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Prioritization of high-speed rail projects

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ABSTRACT

In recent years, intercity transportation has gained momentum towards high-speed rail in Turkey. Ankara-Konya, Ankara-Eskişehir and Istanbul lines were opened for high-speed transportation in this area. There are still high-speed train lines under construction. At the same time, there are also various high-speed rail projects that will be started soon and are in the designing process. However, these projects require a big budget. Because of this, it is not possible to carry out all the projects and some projects are carried out gradually. In this study, prioritization of the high-speed rail projects was done by using the analytical hierarchy process (AHP). As a result of prioritization made through criteria determined by literature review and expert opinion, evaluations are made.

1. Introduction

In the travel route between cities, serious efforts are being made to reduce the travel time and to provide a fast, comfortable and safe transportation. Therefore, in order to increase the share of railway in transportation, high speed rail (HSR) and rapid train investments have been accelerated in our country.

Significant investments in the railway sector have been made in Turkey in recent years. Among these investments, high-speed rail investments are the most noteworthy. In our country, passenger transportation with HSR was started in 2009 and it is currently maintained by the Turkish State Railways (TCDD) on HSR lines between Ankara-Istanbul, Ankara-Eskisehir, Ankara-Konya and Eskisehir-Konya routes. Among the objectives of TCDD, increasing HSR lines and expanding the passenger transportation with HSR have an important place. In addition to the completed lines, HSR investments are continuing on different lines centered to Ankara. It is necessary that both the railway and the vehicles of the HSR which provide the possibility of travel at high speeds should be suitable for these speeds.

With the construction of a new railway line, the construction of signaling and electrification systems, security measures and vehicles having high speed capability, HSR investments have an important start-up cost.

HSR is built on a straight route as far as possible. Although this corresponds to a shorter line length between the two settlement areas compared to the conventional railway, the construction of tunnels, bridges and viaducts built in the construction of these lines increases the costs of construction [1]. Therefore, these projects require a large budget. Because of this, it is not possible to carry out all the projects and some projects are carried out gradually.

There are various reasons for the acceptance and widespread use of high-speed rails. These trains are preferred especially among cities with dense population due to their high speeds and transportation capacity [2].

In addition to this, the most important advantages of HSR are time saving in travel process, its contribution to regional development, being more economical compared to air transport and presenting safer transportation alternative compared to land vehicles.

Today, developed countries focus on fast, convenient, economical, safe and environmentally friendly transportation systems and aim to take the best solution on the basis. High-speed railways, as a system that can provide the most appropriate solution to the desired features, rapidly take their place among transportation modes and increase their share in all transportation modes [3]. Achieving all investments at the same time requires prioritization among projects, sorting between projects or execution of decision mechanisms for selecting process. With their analytical processes, multi-

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criteria decision methods, which are frequently used in decision making processes, provide easy and effective results. AHP, analytic network process (ANP), TOPSIS, VIKOR, Promethee are some of these decision processes.

These methods, which are frequently used in transportation problems, also reveal the experience of the experts around the criteria determined for decision makers and the evaluation process according to the given data.

There are some studies on this area in the literature. Ahern and Anandarajah [4] have developed a model for prioritizing rail system investment projects. Taking in consideration the financial, economic, social, environmental and traffic impacts and benefits of the projects, Tsamboulas [5] has developed a model for prioritizing transport projects. Longo et al. [6] have developed the AHP and ANP models and compared their main characteristics. They have also carried out a real selection work for a new guided system connection.

Wey and Wu [7] have proposed a mixed application of Delphi, ANP and goal programming for the selection of transportation infrastructure projects. By using ANP in prioritization of rail-system infrastructure investment projects, Macura et al. [8] have made prioritization on the benefit-cost ratio, travel time, line capacity utilization, traffic volume, and international agreement harmonization criteria among 5 alternative projects.

Saat and Aguilar Serrano [9] have applied a multi-criteria implication in choosing high-speed train routes. They used the cost, potential user and gross domestic product criteria in the evaluation process.

By using a multi-criteria approach, for the high-speed train route, Sperry et al. [10] have made evaluation taking in to account the main criteria of cost, population, environmental impacts and demand.

Hamurcu and Eren [11], established a goal programming model for urban rail transport project by using AHP and ANP with four main criteria. Rail systems projects selection were made. In their another study [12], they conducted project selection among metro, monorail, tramway and light rail systems by using AHP-GP mathematical model for urban transport.

Project selection is one of the difficult decision-making processes of transportation planners and it needs multi-criteria evaluation process.

There are some studies in the literature about project selection; selection of monorail projects [13-16]; determination of line type [17]; selection of transportation projects [16-20]; technology selection [21,22], route selection [23,25].

2. Analytic Hierarchy Process Method

Various techniques are applied to conduct a multi-criteria decision making process. In the literature, there are some academic studies on multi-criteria decision-making methods, such as strategy selection with ANP and Promethee [26], selection of third-party logistics (3PL) company in an online shopping site with AHP-TOPSIS [27], analysis of television news using AHP-TOPSIS-Promethee [28], personnel selection by using AHP-Promethee [29], supplier selection with ANP-GP [30], conference selection [31]; journal selection with ANP [32], stock control [33], AHP and TOPSIS for maintenance strategy selection[34], selection of high speed rail station location with AHP [35] and transport planning [36-39].

The AHP method, suggested by Saaty, has begun to be used in decision-making problems in various areas. This method is a decision making approach that shows the distribution of the percentages of the criteria and alternatives affecting the decision in the decision matrix created for a problem [40].

After determining the decision problem, the general steps of the AHP method are as follows:

i) Establishment of a hierarchical structure: By introducing a hierarchical structure of the decision maker, the objective is to offer an opportunity for an effective comparison of the criteria and alternatives by placing the criteria and alternatives at the lowest level. The decision problem is fully explained at this stage.

ii) Pairwise comparison matrix and relative importance weight values: In this step, relative importance weight values of the criteria are given, and a paired comparison matrix is formed.

The pairwise comparison values of the criteria are based on the evaluators' knowledge, experience and expertise, or evaluations obtained by the survey study. The values of the criteria in the pairwise comparison matrix is based on the 1-9 scale in Table 1 [41].

Table 1. The 1-9 scale used in the pairwise comparison method

Numbers	Value
1	Equal
3	Moderately more impontant
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2, 4, 6, 8	İntermediate values

Eigenvector value and consistency ratio: Between criteria and for each crierion, equation (1) is used in the calculation of the eigenvector value (wi) of the criteria in the pairwise comparison matrix of the alternatives.

$$w_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{j=1}^{n} a_{ij}} \quad \text{..} (1)$$

After finding the eigenvector value of the criteria, consistency ratio, consistency indicator and eigenvalue are calculated. The Consistency Rate (CR) is a measure of the consistency between the values given at the time of the pairwise comparison. The consistency ratio should be less than 0.10. The consistency rate is calculated by using Equation (2).

$$CR = \frac{CI}{RI} \quad (2)$$

Equation (3) is used to calculate the Consistency Index (CI).

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (3)$$

In order to calculate the value of consistency indicator; the maximum eigenvalue (λmax) must be found by using Equation (4).

$$\lambda_{max} = \frac{1}{n}\sum_{i=1}^{n}\frac{(aw)_i}{w} \quad (4)$$

The Random Index (RI) values (stochastic indicators) in Eq. (2) are shown in Table 2.

Table 2: Randomness index

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0,58	0,90	1,12	1,24	1,32	1,41	1,45	1,49

iii) Finding the importance weights and ranking the alternatives: These operations for the criteria are the same in the evaluation of the alternatives. The decision alternative weights obtained by matrix multiplication of the criterial weights and weights of the alternatives found for each criterion are sorted from small to large.

3. Prioritization of High-Speed Rail Projects

The information about ongoing, planned, and projected High-speed and high-speed rail project were taken from the TCDD website [42].

Ankara - İzmir High Speed Rail Project (Under Construction) (A1): This is a project that will connect İzmir, the third biggest city of our country with its industry, tourism potential and port, to Ankara. The construction of the High Speed Railway Project, which will also take Manisa, Uşak and Afyonkarahisar on the route to Ankara, is ongoing. When the project is completed, the travel time between İzmir and Ankara will decrease from 14 hours to 3 hours and 30 minutes. The infrastructure construction of the Polatlı-Afyonkarahisar section of the Ankara-İzmir HSR project is ongoing and 40% physical progress has been achieved. This line is planned to be completed in 2019. This route is shown in Fig 1.

Figure 1. Ankara - İzmir High Speed Rail Project

Ankara - Sivas High Speed Rail Project (Under Construction) (A2):The construction of the Ankara-Sivas High-Speed Rail, one of the most important axes of the railway corridor that links Asia Minor and Asian countries on the Silkroad, continues.

The high-speed rail line will be connected with Sivas-Erzincan, Erzincan-Erzurum-Kars and Baku-Tbilisi-Kars railway project. The existing Ankara-Sivas railway is 603 km and the travel time is 12 hours. With this project, which will shorten the travel time between the two cities, constructing a new high speed railway having double line, electric, signal, and suitable for a maximum speed of 250 km / h was targeted. When the project is completed, the travel time will be reduced from 12 hours to 2 hours. The HSR project will reduce the distance between Ankara and Sivas to 405 km; the ongoing infrastructure construction works on all line segments is at 75 percent level. The project is planned to be completed by the end of 2018. This line route is shown in Figure 2.

Figure 2. Ankara – Sivas High Speed Rail Project

Yerköy-Kayseri High Speed Rail Project (in the planning stage) (A3): This line will be made as double line in connection with Ankara-Sivas HSR line. It will also have electric, signaling, and capability of speeding 250 km / h between Yerköy-Şeffaatli-Kayseri, which is 142 km long.

Karaman-Ereğli-Ulukişla-Yenice Rapid Rail Project (At the projecting stage) (A4): Infrastructural and signaling constructions, project preparation works for electrification and Ulukışla-Yenice project preparation works are continuing.

Eskisehir-Antalya / Antalya-Kayseri Rapid Railway Project (At the projecting stage) (A5): For Antalya-Burdur / Isparta-Afyonkarahisar-Kütahya-Eskişehir and Antalya-Konya-Aksaray-Nevşehir-Kayseri high speed train projects, the final project preparation works are underway. It is evaluated that together with the existing HSR lines already operating, the development of conventional lines in terms of speed, security, electricity and signal, and giving importance on the conversion of single lines to double lines will be beneficial in terms of the future of the railway.

Enhancing and development of conventional lines is less costly than the construction of new HSR lines and is preferred instead of building new lines. When we look at the examples in the world, it is evaluated that in order for HSR, which have high construction and maintenance costs, to be economic, the occupancy rates shold be close to full capacity. The fact that the number of train services is as high as possible is also important in terms of the number of passengers carried. Twelve criteria have been identified in the study to evaluate alternative projects. These criteria are shown in Table 3.The hierarchy process, goals, criteria and alternatives are shown in Figure 3.

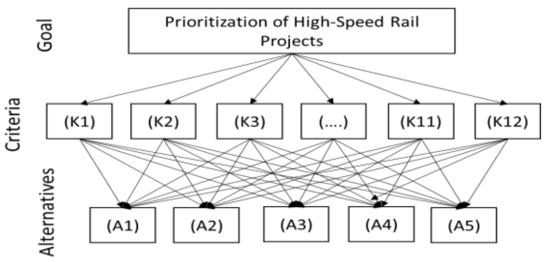

Figure 3. Decision hierarchy

Table 3. Determinated criteria

No	Criteria	Symbolic representation
1	Demand level	K1
2	Cost	K2
3	Travel time	K3
4	Speed	K4
5	Population ratio	K5
6	Regional development	K6
7	Integration	K7
8	Environmental impact	K8
9	Constraction cost	K9
10	Operating cost	K10
11	Transport efficiency	K11
12	Safety	K12

In this process, firstly each criterion is evaluated by paired comparisons among themselves and then alternatives for each criterion are evaluated by paired comparisons between each other. Table 4 and Table 5 show symbolic representations. As a result of the evaluations, the criterion weights are shown in Table 6 were found.

Table 4. Comparision of criteria

Criteria	K1	K2	…..	K11	K12
K1	1	…	…	…	…
K2	…	1	…	…	…
…	…	…	…	…	…
K11	…	…	…	1	…
K12	…	…	…	…	1

Table 5. Comparision of Alternatives

Criteria	A1	A2	A3	A4	A5
A1	1	3	3	5	3
A2	1/3	1	…	…	…
A3	1/3	…	1	…	…
A4	1/5	…	…	1	…
A5	1/3	…	…	…	1

Table 6: The important weights of critaira

No	Criteria	Weights
K1	Demand level	0,1177
K2	Cost	0,0129
K3	Travel time	0,0402
K4	Speed	0,0533
K5	Population ratio	0,0461
K6	Regional development	0,1203
K7	Integration	0,0402
K8	Environmental impact	0,1098
K9	Constraction cost	0,0637
K10	Operating cost	0,0425
K11	Transport efficiency	0,1000
K12	Safety	0,2533

The importance weights of the alternatives compared under each criterion are shown in Table 7.

Table 7: The importance weights and ranking of the projects

Alternatives	The importance weights	Ranking
A1	0,27730	1
A2	0,26087	2
A3	0,16638	4
A4	0,12198	5
A5	0,17335	3

As a result of the evaluations, the criterion weights shown in Table 7. were found. Final ranking are first Ankara-İzmir high speed rail project, second Ankara-Sivas high speed rail project and respectively Eskişehir-Antalya/Antalya-Kayseri rapid rail, Yerköy-Kayseri high speed rail project and Karaman-Ereğli-Ulukişla-Yenice rapid rail project. The Ankara-Sivas and Ankara-İzmir high speed rail lines are under construction. Hence, the result of this study is consistant.

4. Conclusions

In this study, 5 alternative high speed rail and rapid rail projects under 12 criteria were prioritized. As a result of the selection, priority was placed on the selection of ongoing lines, and a network which can be used as a basis for integration is created.These lines are the newly constructed high-speed train lines. As it is understood from this study, the use of analytical methods in the decision making process presents effective results for decision makers. The efficiency of the rail systems built for intercity transportation, especially ensuring the availability of the line has precedence. Therefore, it is necessary to evaluate it by taking into consideration of various factors.

As in this study, the use of multi-criteria decision-making methods in almost every decision point of transportation, will lead to more consistent decision-making processes and results for managers. At the same time, besides the various decision making methods, by the fuzzy evaluation scales that may be included in the process, more appropriate decisions can be taken through offering modeling opportunities which are close to the real life.

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