Sigma J Eng & Nat Sci 9 (4), 2018, 415-426

Publications Prepared for Transist 2017,
10th International İstanbul Transport Congress

Research Article

A FUZZY ANALYTICAL NETWORK PROCESS APPROACH TO THE SELECTION OF THE RAIL SYSTEM PROJECTS

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Received: 08.10.2018 Revised: 20.11.2018 Accepted: 21.12.2018

ABSTRACT

Increased population density and private vehicle usage have led to traffic problems in the metropolitan city of Istanbul. At this point, Istanbul Metropolitan Municipality is trying to improve the urban transportation with the presented projects. The aim of this paper is to encourage public transportation. For this particular purpose, projects are being offered in this field. For example, rail system investment is one of the important projects, including many transportation projects. Since the rail system investments require large amount of budget, it is not practical among all planned projects. Therefore, the projects should be selected by prioritizing. In this study, the project evaluation criteria were determined, and in this respect, the rail system projects were prioritized by using the fuzzy analytical network process (ANP) which is one of the multi-criteria decision-making methods and offers good solutions in difficult decision-making processes.
Keywords: Fuzzy analytical network process, prioritizing, rail system projects.

1. INTRODUCTION

Factors such as the increase in daily travel within the city, the increase in travel generating centers, developing cities and increasing population have led to the increase in the use of private vehicles. All these conditions have increased the time spent in traffic in urban areas and revealed the urban transportation problem. The planners give great importance to the solution of the urban transportation problem and the administrations allocate large budgets to this field.

By putting forward various projects, it is tried to improve the quality of life and create a more livable city. İt is seen that convenient, comfortable, fast and secure transportation types are needed to respond to increased travel demands and to direct people from private vehicles to public transportation. In this context, the types of urban transportation which come to the prominence by being separated from the alternatives in terms of capacity and security are rail systems. Metros that run both under and over the ground, monorails raised from the ground with columns that provide transportation along its own line route, light rail systems with special rail paths and tramways are widely used in urban transportation.

With its short-medium-long-term targets on rail systems, Istanbul has been putting forward many projects with the idea of increasing its rail network, which is approximately 150 km, to 1,000 km. Figure 1 shows the current rail system network in Istanbul and the planned rail system

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Network [1]. With the projects in progress, in project design processes and in tender stage, it is taking important steps in realizing this goal. At the same time, Istanbul is becoming popular and the focus of attention with its huge projects that are related to the country's economy and serve as an example for the metropolises of the world. However, due to limited potentials, it is not possible to put into practice all projects. In particular, limited budget, labor, material and equipment requirements restrict activities. In this case, it is necessary to carry out the projects in a certain order. However, by considering the transportation needs, by evaluating the demands, by considering the main transportation plan, and by sorting the various factors under one roof, making ranking will provide prioritization of the projects that can provide the most improvement in urban traffic.

In the process of making transportation planning decisions, the use of multi-criteria decision-making methods, which are analytical methods, is important in terms of consistency and impartiality of decisions. At the same time, the fact that they involve easy digital processes has led to the frequent use of these methods by decision makers. Evaluation of the factors according to the criterion of fussy has also added sensitivity to the study.

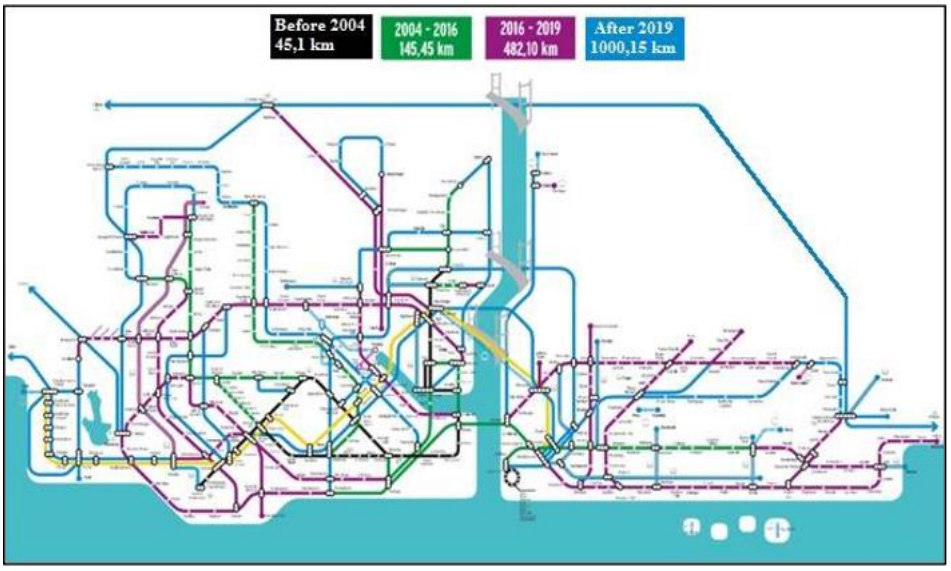

Figure 1. The Current Rail System Network of Istanbul and the Planned Rail System Network

In the second part of this study, where rail systems have been prioritized for Istanbul, project selection has been given. In the third part, the fuzzy ANP (Analytic Network Process) which was used in the evaluation, in the fourth part, the application and its processes, and in the fifth part, results and evaluations are presented.

2. PROJECT SELECTION

This type of problem, which is encountered in the form of sorting, prioritizing or selection of specific projects, is frequently used in various areas. In particular, transportation investments, which are realized by allocating large budgets, need to be considered and evaluated versatile by taking into account various factors. Project selection is one of the difficult decision processes of managers and transportation planners in urban transportation. By making the most appropriate decisions, resource utilization efficiency will be achieved. Various projects are introduced in

many areas of transportation, and mult i-criteria evaluations are carried out in various decision-making processes. When the literature is examined, it is seen that there are various studies on the issue of project selection in urban transportation. While Kosijer et al. focused on the best railway route [2], Mohajeri and Amin studied on the selection of station location for the rail systems [3] and Gerçek et al. conducted study to determine the best rail transport network [4]. In their studies, Banai evaluated the light rail transport corridor and alternative routes [5], Macura et al. focused on prioritization of railway infrastructure investment projects [6], Abastante and Lami evaluated the strategies of transportation and infrastructure [7], Hamurcu and Eren [8-10] , Hamurcu and Eren [11] studied on the selection of the monorail projects in Ankara. In other studies, Kalamaras et al. [12], Piantanakulchai and Saengkhao [13], Piantanakulchai [14], Effat and Hassan [15] interested in highway route, Zhongzhen and Hayashi [16] studied on rail system route, Yao [17], Farkas [18], Brunner et al. [19] focused on the public transportation route, and Kim et al. [20] conducted study on planning of the high-speed rail route.

Regarding project selection, in the literature, there are also studies related to the selection of monorail projects [21], the selection of transportation projects [22], the selection of rail projects [23, 24], monorail route selection [25], the selection of investment projects [26], the selection of technology [27,28], and the selection of urban transportation projects [29]. At the same time, constraint programming for projects selection [30]; evaluation of route efficiency with AHP [31]; selection of tramway alternatives using AHP/FAHP [32]; project selection by using FAHP-VIKOR for urban transport [33] are in the literature. Besides, there are some studies such as prioritization of high-speed rail projects [34]; transportation planning with AHP-HP [35]; selection of electric vehicle by using ANP-TOPSIS [36], AHP-TOPSIS [37] and AHP-TOPSIS-HP [38]; group decision making with fuzzy TOPSIS [39]; metro projects selection with AHP-HP [40].

3. FUZZY ANP

In the ANP method, decision-makers consider the relations of the evaluation criteria with each other when evaluating a set of possible alternatives. This method used in decision making with the established network structure is based on pairwise comparison as in Analytical Hierarchy Process (AHP). In addition, due to uncertainty during the comparisons of decision-makers, the pairwise comparisons in the process are insufficient to reflect the real opinions of decision-makers. In the case of pairwise comparisons, uncertainty in the decision process has been tried to eliminate based on fuzzy numbers. In Table 1, some of the studies carried out with fuzzy ANP are shown. For the detailed explanation of the method, these studies can be looked at.

Table 1. Studies Conducted by Using Fuzzy ANP

Nu.	Authors	Year	Purpose of the study
1	Wang et al. [41]	2018	Solid waste to energy plant location selection
2	Hamal et al [42]	2018	Selection of optimal renewable energy investment project
3	Uslu et al. [43]	2018	Selection of Industry 4.0 strategy
4	RazaviToosi and Samani [44]	2016	Water Resources Management
5	Wang et al. [45]	2015	Evaluation of maneuver capability
6	Demirta et al. [46]	2014	Technology selection
7	Kumru and Humru [47]	2014	Machine selection
8	Isalou et al. [48]	2013	Selection of landfill site
9	Moalagh and Ravasan [49]	2013	Evaluation of ERP post-implementation success
10	Pang and Bai [50]	2013	Supplier selection
11	Demirel et al. [51]	2012	Evaluation of strategy
12	Raei and Jahromi [52]	2012	Portfolio optimization
13	He et al. [53]	2012	Analyzing influencing factors
14	Kang et al. [54]	2012	Supplier selection
15	Macura et al. [55]	2011	Selection of rail system projects
16	Vinodh et al. [56]	2011	Supplier selection
17	Yüksel and Dağdeviren [57]	2010	Balanced scorecard
18	Wu et al. [58]	2009	Location selection
19	Dağdeviren et al. [59]	2008	Work system process
20	Tseng et al. [60]	2008	Use of it in production process
21	Hemmati et al. [61]	2008	Maintenance policy selection
22	Mohanty et al. [62]	2005	Project selection
23	Mikhailov and Singh [63]	2003	Use of it with decision support systems

General steps of the Fuzzy Analytical Network Process:

1st step: creation of the network structure and revealing the relationships and feedback between all criteria and alternatives

2nd step: creation of pairwise matrices of all the associated classes. Comparisons are made based on the scale given in Table 4. Fuzzy numbers are used in pairwise comparisons.

3rd step: By applying clarification process, the weighted super matrix and limit super matrix are obtained. For each alternative, a priority weight is obtained from this limit super matrix and the alternative with the biggest priority weight is determined as the best alternative.

4. APPLICATION

In this study, prioritization study was carried out for the ten-rail system line planned to construct in Istanbul. The processes of these projects (the tender stage, the project design stage and the construction stage) are still in progress. Various rail transportation systems have been evaluated and the information about the projects is shown in Table 2.

Various criteria are used in the selection of transportation projects. These criteria are based on some major topics such as economic, technical, environmental, security, social and land use [64]. In this study, around 4 criteria, with 15 sub-criteria, 10 rail system projects were weighted, and importance levels were found. The used criteria and their explanations are shown in Table 3.

When determining criteria, it should be appropriate for some purposes such as selection of projects in line with the organization's objectives and transportation plan, creating an integrated transportation system by providing transportation integration, prioritization of projects that can provide the most benefit with low costs, and prioritization of projects that have the basis and quality to meet the transportation demands that may arise with the expansion and development of

the city. Otherwise, the desired efficiency will not be gotten from the projects and it will inevitably be wasted as dead investments.

Table 2. Rail System Projects

Symbolic Representation	Project Route	Type	Length (km)	Number of Wagons	Cost (Million US$)		
					Construct+ M&E	Wagon Cost	Total
P_1	AAA	Light Rail Sys.	7.5	45	325.5	76.5	429
P_2	BBB	Monorail 2	7.7	33.2	92.4	56.4	149
P_3	CCC	Metro 1	12.5	67	800	113.9	914
P_4	ÇÇÇ	Monorail 1	8.6	33.9	103.2	57.6	161
P_5	DDD	Metro 2	12.2	61.9	780.8	105.3	886
P_6	EEE	Metro 1	24	107.6	1,536	183	1,719
P_7	FFF	Monorail 2	3.5	46.3	42	78.7	121
P_8	GGG	Metro 2	21.5	117.4	1376	199.6	1,576
P_9	HHH	Tramway	2	48.2	128	81.9	21
P_10	KKK	Tramway	11.6	85.8	42.4	145.8	888

Figure 2 shows the created ANP network structure. In the network structure, the relationship between the criteria and the alternatives is included.

The scale in which FAHP (Fuzzy Analytic Hierarchy Process) was used according to the Chang method is shown in Table 4. Table 5 shows pairwise comparisons of criteria in among the each other, is by using from fuzzy numbers.

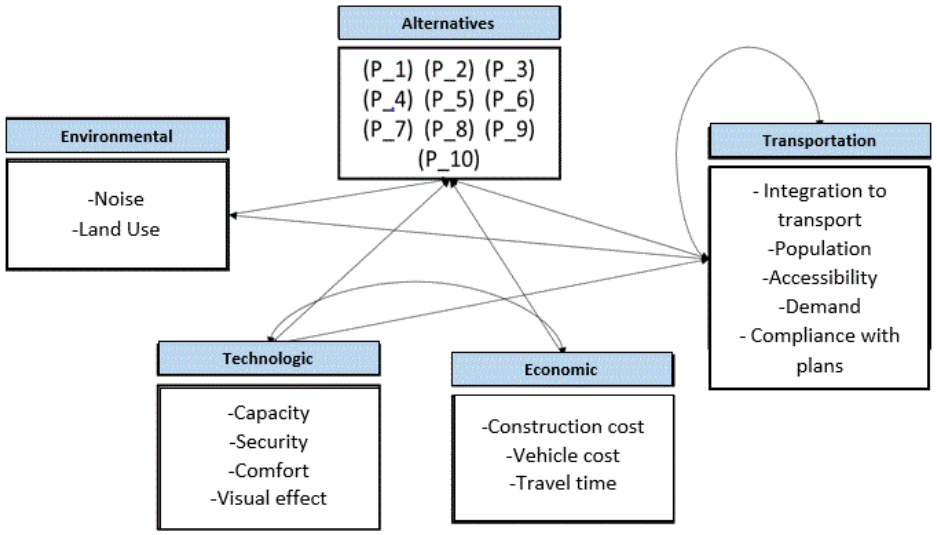

Figure 2. Network Structure of the Problem

Table 3. Criteria and Their Explanations

Nu.	Criteria	Explanation	Explanation
1	Technologic	Capacity	Passenger carrying capacity
2		Security	Safety of the line and the type of transport
3		Comfort	Comfort of transportation type
4		Visual effect	Visual adaptation of the project to the place to be established
5	Environmental	Noise	The sound of the transportation type spreading to the environment
6		Land use	The area for the project to be established
7	Economic	Construction cost	The construction cost of the project
8		Vehicle cost	Cost of the vehicles to be purchased
9		Operating cost	Operating cost of the line
10		Travel time	Travel time to spend along the line
11	Transportation	Integration to transport	Its integration with other public transport systems
12		Population	The population of the region in which the system will be established
13		Accessibility	Ease of access to the line
14		Travel Demand	The fact that the demand for travel along the line can create a daily journey.
15		Compliance with plans	Compliance with city expansion policy and possible future plans

Table 4. The Scale Used in Fuzzy ANP According to Chang Method

Verbal Importance	Fuzzy Scale	Corresponding Scale
Equal importance	$\tilde{1}$	$\widetilde{1/1}$
A little more important	$\tilde{3}$	$\widetilde{1/3}$
Strongly important	$\tilde{5}$	$\widetilde{1/5}$
Extremely important	$\tilde{7}$	$\widetilde{1/7}$
Completely important	$\tilde{9}$	$\tilde{1}/9$

Table 5. Fuzzy Comparison Matrix of the Relationship of Transportation Integration Criterion

Criteria	Population	Accessibility	Travel Demand	Compliance with Plans
Population	$\tilde{1}$	$\tilde{5}$	$\widetilde{1/3}$	$\widetilde{1/3}$
Accessibility	$\widetilde{1/3}$	$\tilde{1}$	$\widetilde{1/5}$	$\widetilde{1/3}$
Travel Demand	$\tilde{3}$	$\tilde{5}$	$\tilde{1}$	$\tilde{3}$
Compliance with Plans	$\tilde{3}$	$\tilde{3}$	$\widetilde{1/3}$	$\tilde{1}$

The criterion weights obtained by converting the fuzzy numbers of the criteria to the real numbers according to the Kwong-Bai method are population, accessibility and compliance with plans, respectively (W=0.25828, 0.63699, 0.10473). These values are entered as criterion weights in “Super Decisions” program and show in fig 3.

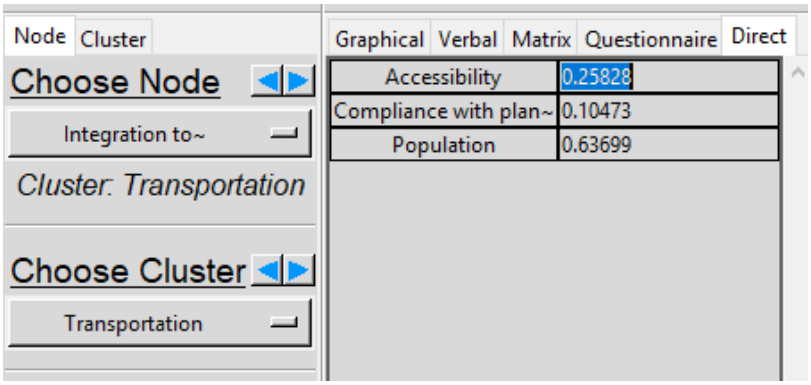

Figure 3. Entrance of the Founded Values to the "Super Decisions" Program

Evaluation of the alternatives under criteria by using fuzzy numbers shown in Table 6, are made for every relationship. Then founded these values are used for "Super Decisions" program.

Table 6. Evaluation of the Alternatives under Criteria by Using Fuzzy Numbers

Alt.	P_1	P_2	P_3	P_4	P_5	P_6	P_7	P_8	P_9	P_10
P_1	$\tilde{1}$	$\tilde{3}$	$\tilde{5}$	$\tilde{3}$	$\tilde{3}$	$\tilde{1}$	$\tilde{1}$	$\tilde{3}$	$\tilde{1}$	$\tilde{5}$
P_2	…	$\tilde{1}$	…	….	…	….	…	…	…	…
P_3	…	…	$\tilde{1}$	….	…	….	…	…	…	…
P_4	…	…	….	$\tilde{1}$	…	….	…	…	…	…
P_5	…	….	…	…	$\tilde{1}$	….	…	…	…	…
P_6	…	….	…	…	…	$\tilde{1}$	…	…	…	…
P_7	…	…	….	…	…	…	$\tilde{1}$	…	…	…
P_8	…	….	…	….	…	…	…	$\tilde{1}$	…	…
P_9	…	…	….	…	…	…	…	…	$\tilde{1}$	…
P_10	…	….	…	….	…	….	…	…	…	$\tilde{1}$

Fuzzy numbers founded by applying these processes for each associated criterion and alternatives are converted to real numbers and entered into Super Decisions program. As a result of all these processes, the importance levels of alternatives and their ranking are shown in Table 7.

In the ranking occurring as a result of the evaluations made, P_6 metro project was the 1st, P_8 metro project was the second and P_9 tramway project was the 3rd. The order of the other projects was P_1, P_4, P_3, P_7, P_5, P_10, and P_2. Especially environmental factors and the impact of capacity, cost, security and demand constraints on the outcome played a major role in this ranking.

Table 7. Evaluation Result and Ranking of the Projects

Projects	Importance weights	Ranking
P_1	0.123203	4
P_2	0.020668	10
P_3	0.073712	6
P_4	0.091253	5
P_5	0.064411	8
P_6	0.216998	1
P_7	0.026198	7
P_8	0.201001	2
P_9	0.124201	3
P_10	0.058355	9

5. CONCLUSION AND EVALUATION

In this study, for the selection of the rail system projects, the fuzzy ANP was used. Fuzziness allows us to better express the verbal expressions numerically. As a result of the study, the best three projects were realized as one monorail project and two metro projects.

With various projects, Istanbul is trying to improve traffic in order to overcome the urban transportation problem. The reasons such as increasing of the time spent in traffic, high number of stop-and-go in urban traffic and stopping of the traffic due to the possible malfunction have led managers to rail system projects which are faster, more comfortable, higher capacity. Istanbul is trying to increase its urban life level and quality by improving traffic with rail system projects. In this context, various projects are put into practice, planned and considered for the coming years. Due to scarce resources, it is not possible to implement all these projects at the same time. Therefore, prioritizing, ranking or selection processes with various evaluation criteria are required. There are various evaluation methods; however, as in this study, multi-criteria decision-making methods provide effective results for these decision processes. In addition, in order to get results closer to the real life, fuzzy methods are used in conjunction with multi-criteria decision-making methods. As a result of this study, the urban rail system projects were prioritized by fuzzy ANP and the best alternatives were ranked.

For future studies, best rankings can be achieved by using ranking methods such as TOPSIS (Technique for Order Preference by Similarity to Ideal Solution) or VIKOR (Vise Kriterijumska Optimizacija I Kompromisno Resenje) together with ANP. Moreover, models can be created only by using fuzzy logic. Benefit-cost analysis is an important part of the project selection process. This study can be expanded by highlighting the cost factor a little more, and resource constrains, and mathematical models can be revealed by taking into account all cost items.

REFERENCES

[1] https://www.ibb.istanbul/ (Erişim traihi: 18.09.2017)

[2] Kosijer M., Ivic M., Markovic M., Belosevic I., (2012) Multicriteria decision-making in railway route planning and design, *Gradevinar*, 64(3), 195-205.

[3] Mohajeri N., Amin G.R., (2010) Railway station site selection using analytical hierarchy process and data, *Computers & Industrial Engineering*, 59(1), 107-114.

[4] Gerçek H., Karpak B., Kılınçaslan T., (2004) A multiple criteria approach for the

evaluation of the rail transit networks in Istanbul, *Transportation*, 31(2), 203-228.

[5] Banai R., (2006) Public transportation decision-making: A case analysis of the Memphis Light Rail Corridor and route selection with Analytic Hierarchy Process, *Journal of Public Transportation*, 9(2), 1.

[6] Macura D., Boškovic B., Bojovic N., Milenkovic M., (2011) A model for prioritization of rail infrastructure projects using ANP, *Rivista Internazionale di Economia dei Trasporti*, 38(3), 285.

[7] Abastante F., Lami I.M., (2012) A complex analytic network process (ANP) network for analyzing Corridor24 alternative development strategies, *In Communications, Computing and Control Applications (CCCA), 2012 2nd International Conference on (pp. 1-8). IEEE.*

[8] Hamurcu M., Eren T., (2015) Ankara Büyükşehir Belediyesi'nde çok ölçütlü karar verme yöntemi ile monoray güzergâh seçimi, *Transist 8. Uluslararası Ulaşım Teknolojileri Sempozyumu ve Fuarı, s 410-419, 17-19 Aralık 2015, TRANSİST,* İstanbul, Türkiye.

[9] Hamurcu, M., Eren, T., 2016, "Using ANP- TOPSIS methods for route selection of monorail in Ankara", 28th European Conference on Operational Research, Poznan, Polland, July 3-6.

[10] Hamurcu M., Gür Ş., Özder E.H., Eren T., (2016) A multicriteria decision making for monorail projects with analytic network process and 0-1 goal programming, *International Journal Of Advances In Electronics And Computer Science (IJAECS)*, 3(7):8-12.

[11] Hamurcu M., Eren T., (2016) A multicriteria decision-making for monorail route selection in Ankara, *International Journal of Industrial Electronics and Electrical Engineering*, 4 (5), 121-125.

[12] Kalamaras G.S., Brino L., Carrieri G., Pline C., Grasso P., (2000) Application of multicriteria analysis to select the best highway alignment, *Tunnelling and Underground Space Technology*, 15(4): 415-420.

[13] Piantanakulchai M., Saengkhao N., (2003) Evaluation of alternatives ın transportation planning using multistakeholders multi-objectives ahp modeling, *In Proceedings of the Eastern Asia Society for transportation studies*, 4:1613-1628.

[14] Piantanakulchai M., (2005) Analytic network process model for highway corridor planning, *Proceedings Of ISAHP*.

[15] Effat H. A., Hassan O.A., (2013) Designing and evaluation of three alternatives highway routes using the analytical hierarchy process and the least-cost path analysis, application ın Sinai Peninsula, Egypt, *The Egyptian Journal of Remote Sensing and Space Science*, 16(2): 141-151.

[16] Zhongzhen Y., Hayashi Y., (2002) GIS-based analysis of railway's origin/destination path-selecting behavior, *Computer-Aided Civil and Infrastructure Engineering*, 3(17): 221-226.

[17] Yao X., (2007) Where are public transit needed: examining potential demand for public transit for commuting trips, *Computers, Environment & Urban Systems*, 5(31): 535-550.

[18] Farkas A., (2009) Route/site selection of urban transportation facilities: an ıntegrated gıs/mcdm approach, *Proceedings-7th International Conference on Management, Enterprise and Benchmarking (MEB)*, 169-184.

[19] Brunner I., Kim K., Yamashita E., (2011) Analytic hierarchy process and geographic information systems to identify optimal transit alignments, *Transportation Research Record: Journal of the Transportation Research Board*, 1(2215),59-66.

[20] Kim H. Y., Wunneburger D. F., Neuman M., (2013) High-speed rail route and regional mobility with a raster-based decision support system: The Texas Urban Triangle Case, *Journal of Geographic Information System*, 5(6):559-566.

[21] Gür Ş., Hamurcu M., Eren T., (2017) Ankara'da monoray projelerinin analitik hiyerarşi prosesi ve 0-1 hedef programlama ile seçimi, *Pamukkale Üniversitesi Mühendislik Bilimleri Dergisi*, 23 (4), 437-443.

[22] Gür Ş., Hamurcu M., Eren T., (2016) Using analytic network process and goal programming methods for project selection in the public ınstitution, *Les Cahiers du MECAS*, 13, 36-51.

[23] Hamurcu, M., Alağaş, H.M. and Eren, T., (2017) Selection of rail system projects with analytic hierarchy process and goal programming, *Sigma Journal of Engineering and Natural Sciences*, 8(2), 291-302.

[24] Hamurcu M., Eren T., (2016) Çok kriterli karar verme yöntemleriyle raylı sistem projelerinin sıralanması, *3rd International Symposium on Railway Systems Engineering (ISERSE'2016*), s. 559-566, 13-15 Ekim 2016, Karabük, Türkiye.

[25] Hamurcu, M., (2016) Ankara'da Çok Ölçütlü Karar Verme Yöntemleriyle Monoray Güzergâhı Belirleme, Yüksek Lisans Tezi, Kırıkkale Üniversitesi, Fen Bilimleri Enstitüsü, Kırıkkale Türkiye.

[26] Hamurcu M., Eren T., (2015) Using analytic hierarchy process and goal programming methods for ınvesment project selection in Ankara, *11th International Conferences on Multiple Objective Programming and Goal Programming (MOPGP 2015*), 13-15 December 2015, Tlemcen, Algeria.

[27] Hamurcu, M. and Eren, T., (2017) Selection of monorail technology by using multicriteria decision making, *Sigma Journal of Engineering and Natural Sciences*, 8(2), 303-314.

[28] Hamurcu M., Eren T., (2016) Analitik ağ süreci ile Ankara'da kentsel ulaşım için monoray teknolojisinin seçimi, *3rd International Symposium on Railway Systems Engineering (ISERSE'2016*), s. 85-96, 13-15 Ekim 2016, Karabük, Türkiye.

[29] Gebeyehu M., Shinei T., (2007) Multi-criteria decision making for public transportation development projects using analytic network process (ANP), *In Proceedings of the Eastern Asia Society for Transportation*, pp. 38-38.

[30] Özcan, E., Hamurcu, M., Alakaş, H.M., Eren, T. (2018) Project selection by using constraint programming, *Journal of Trends in the Development of Machinery and Associated Technology*, 21(1), 89-92.

[31] Dinç, S., Hamurcu, M. ve Eren, T. (2018) Kırıkkale-kampüs dolmuş hattının etkinliğinin çok kriterli karar verme ile değerlendirilmesi, *Mehmet Akif Ersoy Üniversitesi Fen Bilimleri Enstitüsü Dergisi 9(Ek Sayı 1*): 238-247.

[32] Dinç, S., Hamurcu, M. ve Eren, T. (2018) Kentsel ulaşım için alternatif tramvay araçlarının çok kriterli seçimi, *Gazi Mühendislik Bilimleri Dergisi,* 4(2), 124-135.

[33] Hamurcu, M., ve Eren, T. (2018) Kent içi ulaşım için bulanık AHP tabanlı VIKOR yöntemi ile proje seçimi, *Engineering Sciences (NWSAENS*), 13(3), 201-216.

[34] Hamurcu., M and Eren, T. (2018) Prioritization of high-speed rail projects, *International Advanced Researches and Engineering Journal*, 2(2), 98-103.

[35] Hamurcu., M and Eren, T. (2018) Transportation planning with analytic hierarchy process and goal programming, *International Advanced Researches and Engineering Journal*, 2(2), 92-97.

[36] Hamurcu, M. ve Eren, T. (2018), Yüksek kapasiteli elektrikli otobüslerin seçiminde hibrit çok kriterli karar verme uygulaması, *Transist 11. Uluslararası Ulaşım Teknolojileri Sempozyumu ve Fuarı*, İstanbul, 2018, s. 1-10.

[37] Hamurcu, M. and Eren, T. (2018) Determination of electric bus technology to ımprove the public transportation using AHP-TOPSIS methods, *29th European Conference on Operational Research (EURO2018),* Valencia.

[38] Hamurcu, M. and Eren, T. (2018) A hybrid approach of analytic hierarchy process-topsıs and goal programming for electric automobile selection," *The 2018 International Conference of the African Federation of Operational Research Societies (AFROS 2018),* Tunis, 2018.

[39] Hamurcu, M. and Eren, T. (2018) Kamu kurumunda bulanık TOPSIS yaklaşımı ile proje seçimi için bir grup karar verme uygulaması, *Transist 11. Uluslararası Ulaşım Teknolojileri Sempozyumu ve Fuarı*, İstanbul, 2018, s. 11-20.

[40] Hamurcu, M. and Eren, T. (2018) Using multicriteria decision making approach for metro projects selection in Ankara," *The 2018 International Conference of the African Federation of Operational Research Societies (AFROS 2018),* Tunis.

[41] Wang C. N., Nguyen V., Duong D., Thai, H. (2018) A hybrid fuzzy analysis network process (FANP) and the technique for order of preference by similarity to ıdeal solution (TOPSIS) approaches for solid waste to energy plant location selection in Vietnam. *Applied Sciences,* 8(7), 1100.

[42] Hamal, S., Senvar, O., Vayvay, O. (2018) Selectıon of optımal renewable energy ınvestment project vıa fuzzy ANP, *Journal of Economics Finance and Accounting,* 5(2), 224-233.

[43] Uslu, B., Gür, Ş. and Eren, T. (2018) Evaluation of Strategies for Industry 4.0 Application with AAS and TOPSIS Methods, *Anadolu University Journal of Science and Technology-B Theoretical Sciences,* (In Press).

[44] Razavi Toosi S. L., Samani J. M.V., (2016) Evaluating water management strategies in watersheds by new hybrid fuzzy analytical network process (FANP) methods, *Journal of Hydrology*, 534, 364–376.

[45] Wang X., Liu Z., Cai Y., (2015) A rating based fuzzy analytic network process (f-anp) model for evaluation of ship maneuverability, *Ocean Engineering,* 106, 39–46.

[46] Demirta S., Özgürler N., Özgürler M., Güneri A.F., (2014) Selecting e-purse smart card technology via fuzzy AHP and ANP, *Journal of Applied Mathematics,* p, 14.

[47] Kumru M., Humru P. Y., (2014) A fuzzy anp model for the selection of 3d coordinate-measuring machine, *Journal of Intelligent Manufacturing,* 26 (5), 999–1010.

[48] Isalou A.A., Zamani V., Shahmoradi B., Alizadeh H., (2013) Landfill site selection using integrated fuzzy logic and analytic network process (f-anp), *Environmental Earth Sciences,* 68 (6), 1745–1755.

[49] Moalagh M., Ravasan A. Z., (2013) Developing a practical framework for assessing erp post-implementation success using fuzzy analytic network process, *International Journal of Production Research,* 51 (4), 1236–1257.

[50] Pang B., Bai S., (2013) An integrated fuzzy synthetic evaluation approach for supplier selection based on analytic network process, *Journal of Intelligent Manufac- turing,* 24 (1), 163–174.

[51] Demirel N.Ç., Yücenur G. N., Demirel T., Muşdal H., (2012) Risk-based evaluation of Turkish agricultural strategies using fuzzy AHP and fuzzy ANP, *Human and Ecological Risk Assessment: An International Journal,* 18 (3), 685–702.

[52] Raei R., Jahromi M., (2012) Portfolio optimization using a hybrid of fuzzy ANP, VIKOR and TOPSIS, *Management Science Letters,* 2(7), 2473-2484.

[53] He Q.H., Luo L., Wang J., Li Y.K., Zhao L., (2012) Using analytic network process to analyze influencing factors of project complexity, *Proceedings 2012 International Conference on Management Science and engineering, IEEE*, Dallas, USA, pp. 1781–1786.

[54] Kang, H. Y., Lee, A. H., & Yang, C. Y. (2012). A fuzzy ANP model for supplier selection as applied to IC packaging. *Journal of Intelligent Manufacturing*, 23(5), 1477-1488.

[55] Macura D., Bošković B., Bojović N., Milenković M., (2011) A model for prioritization of rail infrastructure projects using ANP, *International Journal of Transport Economics/Rivista internazionale di economia dei trasporti*,38(3), 285-309.

[56] Vinodh S., Anesh Ramiya R., Gautham S.G., (2011) Application of fuzzy analytic network process for supplier selection in a manufacturing organisation, *Expert Syst. Appl.* 38 (1), 272–280.

[57] Yüksel l., Dağdeviren M., (2010) Using the fuzzy analytic network process (anp) for balanced scorecard (bsc): A case study for a manufacturing firm, *Expert Sys- tems with Applications*, 37 (2), 1270–1278.

[58] Wu C.R., Lin C.T., Chen H.C., (2009) Integrated environmental assessment of the

location selection with fuzzy analytical network process, *Qual. Quant.* 43, 351–380.

[59] Dağdeviren M., Yüksel İ., Kurt M., (2008) A fuzzy analytic network process (ANP) model to identify faulty behavior risk (FBR) in work system, *Saf. Sci.* 46, 771–783.

[60] Tseng M.L., Lin Y.H., Chiu A.S.F., Liao J.C.H., (2008) Using FANP approach on selection of competitive priorities based on cleaner production implementation: a case study in PCB manufacturer, *Taiwan. Clean Techn. Environ. Policy*, 10, 17–29.

[61] Hemmati, N., Rahiminezhad Galankashi, M., Imani, D. M., & Farughi, H. (2018) Maintenance policy selection: a fuzzy-ANP approach. *Journal of Manufacturing Technology Management*, 29(7), 1253-1268.

[62] Mohanty R. P., Agarwal R., Choudhury A.K., Tiwari M.K., (2005) A fuzzy ANP-based approach to R&D project selection: a case study, *International Journal of Production Research,* 43(24), 5199-5216.

[63] Mikhailov L., Singh M.G., (2003) Fuzzy analytic network process and its application to the development of decision support systems, *IEEE Transactions on Systems, Man and Cybernetics-Part C: Applications and Revıews*, 33, 1, 33-41.

[64] Pérez J. C., Carrillo M.H., Montoya-Torres J. R., (2015) Multi-criteria approaches for urban passenger transport systems: a literature review, *Annals of Operations Research*, 226(1), 69-87.