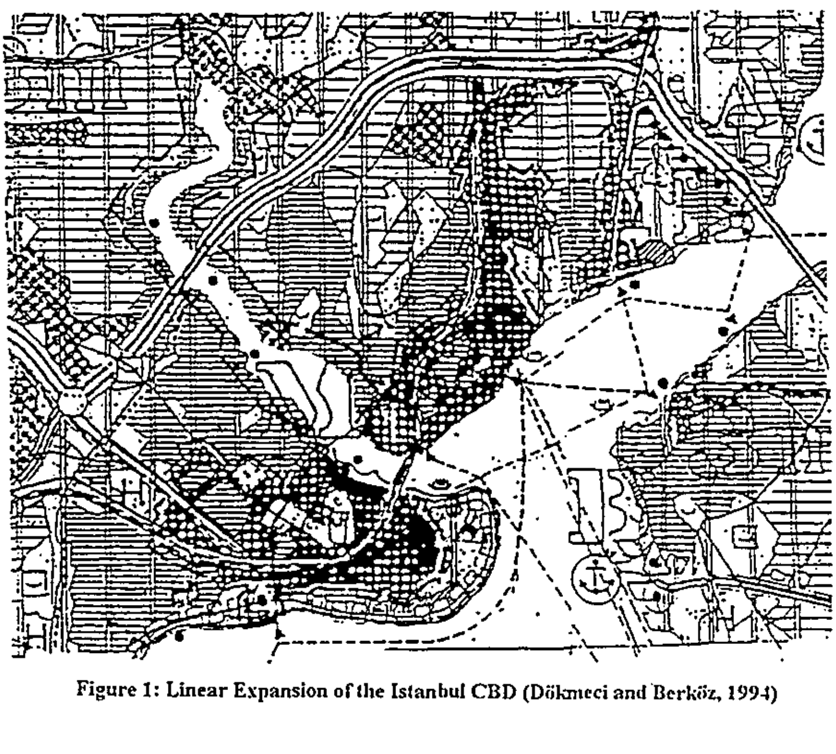

Figure 1: Linear Expansion of the Istanbul CBD (Dökmeci and Berköz, 1994)

2. The Bosphorus Crossing

There is an imbalance between active population and employment on two sides of the city of İstanbul (16). Since a large number of places of employment are located on the European side and residential areas are densely located on the Anatolian side; an active population has to commute from the Anatolian side to the European coast (See Figure 2 and 3).The number of commuters between the two shores of İstanbul increased 20% in 1990, 35 % in 1995 (İstanbul Master Plan, 1995).

The public transport system, consisting of train, light rail transport, bus, minibus, ship and seabus, is inadequate and most commuters prefer to drive their private cars. Car ownership is on an increase; the first Bosphorus bridge has already reached its capacity; the average daily traffic is around hundred thousand vehicles a day resulting in long waiting times, due to traffic congestion at access and exits of the Bridge.

In order to decrease.traffic congestion a reliable public transport system should be promoted. This situation would discourage the use of private cars on the Bosphorus crossing and encourage the use of public transport.

In a metropolitan area most daily trips can not be made by only one vehicle; commuters have to select a combination of transport modes which are called itineraries in the paper. Transfers from one mode to another have to be made at terminal points which are developed in the city transport system.

Mecidiyeköy is a primary terminal point located on the European side and Pendik is another main terminal in the city transport system which is located on the Anatolian side. Bostancı and Kadıköy, Üsküdar are secondary terminals on the Anatolian side, Beşiktaş, Karaköy, Kabataş and Tünel are secondary terminals on the European side.

In this paper, Mecidiyeköy and Pendik have been accepted as origin and destination points for itineraries. Thirty-four alternative itineraries are available between Mecidiyeköy and Pendik. Direct connection is provided only by bus services. The other connections are provided by several transport modes requiring transfers at sub-terminals.

The traffic crossing on the Bosphorus are assumed under free traffic conditions; including all trip types, equal toll fees, no capacity restrictions. The itineraries which connect Mecidiyeköy and Pendik, two major terminal points, are evaluated and prioritized by AHP.

3. Analytic Hierarchy Process

The Analytic Hierarchy Process(AHP) is a quantitative approach designed to handle situations in which subjective judgments are a major part of the decision process(Dyer, 1990). This approach is particularly suitable for selecting among competing alternatives that involve evaluation of multiple criteria.

Typically, the AHP is described in terms of three basic components:(a) design of the hierarchy, (b)the prioritization procedure, and (c)calculation of results. The AHP first breaks down a complex multicriteria decision-making problem into a hierarchy, in which each level is composed of specific elements(Saaty, 1990b). The overall objective of the decision-making process is at the top of the hierarchy, and the criteria, sub-criteria, and decision alternatives are at each descending level of the hierarchy.

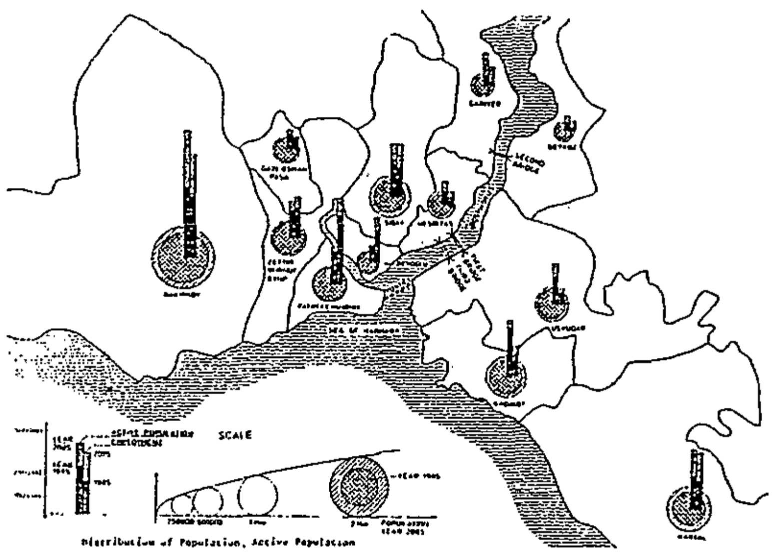

Fig. 2. Distibution of Population, Active Population and Employment (1985-2005)
(Imar-Weidleplan, 1994)

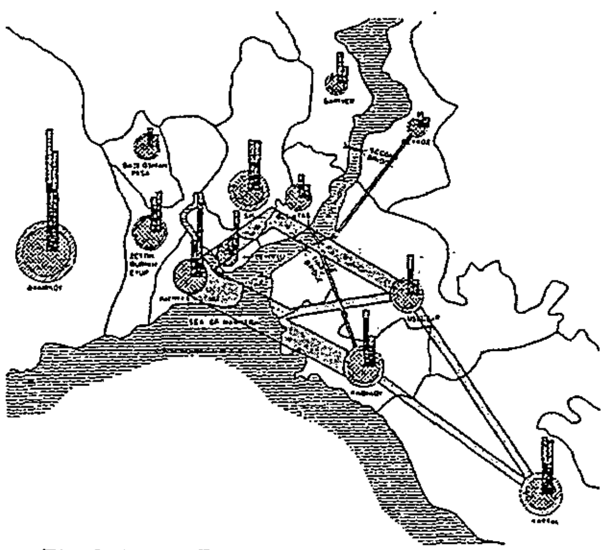

Fig. 3. Traffic Desire (Commuters East to West)
(Imar-Weidleplan, 1994)

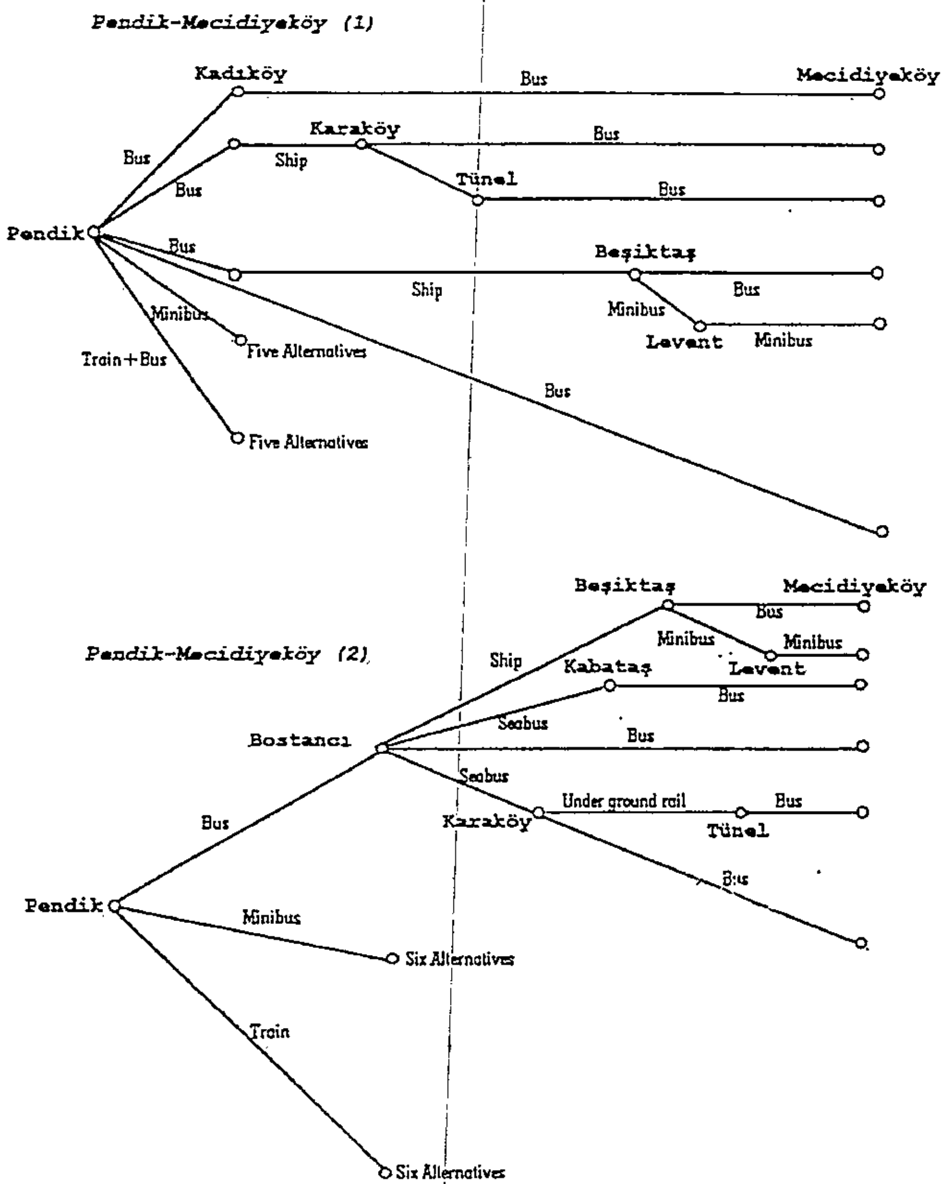

Fig. 4. Existing Itineraries Between Pendik-Mecidiyeköy.

Once the hierarchy has been constructed, the decision maker begins the prioritization procedure to determine the relative importance of the elements in each level. Elements in each level are compared pairwise in terms of their importance to an element in the next higher level.

The nominal scale used for comparisons in AHP enables the decision maker to incorporate experience and knowledge intuitively (Harper and Vargas, 1990). The decision maker can express his preference between every two elements verbally as equally important (or preferred), moderately more important, strongly more important, very strongly more important, or extremely more important. These descriptive preferences would then be translated into numerical ratings 1,3,5,7 and 9 respectively with 2,4,6 and 8 as intermediate values for compromises between two successive qualitative judgments(Saaty, 1990a). This scale is insensitive to small changes in a decision maker's preferences, thereby minimizing the effect of uncertainty in evaluations.

After forming the preference matrices, the process moves to deriving relative weights for the various elements. The composite weights of the decision alternatives are determined by aggregating the weights throughout the hierarchy.

Not only does Expert Choice (EC) calculate priorities based on judgements, it also produces a measure of inconsistency (Forman and Saaty, 1993). This measure is useful in identifying possible errors in expressing judgements as well as actual inconsistencies in the judgements themselves. Suggestions can be requested for improving consistency.

Finally, all the comparisons are synthesized to rank the alternatives overall. The result is a set of priorities for the alternatives. AHP serves as an excellent tool for communicating a recommended decision to other levels within an organization (Vargas, 1990).

4. Determination of Criteria

Transport authorities who aim to provide the most efficient transportation system for commuters have to consider passenger preferences. It has been accepted that three main criteria have effects on passenger preferences; time, comfort and cost. Distance has been taken as a proxy to confort criterion.

İstanbul commuters are also exposed to air pollution and thus sensitive to this issue. Until recently, Istanbul had been accepted as an environmentally clean city. Little regard was given to the side effects of the transportation vehicles. Since transportation vehicles affect environmental pollution, the transport mode selection has become an important issue. Nowadays, polluted air is one of the main concerns of the municipalities (Envir. Mngt. in Municip., 1995).

The air pollution caused by transportation vehicles is primarily concentrated around the metropolitan areas and urban traffic is one of the main cause.The environmental impact produced by each mode of transportation vary in terms of intensity. Considering the existing situation. in this paper air pollution is taken as a criterion which affects passenger preference.

Time (minute): is the total time spend along the route including waiting time at the terminals.
Terminal waiting time is calculated as: (total time for a round trip x 0.05)÷ 3 minutes.
This calculation has been used by İstanbul Bus Authority in their service amelioration projects (IETT. 1994). Savings in travel time has an important effect on a passenger's decision.
Comfort level of the transport vehicles has an effect on passenger preference.
Cost (TL/passenger): Ticket price paid by each passenger during the trip, including all modes used.

In İstanbul, public transportation is mostly preferred by low and middle income groups .(IETT, 1994). These groups are quite sensitive to price chances. Travel expense is an important criteria which has high priority on personal itinerary selection.

Air Pollution

Pollution, as a chemical agent can be quantified and measured as to level and effect. Some transportation sources emit pollutants in relatively large quantities, but all pollutants are not equally harmful. About 70% of man-made carbon monoxide (CO) is attributed to highway vehicles; and CO comprises a large portion of pollution (Homburger, 1976).

5. Design of The Hierarchy

The goal, selected criteria and alternative itineraries are structured in a hierarchical manner . The goal is to prioritize the itineraries. The relevant criteria are defined in two levels. First level criteria are *time, comfort, cost, and air pollution.* Air pollution is divided into *sulfur dioxide(SO_2), carbon monoxide(CO), hydrocarbon(HC) and nitrogen oxide(NO)* as sub-criteria.

Data related to time, comfort and cost have been provided from the official records of The State Railways, Istanbul Bus Authority, İstanbul Maritime Lines , İstanbul Seabus Company and the Minibus Association (See Table 1).

Air pollution emissions are influenced by several factors including power source(steam or diesel), engine size (in kilowatts or horsepower), fuel used (coal, residual oil or diesel oil), operating speed, and load.

In the paper, calculations for average emission factors have been based on fuel consumptions of coastal commercial motorships for sea trips and heavy duty diesel powered vehicles for land transportation (Env. Protection Agency, 1973). Since railways are operated by electric energy, they are air pollution free vehicles. Data about fuel consumption have been derived from official records.

Gr/kilometer/ passenger air pollutants have been calculated and then results have been multiplied by distance for each vehicle which has been used in the itinerary. Total air pollution has been calculated for each itinerary per passenger.

6. Prioritization Procedure

Since there are thirty-four alternative itineraries, it is not practical to compare each item with all other items in respect to each of the established criteria. The decision maker must rate the alternatives with respect to each of the criteria. The ratings method for entering judgments is used when the alternatives have been evaluated against standards rather than against each other under all of the subcriteria.

Measurement against a standard is referred to as absolute measurement. This method has the advantage that hundreds of alternatives can be ranked easily. But standards must be well understood and the person who is doing the ratings should be comfortable comparing alternatives against them. This procedure is referred to as the intensity mode of AHP. Expert Choice (EC) labels this procedure the "absolute" mode of AHP. This process has been described by Forman and Saaty (Saaty. 1986).

TABLE 1
Alternative Itineraries

ITINERARY		TIME	DISTANCE	COST	SO_2	CO	HC	NO
PM-B		83.0	35.00	20	0.6563	5.5560	0.9168	9.1875
PKM-BB		126.0	41.00	30	0.7658	6.5068	1.0763	10.7625
PKKrM-BSB		124.4	35.40	35	1.6076	9.1497	2.7324	18.4562
PKKrM-BSMtB		127.0	34.90	40	1.5672	8.9752	2.7036	18.1675
PKBeM-BSB		130.0	34.83	35	1.8963	9.6021	3.2902	21.2471
PKBeM-BSMbMb		122.0	34.83	49	2.1765	11.0297	3.6493	23.7638
PKM-MbB		106.0	41.00	40	2.7156	12.2366	4.9611	28.2472
PKKrM-MbSB		104.4	35.40	45	3.5546	14.8777	6.6172	35.9409
PKKrM-MbSMtB		107.0	34.90	50	3.5342	14.7032	6.5684	35.6522
PKBeM-MbSB		110.0	34.83	45	3.6433	15.3301	7.1750	38.7316
PKBeM-MbSMbMb		102.0	34.83	59	4.1235	16.7577	7.7341	41.2485
PKM-TrBB		114.6	40.00	40	0.3376	2.6575	0.8033	8.0325
PKKrM-TrBSB		113.0	34.40	45	1.1766	5.4964	2.4594	15.7262
PKKrM-TrBSMtB		115.6	33.90	50	1.1560	5.3239	2.4306	15.4375
PKBeM-TrBSB		118.6	33.63	45	1.4651	5.9508	3.0172	18.5171
PKBeM-TrBSMbMb		110.6	33.63	59	1.7453	7.3784	3.5763	21.0338
PBoM-BB		86.0	37.60	30	0.7049	5.9690	0.9670	9.8701
PBoKbM-BSbB		78.2	3.79	70	6.4545	35.6618	15.5236	85.2302
PBoBeM-BSB		101.0	34.83	35	4.2461	16.6596	7.8064	43.9738
PBoBeM-BSMbMb		93.0	34.83	49	4.5283	19.6641	8.3655	46.4905
PBoKrM-BSbB		77.4	33.60	70	6.4545	26.0457	11.9755	66.3932
PBoKrM-BSbMtB		80.0	33.07	75	6.4639	27.5711	11.9467	66.1044
PBoM-MbB		79.0	37.60	40	1.8334	9.2883	3.2384	20.0032
PBoKbM-MbSbB		71.2	33.79	80	7.6130	38.9811	17.7750	95.3633
PBoBeM-MbSB		94.0	34.63	45	5.3766	22.1769	10.0578	54.1069
PBoBeM-MbSMbMb		86.0	34.63	59	5.6586	23.0034	10.6169	56.6236
PBoKrM-MbSbB		70.4	33.60	80	7.6130	31.3650	14.2269	76.5263
PBoKrM-MbSbMtB		73.0	33.07	85	7.5924	31.1904	14.1961	76.2375
PBoM-TrB		85.0	37.70	30	0.4161	3.5411	0.5654	5.8535
PBoKbM-TrSbB		77.2	33.89	70	6.1977	33.2329	15.1220	81.2139
PBoBeM-TrSb		100.0	34.93	35	3.9613	16.4307	7.4048	39.9575
PBoBeM-TrSMbMb		92.0	34.93	49	4.2415	17.2552	7.9639	42.4742
PBoKrM-TrSBb		76.4	33.70	70	6.1977	25.8166	11.5739	62.3769
PBoKrM-TrSbMtB		79.0	33.17	75	6.1771	25.4422	11.5451	62.0681
P	Pendik							
K	Kadıköy							
M	Mecidiyeköy							
Kr	Karaköy							
Kb	Kabataş							
Be	Beşiktaş							
Bo	Bostancı							
B	Bus							
Mb	Minibüs							
S	Ship							
Sb	Sea-bus							
Tr	Train							
Mt	Metro							

In the paper, the rating scale for time criterion uses six intensity levels : 70-80 minutes travel time, 80-90 minutes, 100-110 minutes, 110-120 minutes, and > 120 minutes . The weight of each intensity level has been determined by pairwise comparisons. Questiôns are asked; such as "in evaluating best itineraries, how much more preferable is 70-80 minutes travel time than 80-90 minutes travel time?". The comparision procedure continues as before, and the local weights of these ratings are computed as .441, .248, .148, .086, .048, and .029 for 70-80 minutes, 80-90, 90-100, 100-110, 110-120, and more than 120 minutes travel times respectively (See Table 2).

Comfort and cost criteria are similarly analyzed. For pollution, local priorities of sub criteria SO_2, CO, HC and NO have been calculated by pairwise comparisons. Local priorities have been defined by interviewing Dr.Kadir Alp, Depertment of Environmental Engineering, İstanbul Technical University, whose specialty is air pollution.

Comparison matrix is given as follows:

	SO_2	CO	HC	NO
SO_2	1	1/9	1/5	1/5
CO	9	1	1	2
HC	5	1	1	1
NO	5	1/2	1	1

In SO_2 column "9" shows that CO is extremely more pollutant than SO_2, the first "5" indicates that HC is strongly more pollutant than SO_2; in hydrocarbon column the first "1" shows that CO and HC pollute the air equally. The priorities calculated by EC based on importance which given above, are .05, .407, .296, and .246 for SO_2, CO, HC, and NO sub criteria respectively ..

Seven intensity levels of SO_2 and weights of these ratings are shown in Table 3. They are calculated by EC in a similar way to them which has been described for time criterion. Intensity levels of CO, HC and NO sub-criteria are similarly interpreted.

Before we insert the thirty-four alternatives to be ranked by EC, we need to specify the importance of first level criteria; time, comfort, cost and pollution.

Importance comparison of the first level criteria; time, comfort, cost and pollution has been defined by interviewing passengers. Students from the Faculty of Architecture interviewed the passengers at the terminal points. Comparison matrices have been formed according to their preferences. Emission factor calculations are based on fuel consumption of each transport mode(gr/passenger).

	Time	Comfort	Cost	Pollution
Time	1	5	3	1/3
Comfort	1/5	1	1/3	1/7
Cost	1/3	3	1	1/5
Pollution	3	7	5	1

In forming this matrix it has been assumed that transport authorities want to satisfy public expectations, therefore passenger preferences have been taken into consideration. In addition, it is assumed that each passenger would support environmentally safe investments.

In the pollution row, "3" shows that pollution is moderately more important than transport time; "7" indicates that pollution is very strongly more important than comfort; and pollution is strongly more important than cost. Under the comfort column, time is strongly more important than comfort; cost is

TABLE 2
Criteria and Intensity Levels

ITINERARY

GOAL
L 1.000
G 1.000

TIME	COMFORT	COST	POLLUTION
L 0.262	L 0.055	L 0.118	L 0.565
G 0.262	G 0.055	G 0.118	G 0.565
70-80	33-34 KM	<20	SO_2
L 0.441	L 0.329	L 0.386	L 0.050
G 9.116	G 0.018	G 0.045	G 0.028
80-90	34-35 KM	20-30	CO
L 0.248	L 0.243	L 0.229	L 0.407
G 0.065	G 0.013	G 0.027	G 0.230
90-100	35-36 KM	30-40	HC
L 0.148	L 0.81	L 0.169	L 0.296
G 0.039	G 0.010	G 0.020	G 0.168
100-110	36-37 KM	40-50	NO
L 0.086	L 0.102	L 0.094	L 0.246
G 0.022	G 0.006	G 0.011	G 0.139
110-120	37-38 KM	50-60	
L 0.048	L 0.089	L 0.061	
G 0.013	G 0.005	G 0.007	
>120 MIN	38-39 KM	60-80	
L 0.029	L 0.033	L 0.038	
G 0.008	G 0.002	G 0.004	
	>39 KM	> 80	
	L 0.021	L 0.024	
	G 0.001	G 0.003	

100-110	---	100-110 (<100) minutes travel time
110-120	---	110-120 (<120) minutes travel time
20-30	---	20,000- 30,000 TL per passenger
30-40	---	30,000- 40,000 TL per passenger
33-34 KM	---	33-34 km (<34) travel distance
34-35 KM	---	34-35 km (<35) travel distance
35-36 KM	---	35-36 km (<36) travel distance
36-37 KM	---	36-37 km (<37) travel distance
37-38 KM	---	37-38 km (<38) travel distance
38-39 KM	---	38-39 km (<39) travel distance
40-50	---	40,000- 50,000 TL per passenger
50-60	---	50,000- 60,000 TL per passenger
60-80	---	60,000- 80,000 TL per passenger
70-80	---	70-80 (<80) minutes travel time
80-90	---	80-90 (<90) minutes travel time
90-100	---	90-100 (<100) minutes travel time
<20	---	<20,000 TL per passenger
>120 MIN	---	>120 minutes travel time
>39 KM	---	>39 km travel distance

TABLE 3
Subcriteria of Pollution and Intensity Levels

POLLUTION L 1.565 G 1.565

SO_2 L 0.050 G 0.028	CO L 0.407 G 0.230	HC L 0.296 G 0.168	NO L 0.246 G 0.139
<0.7 GR L 0.342 G 0.010	<3 GR L 0.336 G 0.077	<1 GR L 0.384 G 0.064	<10 GR L 0.373 G 0.052
0.7-1.0 L 0.255 G 0.007	3-5 GR L 0.242 G 0.056	1-4 GR L 0.247 G 0.041	10-20 GR L 0.278 G 0.039
1.0-1.2 L 0.154 G 0.004	5-6 GR L 0.176 G 0.041	4-7 GR L 0.157 G 0.026	20-30 GR 0.157 G 0.022
1.2-1.9 L 0.138 G 0.004	6-9 GR L 0.110 G 0.025	7-10 GR L 0.114 G 0.019	30-50 GR L 0.097 G 0.014
1.9-3.0 L 0.054 G 0.002	9-15 GR L 0.068 G 0.016	10-15 GR L 0.059 G 0.010	50-8- GR L 0.059 G 0.008
3.0-5.0 L 0.036 G 0.001	15-30 GR L 0.044 G 0.010	> 15 GR L 0.039 G 0.007	>80 GR L 0.036 G 0.005
>5.0 L 0.022 G 0.001	>30 L 0.024 G 0.006		

0.7-1.0	—	0.7-1.0 gr SO_2 emission per passenger
1-4 gr	—	1-4 gr HC emission per passenger
1.0-1.2	—	1.0-1.2 gr SO_2 emission per passenger
1.2-1.9	—	1.2-1.9 gr SO_2 emission per passenger
1.9-3.0	—	1.9-3.0 gr SO_2 emission per passenger
10-15 GR	—	10-15 gr HC emission per passenger
10-15 GR	—	10-20 gr NO emission per passenger
15-30 GR	—	15-30 gr CO emission per passenger
20-30 GR	—	20-30 gr NO emission per passenger
3-5 GR	—	3-5 gr CO emission per passenger
3.0-5.0	—	3.0-5.0 gr SO_2 emission per passenger
30-50 GR	—	30-50 gr NO emission per passenger
4-7 GR	—	4-7 gr HC emission per passenger
5-6 GR	—	5-6 gr CO emission per passenger
50-80 GR	—	50-80 gr NO emission per passenger
6-9 GR	—	6-9 gr CO emission per passenger
7-10 GR	—	7-10 gr HC emission per passenger

moderately more important and pollution is very strongly more important than comfort in itinerary selections.

Results:
In the last stage, thirty-four alternative itineraries have been inserted in the EC ratings spreadsheet and results are derived (See Table 4).
The best itinerary is :

" Pendik-Mecidiyeköy by bus" (Alternative 1)

Other alternatives in decreasing order of importance are as follows:

"Pendik-Bostancı-Mecidiyeköy by train and bus"	(Alternative 29)
"Pendik-Bostancı-Mecidiyeköy by bus and bus"	(Alternative 17)
"Pendik-Kadıköy- Mecidiyeköy by train, bus and bus"	(Alternative 12)
"Pendik-Bostancı-Mecidiyeköy by minibus and bus"	(Alternative. 23)

Conclusion and Suggestions

This paper presents an application of the EC in the Istanbul transportation system. It is intended to evaluate the viability of alternatives towards ameliorating the cross-Bosphorus public transport services. Examining passenger preference provides local authorities with data upon which to base their traffic decisions.. Since transportation problems have a multifaceted character, the EC provides a very useful framework for planners and also decision makers.

Results indicate that peripheral itineraries have higher priorities. It has to be taken into account that degree of uncertainty has an effect on the preferences; services which are operated by timetable display higher priorities. Those transport modes which provide service frequency with a moderate comfort level and less environmental pollution have priorities.

In the Istanbul Metropolitan area the rail and the sea transportion services are inefficient. The municipality aims to improve maritime lines. The results of this study, however, reveal that bus and minibus services with the nature of flexible timetables, itinerary changes, and frequent stops are more atractive for passengers. Also, squatter settlements along the periphery stimulate the demand for minibus and bus services.

If the sea and the railroad services are improved, these changes would have an effect on passenger preferences. Therefore, comfort levels of each transport mode should be considered in the local government decision making. As passenger life standards change, this change will find its reflections in the passenger preferences. EC will provide this flexibility and will bring new results for each new situation.

TABLE 4
Prioritization of Itineraries

	Time	Comfort	Cost	Pollution SO_2	Pollution CO	Pollution HC	Pollution NO	
Alternatives	0.2622	0.0553	0.1175	0.0265	0.2299	0.1675	0.1391	Total
1 PM-B	80-90	34-35KM	<20	<0.7GR	5-6GR	<1GR	<10GR	0.761
2 PKM-BB	>120 MIN	>39KM	20-30	0.7-1.0	6-9GR	1-4GR	10-20GR	0.396
3 PKKrM-BSB	>120 MIN	35-36KM	30-40	1.2-1.9	9-15GR	1-4GR	10-20GR	0.369
4 PKKrM-BSMtbB	>120 MIN	34-35KM	30-40	1.2-1.9	6-9GR	104GR	10-20GR	0.408
5 PKBe-BSB	>120 MIN	34-35KM	30-40	1.9-3.0	9-15GR	1-4GR	20-30GR	0.334
6 PKBeM-BSMbMb	>120 MIN	34-35KM	40-50	1.9-3.0	9-15GR	1-4GR	20-30GR	0.304
7 PKM-MbB	100-110	>39KM	30-40	1.9-3.0	9-15GR	4-7GR	20-30GR	0.284
8 PKKrM-MbSB	100-110	35-36KM	40-50	3.0-5.0	9-15GR	4-7GR	30-50GR	0.265
9 PKKrM-MbSMtB	100-110	34-35KM	40-50	3.0-5.0	9-15GR	4-7GR	30-50GR	0.275
10 PKBeM-MbSB	100-110	34-35KM	40-50	3.0-5.0	15-30GR	7-10GR	30-50GR	0.24
11 PKBeM-MbSMbMb	100-110	34-35KM	50-60	3.0-5.0	15-30GR	7-10GR	30-50GR	0.229
12 PKM-TrBB	110-120	>39KM	30-40	<0.7GR	<3GR	<1GR	<10GR	0.648
13 PKKrM-TrBSB	110-120	34-35KM	40-50	1.0-1.2	5-6GR	1-4GR	10-20GR	0.443
14 PKKrM-TrBSMtB	110-120	33-34KM	40-50	1.0-1.2	5-6GR	1-4GR	10-20GR	0.457
15 PKBeM-TrBSB	110-120	33-34KM	40-50	1.2-1.9	5-6GR	1-4GR	10-20GR	0.456
16 PKBeM-TrSMbMb	110-120	33-34KM	50-60	1.2-1.9	6-9GR	1-4GR	20-30GR	0.355
17 PBoM-BB	80-90	37-38KM	20-30	0.7-1.0	5-6GR	<1GR	<10GR	0.68
18 PBoKbM-BsbB	70-80	33-34KM	60-80	>5.0	<30GR	>15GR	>80GR	0.378
19 PBoBeM-BSB	100-110	34-35KM	30-40	3.0-5.0	15-30GR	7-10GR	30-50GR	0.262
20 PBoBeM-BSMbMb	90-100	34-35KM	40-50	3.0-5.0	15-30GR	7-10GR	50-80GR	0.262
21 PBoKrM-BSbB	70-80	33-34KM	60-80	>5.0	15-30GR	10-15GR	50-80GR	0.409
22 PBoKrM-BSbMtB	70-80	33-34KM	60-80	>5.0	15-30GR	10-15GR	50-80GR	0.409
23 PBoM-MbB	70-80	37-38KM	30-40	1.2-1.9	9-15GR	1-4GR	20-30GR	0.553
24 PBoKbM-MbSbB	70-80	33-34KM	60-80	>5.0	>30GR	>15GR	>80GR	0.378
25 PBoBeM-MbSB	90-100	34-35KM	40-50	>5.0	15-30GR	10-15GR	50-80GR	0.237
26 PBoBeM-MbSMbMb	80-90	34-35KM	50-60	>5.0	15-30GR	10-15GR	50-80GR	0.266
27 PBoKrM-MBSbMtB	70-80	33-34KM	60-80	>5.0	>30GR	10-15GR	50-80GR	0.395
28 PBoKrM-MbSbMtB	70-80	33-34KM	>80	>5.0	>30GR	10-15GR	50-80GR	0.391
29 PBoM-TrB	80-90	37-38KM	20-30	<0.7GR	3-5GR	<1GR	<10GR	0.733
30 PBoKbM-TrSbB	70-80	33-34KM	60-80	>5.0	>30GR	>15GR	>80GR	0.378
31 PBoBeM-TrSB	90-100	34-35KM	30-40	3.0-5.0	15-30GR	7-10GR	30-50GR	0.299
32 PBoBeM-TrSMbMb	90-100	34-35KM	40-50	3.0-5.0	15-30GR	7-10GR	30-50GR	0.277
33 PBoKrM-TrSbB	70-80	33-34KM	60-80	>5.0	15-30GR	10-15GR	50-80GR	0.409
34 PBoKrM-TrSbMtB	70-80	33-34KM	60-80	>5.0	15-30GR	10-15GR	50-80GR	0.409

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