IOP Conf. Series: Earth and Environmental Science **44** (2016) 052061 doi:10.1088/1755-1315/44/5/052061

Evaluation of Park and Ride Scenarios for Eskisehir with AHP

Polat Yaliniz [1], Ozden Ustun [2], Safak Bilgiç [3], Yasar Vitosoglu [1]

[1] Dumlupinar University, Faculty of Engineering, Department of Civil Engineering, Kutahya, Turkey
[2] Dumlupinar University, Faculty of Engineering, Department of Industrial Engineering, Kutahya, Turkey
[3] Eskisehir Osmangazi University, Faculty of Engineering and Architecture, Department of Civil Engineering, Eskişehir, Turkey

E-mail: safakbilgic@gmail.com

Abstract. Nowadays, limiting individual transportation and increasing share of mass transit represent an important place in planning a sustainable urban transportation system. In order to attract private automobile users into public transportation, a number of applications can be employed. Among these applications, "park and ride" system comes in first. Therefore, in this study, park and ride system as well as the other applicable scenarios have been evaluated with Analytical Hierarchy Process (AHP) method. The alternatives evaluated include the Protection of the Current Situation, the Introduction of Only Restrictive Factors and the Park and Ride Implementation. Consequently, the overall relative priority values of alternatives were calculated and found to be the highest in the case of Park and Ride Implementation. Hence, it was determined that the "park and ride" application provided a clear superiority compared to other alternatives.

1. Introduction

Sustainability can be defined as meeting the future needs by taking the necessary measures, determining the difficulties to be encountered in the future. Because quality of life is evaluated with economic development at transport policies, sustainability appears to be important. In planning studies based on sustainability, economical, ecological and social sustainability parameters are addressed together.

Sustainable transport is defined as meeting transportation needs without harming human health and the ecosystem. Here, it is important to develop and use alternatives of non-renewable resources and to ensure consumption of renewable resources under their renewal rates. In the sustainability principle, the planning approach to be designed should be based on human [1].

There are many studies related to sustainable transport in the literature. For example, Black [2] investigated sustainable transportation in detail, and explained problems encountered and their solutions. Gudmundsson and Höjer [3] developed some principles related to sustainable development and gave their implications for transport sector.

A large number of multi-criteria decision methods (MCDM) have been reported in the literature. These methods involve assessing given alternatives using a selected set of criteria by a group of decision makers. Beinat [4] reported the use of MCDM for environmental management. Solnes [5] performed environmental quality indexing of large industrial development alternatives by using AHP. Based on expert opinions, Yedla and Shrestha [6] evaluated different scenarios in sustainable transportation in terms of environmental factors in the city of Delhi. Yi et al. [7] used AHP for selecting a sustainable renewable energy source for energy assistance to North Korea. Besides, Omrani et al. [8] presented an AHP based approach for evaluating sustainable transport solution measures like car-sharing, park and ride and access control zones.

2. Problem Definition

As a result of inaccurate urban transport policies, it has been understood that automobile and urban structure does not meet each other. The way to solve this problem is not to try to adjust cities to automobile by constructing more roads, parking lots and multi-level intersections. On the contrary, the solution is to adjust automobile to city for a liveable city.

The simplest and most effective way to solve traffic problems in the city centres is transferring private car trips to public transport as much as possible. For this purpose, determining under which conditions car users could be transferred to public transport emerges as an important issue.

In this study, a sustainable solution is sought for the transportation problem in Eskisehir by directing the car trips to public transport. For this purpose, three alternatives have been given high priority. These three alternatives include “the Protection of the Current Situation”, “the Introduction of Only Restrictive Factors” and “the Park and Ride Implementation”. However, other alternatives have also been considered. These alternatives include establishing access control zones, constructing multi-storey car parks in the city centre, and encouraging the usage of environmentally friendly vehicles in the city centre. However, these alternatives were not considered to be appropriate by the city administration due to their high costs, the formation of the city and the habits of people.

The roads in the city centre of Eskisehir are narrow, and some of these roads are reserved for pedestrians. In addition, there is a dense construction because of high-rise buildings in the city centre. There is also no parking space in these buildings. So, there is a limited parking capacity in the city centre, and serious parking problems occur in the city centre throughout the day. On the other hand, there is ample land for constructing parking areas at the outskirts of Eskisehir. Hence, it has been understood that park and ride application is one of the most suitable solutions for the transportation problem in Eskisehir.

In this study, it is thought that treating the evaluation of three alternatives as a multi-criteria decision making problem is the correct approach in terms of producing a sustainable solution. Hence, considering different alternatives, it is aimed to examine these alternatives in the context of AHP. This AHP based approach was chosen because of its ability to deal with heterogeneous data types.

Conventional decision making processes often consider quantitative criteria whereas the multi-criteria approach involves both qualitative and quantitative criteria. The present problem of choosing alternative transport options for Eskisehir also presents a case where there is a need to use combination of qualitative and quantitative criteria for ranking the options. AHP is one such effective tool which can handle both types of criteria, and was developed by Saaty [9].

In AHP method, employing sensitivity analysis could be used to analyse how the priorities of alternatives change for the weights of different criteria. In evaluating alternatives, calculating the numerical data for all the criteria is often difficult. Consequently, AHP comes forward as a suitable method for these kinds of situations.

3. The AHP Application in Evaluation of Scenarios Prepared for Sustainable Transportation

AHP is the decision mechanism of a human being that is instinctively adopted by him or her when faced with the problem of decision-making [10]. AHP determines the set of criteria that will affect the complex and multi-purpose decisions given in real life and the relative importance of these criteria in these decisions, based on the evaluations of experts.

In this study, three different transportation scenarios for Eskisehir were considered, and evaluation of these scenarios with AHP method in terms of sustainable transportation was carried out by four experts.

3.1. Presentation of Eskisehir, Its Current Transportation Problems and Opportunities for Sustainable Transportation Application

Eskisehir is a medium-sized city which is located in the west of Turkey. The city's population is approximately 600,000 people, and is estimated to approach nearly 700,000 people in 2020.

In the city centre of Eskisehir, 34 parking lots have a capacity of 3575 parking spaces. Moreover, the number of private cars registered in the city centre is approximately 70,000. Due to the rapid increase in this number, it is seen that significant amounts of roadside parking cases occur. Because some roads were closed after the opening of the ESTRAM tramway system, the car drivers began to use the roads where the tramway does not pass by. The vehicles parking on these roads cause narrowing of them. In Eskisehir, people park their vehicles when they need and where they want. This habit and lack of adequate traffic control have caused the roads in city centres to become congested [11]. On some main streets in the city centre, it is possible to see two-lane roadside parking in each direction. Therefore, the necessity of taking measures in the context of sustainable transportation is emerging in order to solve these problems.

3.2. Alternative Scenarios

Alternative scenarios evaluated in this study include Protection of the Existing Situation, Introduction of Only Restrictive Factors and Implementation of Park and Ride Application.

3.2.1. The protection of the current situation

When the current situation in the city of Eskisehir is examined, it can be seen that the most important problem in transportation arises from the structure of the city. Because the city is a single-centre city, the huge traffic demands directed to the city centre arise.

The main problems in the city are the low capacities of urban roads, the difficulties encountered in the opening of new roads and the parking problems in the city centre. Since a number of measures cannot be taken due to the cost related reasons, it is clear that the problems are to increase further.

3.2.2. The introduction of only restrictive factors

In the context of sustainable transport, promoting the use of public transport and implementing a number of policies that reduce the entries of private cars into the city centre are required. As the applications carried out by developed countries are examined, it is seen that restricting the entries of cars into the city centre could be realized in three ways including physical restriction, restriction by means of parking lot policies and restriction by means of pricing policies.

3.2.3. The park and ride application

In a healthy functioning of the application, supporting the system with a number of policies that restrict the car entry to the city centre is of great importance. So, in this study, the expert opinions have been consulted, considering the park and ride application together with the restrictive policies.

3.3. AHP Hierarchy for Sustainable Transportation

After the alternative scenarios were determined, the criteria to be used in evaluation were established by the experts as 18 sub-criteria under the main criteria of Benefit, Cost, Opportunity and Risk. The AHP structure is given in Figure 1.

3.4. Generation of Pair-wise Comparison Matrices and Consistency Analysis

In order to determine the criteria and the priorities of alternatives, pair-wise comparisons need to be done. Since pair-wise comparisons made by individuals separately may cause instability in the pair-wise comparison matrices, the group was jointly asked to compromise on a single value in order to avoid this risk. These team members were gathered together, and it was ensured that they reached an agreement on a single degree of significance for each pair-wise comparison matrix.

The pair-wise comparison matrices as well as the criteria and the sub-criteria in AHP hierarchy were entered into the program “Expert Choice 11.5”, and the calculations were carried out with the support of this software. The compromise pair-wise matrix is displayed in Table 1.

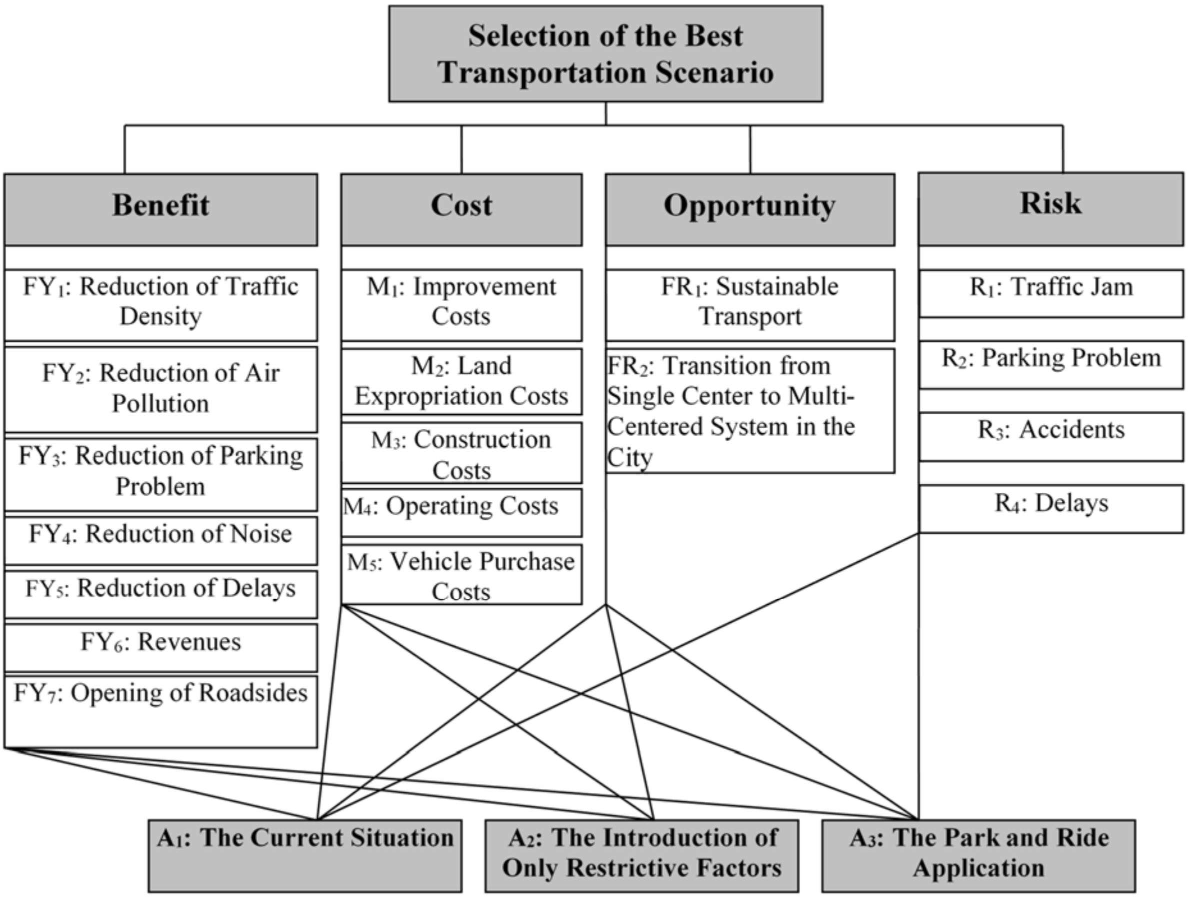

Figure 1. AHP hierarchy

Table 1. The pair-wise comparisons matrix for the main criteria.

	Benefit	Cost	Opportunity	Risk	Relative Importance Ratings
Benefit	1	2	1	2	0.333
Cost	1 / 2	1	1 / 2	1	0.167
Opportunity	1	2	1	2	0.333
Risk	1 / 2	1	1 / 2	1	0.167

Since the consistency ratio of the pair-wise comparisons matrix for the main criteria is equal to 0 and this value is smaller than 0.10, the matrix is consistent. The relative importance ratings of the main criteria are also indicated in Table 1. The most important main criteria have been identified as Benefit and Opportunity. In addition, the pair-wise comparisons for other sub-criteria were carried out. Instead of giving all of the pair-wise comparison matrices for 18 sub-criteria, the relative importance ratios of alternatives for the main and sub-criteria and the matrix consistency ratios are given. These are shown in Table 2.

Table 2. The relative importance ratios of alternatives for the sub-criteria of the main criterion of Benefit and the matrix consistency values.

Sub-criteria / Alternative	A_1	A_2	A_3	CR
FY_1	0.122	0.230	0.648	0
FY_2	0.163	0.297	0.540	0.01
FY_3	0.085	0.271	0.644	0.05
FY_4	0.136	0.238	0.625	0.02
FY_5	0.163	0.297	0.540	0.01
FY_6	0.109	0.309	0.582	0
FY_7	0.085	0.271	0.644	0.05

The relative importance ratios of the alternative scenarios in terms of the sub-criteria of the main criteria of Cost, Opportunity and Risk are given in Table 3, Table 4 and Table 5, respectively.

Table 3. The relative importance ratios of alternatives for the sub-criteria of the main criterion of Cost and the matrix consistency values.

Sub-criteria / Alternative	A_1	A_2	A_3	CR
M_1	0.571	0.286	0.143	0
M_2	0.429	0.429	0.143	0
M_3	0.571	0.286	0.143	0
M_4	0.540	0.297	0.163	0.01
M_5	0.637	0.258	0.105	0.04

Table 4. The relative importance ratios of alternatives for the sub-criteria of the main criterion of Opportunity and the matrix consistency values.

Sub-criteria / Alternative	A_1	A_2	A_3	CR
FR_1	0.095	0.250	0.655	0.02
FR_2	0.094	0.167	0.740	0.01

Table 5. The relative importance ratios of alternatives for the sub-criteria of the main criterion of Risk and the matrix consistency values.

Sub-criteria / Alternative	A_1	A_2	A_3	CR
R_1	0.109	0.309	0.582	0
R_2	0.085	0.271	0.644	0.05
R_3	0.143	0.286	0.571	0
R_4	0.163	0.297	0.540	0.01

The relative importance ratios of alternatives for the main criteria are given in Table 6. In addition, the relative importance ratios of sub-criteria have been calculated and shown in Table 7.

The overall relative priority values of alternatives were calculated as 0.195 in the case of Current Situation, as 0.268 in the case of Introduction of Only Restrictive Factors and as 0.537 in the case of Park and Ride Implementation, respectively. Thus, Park and Ride Implementation for sustainable transport seems to be a much more preferential alternative compared to other scenarios.

Table 6. The relative importance ratios of alternatives for the main criteria.

Sub-criteria / Alternative	A_1	A_2	A_3
Benefit	0.123	0.269	0.608
Cost	0.557	0.302	0.142
Opportunity	0.095	0.231	0.674
Risk	0.127	0.297	0.576

Table 7. The relative importance ratios of sub-criteria and the matrix consistency values.

Benefit	FY_1	FY_2	FY_3	FY_4	FY_5	FY_6	FY_7	CR
	0.254	0.071	0.157	0.089	0.185	0.087	0.157	0.02
Cost	M_1	M_2	M_3	M_4	M_5	CR		
	0.309	0.096	0.249	0.188	0.158	0.04		
Opportunity	FR_1	FR_2	CR					
	0.750	0.250	0					
Risk	R_1	R_2	R_3	R_4	CR			
	0.425	0.144	0.161	0.270	0.02			

3.5. *Sensitivity Analyses*

Because sustainable transport is the multiple criteria decision problem and based on personal judgments, it would be useful to perform the sensitivity analysis of the preference orders and relative importance ratios of the alternative scenarios with respect to the criteria weights.

According to the changes that may occur, the sensitivity of the preference order of alternative scenarios was analysed, depending on the different expert opinions. As a result of the sensitivity analysis, it has been determined that the “park and ride” application provides a clear superiority compared to other alternatives, as shown in Figure 2.

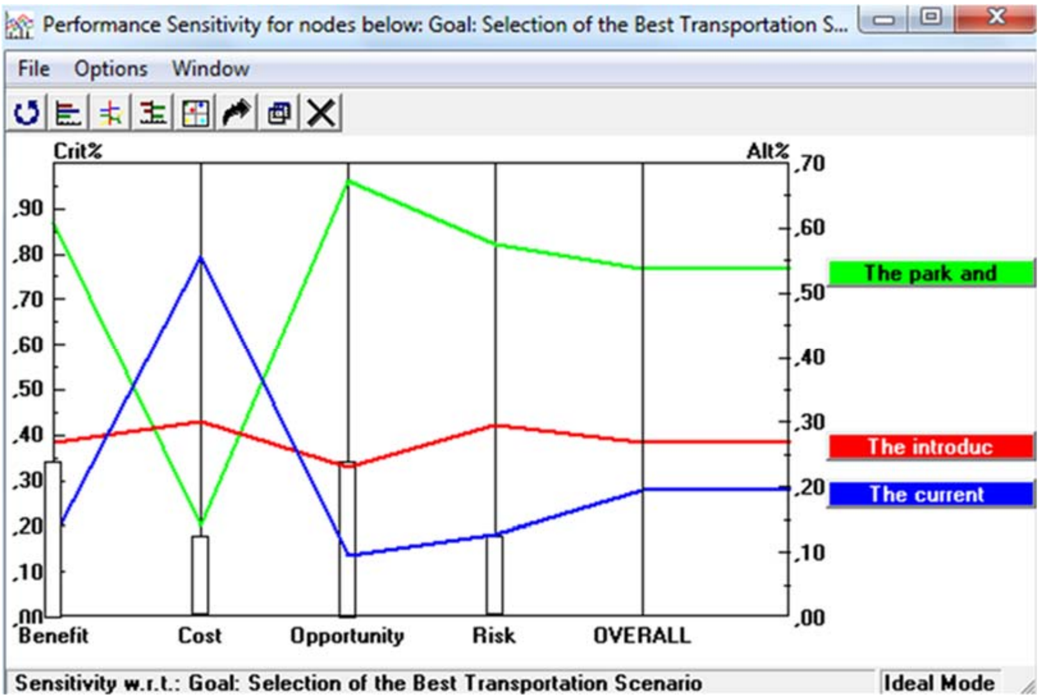

Figure 2. The relative importance ratios of alternatives according to the main factors [Benefit (0.333), Cost (0.167), Opportunity (0.333), Risk (0.167)]

IOP Conf. Series: Earth and Environmental Science **44** (2016) 052061 doi:10.1088/1755-1315/44/5/052061

4. Results and Discussions

In this study, the alternative scenarios for sustainable transportation were generated, and the multiple criteria evaluation of these scenarios was carried out, based on expert opinions. The Alternative Scenarios which are the Protection of the Current Situation, the Introduction of Only Restrictive Factors and the Park and Ride Application have been evaluated with the method of AHP. As a result, the overall relative priority values of alternatives were calculated as 0.195 in the case of the Protection of Current Situation, as 0.268 in the case of Introduction of Only Restrictive Factors and as 0.537 in the case of Park and Ride Application, respectively. According to these results, the contribution of "park and ride" application to the sustainable transportation has emerged. Within the scope of the study, the 18 criteria have been determined, and these 18 criteria have been grouped under the main criteria of Benefit, Cost, Opportunity and Risk. Alternative scenarios were evaluated for each criterion. Thus, the importance ratios of alternatives were calculated for every sub-criterion. The consistency ratios of comparison matrices were found to be within acceptable limits.

5. Conclusions

In this study, four expert opinions were used. According to the changes that may occur, the sensitivity of the preference order of alternative scenarios was analysed, depending on the different expert opinions. From this analysis, it has been determined that the "park and ride" application provides a clear superiority compared to the other alternatives.

References

[1] OECD. Transport and environment: synthesis of OECD work on environment and transport and survey of related OECD. Paris: IEA and ECMT Activities/Environment Directorate, Environment Policy Committee; 1999

[2] Black WR. Sustainable transportation: problems and solutions. New York: Guilford Press; 2010.

[3] Gudmundsson H, Höjer M. (1996). Sustainable development principles and their implications for transport. Ecological Economics 1996; 19 (3): 269-282

[4] Beinat E. Multi-criteria analysis for environmental management. *Journal of Multi-Criteria Decision Analysis* 2001; 10 (2): 51

[5] Sólnes J. Environmental quality indexing of large industrial development alternatives using AHP. Environmental Impact Assessment Review 2003; 23 (3): 283-303

[6] Yedla S, Shrestha RM. Multi-criteria approach for the selection of alternative options for environmentally sustainable transport system in Delhi. *Transportation Research* Part A 2003; 37: 717-729

[7] Yi SK, Sin HY, Heo E. Selecting sustainable renewable energy source for energy assistance to North Korea. *Renewable and Sustainable Energy Reviews* 2011; 15 (1): 554-563

[8] Omrani H, Awasthi A, Ion L, Trigano P. A hybrid approach for evaluating environmental impacts for urban transportation mode sharing. *Journal of Decision Systems* 2009; 18 (2): 185-201

[9] Saaty TL. The analytical hierarchy process. New York: McGraw-Hill Company; 1980

[10] Saaty TL. Decision-making with the AHP: why is the principal eigenvector necessary. European *Journal of Operational Research* 2003; 145 (1): 85-91

[11] Elker CH. Policy and practice in transport (in Turkish). Ankara: Gölge Offset Typography; 2002