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Research Article

SELECTION OF MONORAIL TECHNOLOGY BY USING MULTICRITERIA DECISION MAKING

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ABSTRACT

Urban public transport diversified increasingly with technology. Monorail, one of the latest technologies of urban mass transport, is the result of this diversity. The monorail which has been mentioned frequently in the recent periods among the rail systems in urban transportation and started to take place in the transportation plans is diversified by its physical and technical characteristics. Multicriteria decision-making techniques based on selection by making pairwise comparisons among alternatives and criteria are needed to select the best monorail technology around various technical and physical features. In this study, 3 different monorail technologies were considered and monorail technology selection was made for urban transportation with analytic hierarchy process (AHP) and the technique for order performance by similarity to ideal solution (TOPSIS) methods. The AHP is used to determine weights of the criteria, and TOPSIS method is used to find result ranking.
Keywords: AHP, multicriteria decision making, urban mass transport, monorail technology, TOPSIS.

1. INTRODUCTION

One of the most important components of metropolitan city is urban transport. The urban mass transport is varied day by day. The public transport come to the forefront in urban transport with the expansion of urban areas, increasing traffic elements, waste of time in traffic and traffic accidents. At the same time, urban transport is trended higher-capacity and more reliable rail systems due to the ever-increasing demand. These systems try to meet the increasing demand in the urban area with its high capacities and are comfortable, safe and fast with rail system.

The rail systems vary as suburban, tram, light rail system, metro and monorail within themselves in the urban transport. These systems, which are alternatives to each other, come to the forefront with their different characteristics. When we consider it all, there are taking place in urban transportation with their features as high capacity, reliability and comfort.

Due to over population and urbanization in metropolitan, car ownership and personal vehicles lead to traffic congestion. So, to deal with such problems of moving large numbers of people and vehicle and air pollution public transport be a good solution to used. İn this point, a monorail which is urban mass transport system, is one of the last technology of urban transport. The

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monorail is a railway in which the track consists of a single rail, typically elevated [1]. This system has their own route on the elevated. So, it doesn't cut to traffic and other transport systems. This system, which is the application examples in the world, has been mentioned frequently in recent times.

Some features that distinguish monorail from alternatives are: environmentally friendly, less space use, high capacity, safe, easy to install on busy streets and areas, low cost compared to alternatives, and ability to maneuver. A disadvantage of the monorail is high energy used.

Application examples are in the world and they are operated in urban transport in many countries and especially Japan and China. In the Table 1 shows examples of monorail in the world [2].

Table 1. Examples of Monorail Application in the World

Number	Name of the Route	Line Length (km)	Speed (km/h)	Opening Year	Country
1	Inuyama Monorail	1,3	35	1962	Japan
2	Okinawa Monorail	13,1	60	2003	Japan
3	Chongqing Monorail	19,2	75	2005	China
4	Sentosa Monorail	2,1	60	2007	Singapore
5	Palm Jumeirah Monorail	5,4	70	2009	United Arab Emirates (UAE)
6	Daegu Metro Line No.3 Monora	24	70	2015	Korea
7	Düsseldorf International Airport	2,5	50	2002	Germany
9	Tama Monorail	16	60	1998	Japan
10	Jacksonville	7	48	1997	America

This system which is not yet applied for urban transportation in Turkey is gradually included in the main transportation plans of our cities. Particularly in the Istanbul and Izmir are continued project design processes of monorail. In the Ankara and Kocaeli are undergoing preliminary assessments for projects. And the monorail system is considered for the other some cities.

The monorail is preferred over alternative rail systems in terms of some features. Some features for metro, monorail, light rail system and tram are shown in Table 2 [3].

In the second section of the study, the technology selection problem is explained. In the third section, multicriteria decision making methods used in the study are briefly explained. The fourth section is contained the application of study. In the fifth section, the conclusions of study are given. Finally, given suggestions for future studies.

Table 2. Char acteristics of Alternative Rail Systems

Characteristics	Metro	Monorail	Light rail system	Tramway
Capacity of vehicle	140-280	140-280	140-280	100-180
Passenger capacity of vehicle (*1000)	32-70	max.35	15-35	max.15
Headway(sec)	90	120	120	120
Maximum speed (km/h)	80	80	80	50
Mean speed(km/h)	35-40	30-35	30-35	20
Stopping distance (m)	500-200	---	500-200	250-500
Max. slope	4.50%	%6-7	5.50%	%6-7
Radius of curvatureı(m)	300	50-60	250	35
Line strip width(m)	3.70-4.30	80-90 cm	3.70-4.30	3.0-3.5
Supply system	Katanер 3.rail	3. rail	Katanер 3.rail	Katanер
Number of vehicles	4-6-8-10	2-4-6-8	3-4	1-2
Time of shear(sec)	0.6	15	0,6	0,6

2. TECHNOLOGY SELECTION PROBLEM

Technology is developing and advancing day by day. This development is causing diversity. Existing vehicles of transport are being developed and winning new features. Thus, it is in urban transport vehicles diverse with the increasing urbanization. Determining the best of the increasing alternatives reveals the need to make choices for decision makers / managers. A short description of technology selection can be made as a selection of the best among alternative technologies. In this study, we select the best technology for the determination of the systems which will provide improvement in the traffic by providing the user and manager demands. In the Figure 1, shows the monorail and monorail line operated in Dubai [4].

Figure 1. Monorail in Dubai

The monorail has been used more and more in recent years for existing urban transport networks are more efficient. It is introduced for urban transport as could be understood from the

academic studies about the monorail, and is mentioned its technical features and suggested for urban transport. About the describing features of the monorail [5], to observing recent developments about the monorail, evaluating the potential of urban transport alternatives [6], in evaluating the economic effect of monorail [7], from short construction time and low cost advantages of monorail [8-9], the advantages of the monorail system [10], to introduce the monorail system its technical characteristics [11], about the distinguishing features of monorail from other urban transport systems [12], to inform about monorail [13], application of Monorail as an urban transport vehicle [14], to advise of monorail for urban transport[15], from the features that make the monorail popular in urban areas [16], about the similar and different features of monorail and other transport systems [17], about the increasing the popularity of monorail [18], about the application for mass transport in different areas [19]. Monorail and other public transportation vehicles have been compared [120-24] and multicriteria decision making methods have been applied to determine of the monorail route [25-27], selection of monorail projects in urban transport [28-29], scenarios with simulated application for monorail have been produced [30]. Finally, ANP (Analytical network process) was used to select monorail technology from multi-criteria decision making [31]. In this study, the best suitable vehicle has been selected for the monorail among developed and diversified urban rail public transport vehicles.

3. MULTICRITERIA DECISION MAKING

Multicriteria decision making methods based on pairwise comparison involve decision makers in the decision process by gathering the different criteria and factor in a model. It helps decision makers to ensure that alternatives are selected, sorted or weighted. Nowadays, multicriteria decision making is often used in many areas and in this method, AHP, ANP, TOPSIS, VIKOR and PROMETHE are coming the front of and these methods are frequently used.

3.1. The AHP Method

AHP, developed by Saaty in 1980 [32], is a multicriteria decision problem that addresses how to determine the relative importance of a set of actions in this process. In the literature, AHP, has been widely used in solving many complicated decision-making problems [33]. The process includes that it possible to incorporate judgments on intangible qualitative criteria alongside tangible quantitative criteria [34].

The AHP method process is include three principles: first, structure of the model; second, comparative pairwise among of the alternatives and the criteria; third, analysis. The multiple pairwise comparisons are based on a standardized comparison scale of nine levels find by Saaty in AHP [35].

3.2. The TOPSIS Method

This method is developed by Hwang and Yoon (1981), it is based on the idea of selecting alternative the shortest distance from the positive ideal solution and the longest distance from the negative ideal solution. The TOPSIS method, which is one of the multicriteria decision making methods, is frequently used in decision making processes. The assumption is that every measure is either a monotone increasing or monotonously decreasing one-way benefit in this method [36]. TOPSIS method is follows general 6 steps [37];

Step 1: Establish a decision matrix for the ranking
Step 2: Calculate the normalized decision matrix
Step 3: Calculate the weighted normalized decision matrix
Step 4: Determination of ideal (A^+) and negative ideal (A^-) solution

Step 5: Calculation of the separation measure
Step 6: Calculation of the relative closeness to the ideal solution and final rank (C*).

TOPSIS method is used in some study area such as to select the location [38], service provider selection [39], staff selection [40], project evaluation [41-43], performance evaluation [44-49], multi-criteria inventory planning [50], vendor selection [51], ship design [52], scholarship student selection [53], transshipment site selection [54], maintenance strategy selection [55] and evaluation of the renewable energy investments [56].

4. AN APPLICATION

Monorail is an increasingly popular type of public transport in the metropolitan area. This system stands out with their own characteristics to survive in the competitive environment and can being preferred to with their vehicles. In this diversity that emerges with technological developments, managers are going to choose the best technology with the execution of the decision processes. The three different monorail technologies discussed in this study are evaluated with their different characteristics. One of these monorail vehicles comes to the forefront with its high capacity, the other is the aesthetic appearance, and the other is a combination of these two features. The dimensions of the lines that these vehicles have changed also change with the different features of the vehicles. At the same time, it reflects capacity, speed and maneuverability. The raising of the monorails from the ground makes it difficult to evacuate the passengers in a disruption that may arise, and it seems that there is a need for evacuation systems. This evacuation is carried out by some monorail vehicles in some systems while in some systems it is provided by means of intermediate walkways. This system distinguishes from other systems and diversify within themselves with features such as sudden stop, acceleration and stopping maneuvers, maneuverability, applicability for sloping areas, and minimum turning radius. In this study, all these features were considered and monorail alternatives ranked for selection with multicriteria decision making techniques.

4.1. Research Methodology

The process of monorail technology selection begins with the identification of alternatives. The selection criteria were determined in the light of literature survey and expert opinion. In the next step, it comes up the gathering of the information of alternative technologies and creating the hierarchy around the specified criteria. Firstly, weights of criteria were found by making pairwise comparisons of the among the criteria through the AHP method. These calculated criteria weights will be input for the TOPSIS method in the its first step. In the last stage, the TOPSIS method is solved and the order of alternative technologies to be selected is found. it is shown the research methodology in the Figure 2.

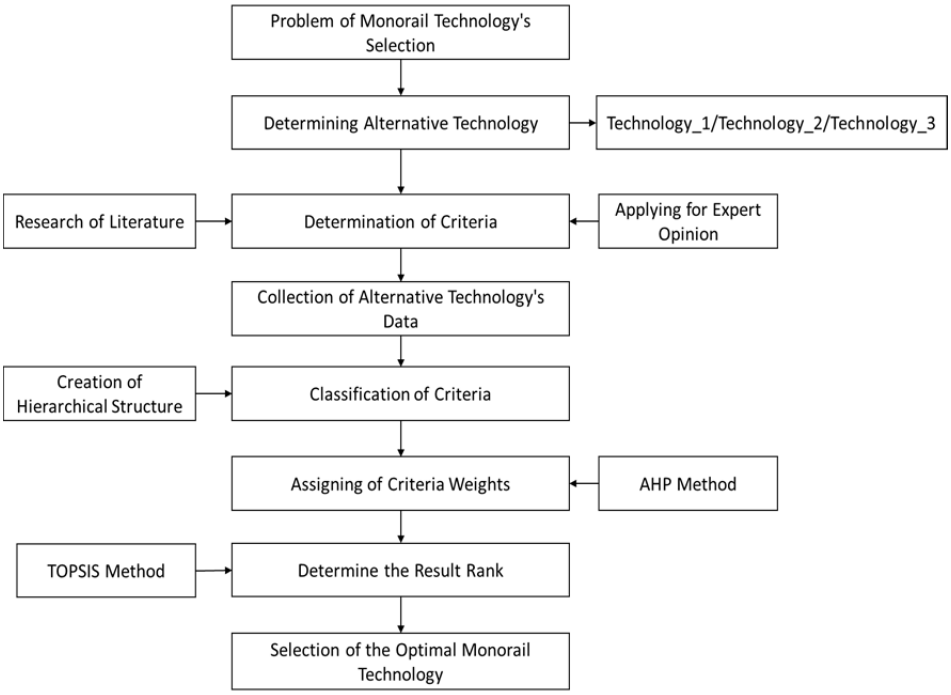

Figure 2. Research Methodology

4.2. Determination of Alternatives

The technology is diversifying and developing at the point of meeting the emerging transportation needs and meeting the demands. The capacity, aesthetic appearance and, depending on these, the dimensions of the vehicle, the speeds, the weights and the passenger evacuation patterns of the vehicles vary. Choosing the best one in terms of your goals and criteria from all these differences constitutes the most important step of transportation planning. In this study, evaluated 3 different the monorail vehicles were ranked and selected the best. The characteristics of the 3-different technology are shown in Table 3.

4.3. Determination of Criteria

The evaluation criteria were determined in the light of literature review and especially expert opinion, based on the technical characteristics of the monorail system. Line characteristics, capacity, vehicle size, speed, weight, safety and acceleration criteria were evaluated. The features that distinguish monorail technology from each other were taken into consideration. Of course, the different monorail technologies have different structures. It is necessary to consider the monorail as a whole system together with the line. Because of the vehicle's size will change, it will be needed different monorail vehicles as depending on the its installed line.

Table 3. Characteristics of Three Different Monorail Technology

Monorail Technology			**Technology_1**	**Technology _2**	**Technology _3**
Size	K1	Length * Amplitude * Dimension (m^3)	456,0	383,3	951,6
Passenger Capacity of Vehicle	K2	0,33 m2/passenger	194	186	415
Speed (km/s^2)	K3	Max. Speed	60	80	80
	K4	Mean speed	40	48	40
Acceleration (m/s^2)	K5	Acceleration	0,97	1	1
	K6	Stop	1	1	1
	K7	Emergency stop	1,25	1,3	1,23
Monorail Line Features	K8	Height (m)	1,3	1,89	1,5
	K9	Amplitude (m)	0,7	0,66	0,85
	K10	Yard	4,5	5,1	5,15
	K11	Max. Slope	6	6,5	6
	K12	Minimum Turning Diameter	40	45	70
	K13	Line Supply(V)	750	750	1500
Security	K14	Evacuation of passengers	From train to train (3)	Walking on the line (5)	From train to train (3)
Train Weight (ton)	K15	Full Weight	72	80	160

4.4. Hierarchy Structure and Finding of Criteria Weights

The AHP is the evaluation process in the with respect to a hierarchy. Decision hierarchy consists of goal, criteria and sub-criteria levels. It was found criteria weights or importance levels with the model. In the Figure 3, is shown the hierarchy. Firstly, the criterions were compared with each other and the importance levels were found and then the sub-criteria were weighted by pairwise comparisons.

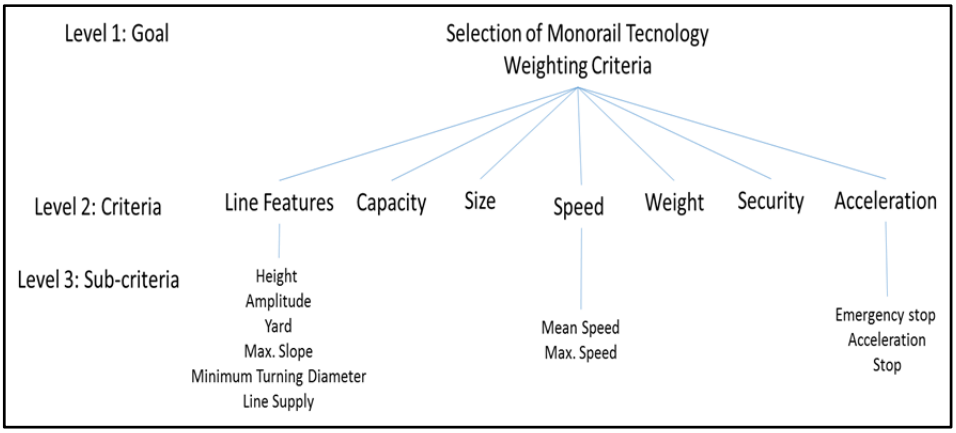

Figure 3. The Decision Hierarchical of AHP

Creating the pairwise comparison matrix shown in Table 4 to find the weights of the criteria. In here, we will compare the line feature and the capacity of monorail vehicle technology. According to the comparison of Saaty's score of 1-9, 3 points are given for the capacity, which is more important compared to the capacity to line feature. 1/3 value is given for reverse comparison. These comparisons are done for all couples.

Table 4. The Pairwise Comparison Matrix for Criteria

	Line Features	Capacity	Size	Speed	Weight	Security	Acceleration
Line Features	1,000	0,333	3,000	3,000	3,000	0,333	3,000
Capacity	3,000	1,000	5,000	3,000	5,000	0,333	3,000
Size	0,333	0,200	1,000	0,333	3,000	0,333	0,333
Speed	0,333	0,333	3,000	1,000	3,000	0,333	0,333
Weight	0,333	0,200	0,333	0,333	1,000	0,200	0,333
Security	3,000	3,000	3,000	3,000	5,000	1,000	3,000
Acceleration	0,333	0,333	3,000	3,000	3,000	0,333	1,000

4.5. Finding of Final Ranking with TOPSIS Method

The initial matrix table of the TOPSIS method is shown in the Table 5. These values are purely numerical values of properties belonging to these technologies. Only for the "safety" criteria, it was scored "from train to train" by giving 3 point and “Walking on the monorail line" by giving 5 point with the intent of the evacuation of the passengers.

Table 5. Decision Matrix for TOPSIS

Alternatives	Criteria														
	K1	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**	**K11**	**K12**	**K13**	**K14**	**K15**
Technology_1	456,0	194,0	60,0	40,0	0,97	1,00	1,25	1,30	0,70	4,50	6,00	40,0	750,0	3,0	72,0
Technology_2	186,0	186,0	80,0	48,0	1,00	1,00	1,30	1,89	0,66	5,10	6,50	45,0	750,0	5,0	80,0
Technology_3	415,0	415,0	80,0	40,0	1,00	1,00	1,23	1,50	0,85	5,15	6,00	70,0	1500	3,0	160,0

The weighted criteria by the weights of the AHP will be used for the TOPSIS method. This table is shown the criteria weights and the TOPSIS weighted matrix in the Table 6.

Table 6. The Weighted Normalized Decision Matrix

Alternatives	Criteria														
	K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12	K13	K14	K15
Weights of AHP	0,062	0,235	0,026	0,062	0,017	0,039	0,062	0,017	0,012	0,008	0,052	0,038	0,028	0,305	0,038
Technology_1	0,044	0,092	0,012	0,033	0,009	0,023	0,035	0,008	0,007	0,004	0,029	0,017	0,012	0,140	0,014
Technology_2	0,018	0,088	0,016	0,040	0,010	0,023	0,037	0,011	0,006	0,005	0,032	0,019	0,012	0,233	0,016
Technology_3	0,040	0,197	0,016	0,033	0,010	0,023	0,035	0,009	0,008	0,005	0,029	0,029	0,023	0,140	0,031

The ranking of the interim transactions and the evaluation results are shown in Table 7. The ranking of result is technology_3 with 48%, technology_2 with 39%, and technology_1 with 13%.

Table 7. The Final Ranking of TOPSIS Method

Alternatives	A*	A-	Ci (A-/(A-+A*)	Percent(%)	Ranking
Technology_1	0,143	0,021	0,130	11	3
Technology_2	0,109	0,099	0,475	42	2
Technology_3	0,098	0,110	0,528	47	1

In this study, according to expert opinion, the criterion weights are given as; size with 0,062; passenger capacity of vehicle with 0,235; max. speed with 0,026 and mean speed with 0,062; acceleration with 0,017-stop with 0,039- emergency stop with 0,062; height with 0,017, amplitude 0,012, yard 0,008, max. slope, 0,052; minimum turning diameter with 0,038 and line supply with 0,028; evacuation of passengers with 0,305 and full weight with 0,038. It seems that the most important criteria for planners are to provide safety and to meet demands with high capacity for urban transport.

The study was conducted around the objectives of particularly having the capacity to meet demands, being safe, having good maneuverability and having a good aesthetic appearance. In terms of the weight of criteria, safety and capacity have the highest weight and the line features, acceleration, speed, vehicle size and vehicle weight follows respectively these criteria. The monorail technology_3 has been effective to be in the foreground with its high capacity. Despite its disadvantages such as excessive energy use and large size, this technology ranks first. The Planners who have aim to meet high demands in urban transport preferred to the high capacity monorail vehicles. At the same time, the select process was affected security, line features and maneuverability. As a result, monorail technology, which will be able to improve the urban transport, has been selected.

5. RESULT AND DISCUSSION

In this paper, an integrated AHP–TOPSIS methodology is proposed to make a selection among the alternative monorail technologies. The criteria determined with AHP were the input to the TOPSIS method and the order of technology_3, technology_2 and technology_1 were found in the result of TOPSIS method

The monorail technology for transportation has not yet available in Turkey. However, it is taking place in the main transportation plans of the cities and the projecting processes are continuing in some cities, In the following years, for many cities will be thought to could prefer this type of transportation, and many municipalities are working on this area. The selection of the monorail vehicle, which will provide the desired characteristics among the monorail technologies that are diversified in the preliminary evaluation, feasibility and projecting processes for transportation projects, is important. At the same time, with the choice of monorail technology to provide improvement in urban transport, sustainable urban transport will be provided to be more livable cities and comfortable transportation.

Finally, this study introduces an approach that integrates improved AHP with TOPSIS method to support technology selection decisions It is multidimensional thinking necessary in almost every decision process in urban transport. The usage of multicriteria decision making methods in other transport modes and equivalent areas will yield beneficial results as well as the monorail technology selection. It will ensure that correct and best decisions are made in planning decisions. At the same time, it can be used together with multicriteria decision making and fuzzy numbers for this study and results can be compared. The monorail vehicles can be evaluated also financially in addition to the evaluation criteria used in the study.

REFERENCES

[1] Marathe, R., Hajiani, N. D. (2013) A Review of Research on Monorail as an Alternative Mass Rapid Transit System. *International Journal of Science and Research (IJSR),* 4(2), 275-277.

[2] http://www.monorails.org [Erişim tarihi: 01.10.2016].

[3] http://www.ubak.gov.tr/BLSM_WIYS/DLH/tr/DOKUMAN_SOL_MENU/Rayli_Sistem_Kriterleri/20140228_151652_10288_1_10315.html [Erişim tarihi: 20.09.2016].

[4] http://lirikmusik.me/palm-monorail-dubai.html [Erişim tarihi: 01.10.2016].

[5] Brackett. Q, Biswas. M and Lucy S.H., (1982) Monorail Tecnology Study, *Texas Transportation Institute Texas A&M University College Station*, Texas.

[6] Kikuchi, S., Onaka, A., (1998) Monorail Development and Application in Japan, *Journal of Advanced Transportation*, 22(1), 17-38.

[7] Jakes A.S., (1997) Economic Analysis of a Monorail Link Between the Stratosphere Tower and Downtown Las Vegas, *In Automated People Movers VI@ sCreative Access for Major Activity Centers*, 213-223, ASCE.

[8] Kuwabara, T., Hiraishi, M., Goda, K., Okamoto, S., Ito, A., and Sugita, Y., (2001) New Solution for Urban Traffic: Small-Type Monorail System, *Automated People Movers.* 50(4), 139.

[9] Wang, B., (2003) Constructability Analysis of Monorail Project. *Pre-Project Planning & Constructablility Analysis.*

[10] Kato, M., Yamazaki, K., Amazawa, T., and Tamotsu, T., (2004) Straddle-Type Monorail Systems with Driverless Train Operation System", *Hitachi Review*, 53(1), 25.

[11] Taketoshi, S., Motomi H., Soichiro Y. and Takayuki T., (2005) China's First Urban Monorail System in Chongqing, *Hitachi Review,* 54(4), 193.

[12] Ryan R. Kennedy, (2008) Considering Monorail Rapid Transit for North American Cities, *The Monorail Society,* 41.

[13] Kimijima, N., Takahashi, H., Kawabata, I., and Matsuo, S., (2010) New Urban Transport System for Middle East Monorail System for Dubai Palm Jumeirah Transit System, *Hitachi Review,* 59(1), 47.

[14] Timan, P. E., (2015) Why Monorail Systems Provide a Great Solution for Metropolitan Areas, *Urban Rail Transit,* 1(1), 13-25.

[15] Marathe, R., Hajiani, N. D., (2013) A Review of Research on Monorail as an Alternative Mass Rapid Transit System, *International Journal of Science and Research (IJSR*), vol 4(2), 275-277.

[16] Parekh, J: A, Raval N.G. and Dodiya D., (2013) Overview of Monorail Rapid Transit System, *Journal of information, Knowlwdge Research in Computer Engineering*, 2(2), 285-291.

[17] Liu, X., Huan, S. and Liu F., (2014) Study on the Application and Development of Monorail Transit System, *International Journal of Engineering Research & Technology (IJERT)*, 3(5), 213-216.

[18] He, X., (2015) Application and Prospect of Straddle Monorail Transit System in China, *Urban Rail Transit*. 1(1), 26-34.

[19] Hamurcu, M., Eren, T., (2015) Monoray ve Türkiye'de Potansiyel Uygulanabilirliği, *Transist 8. Uluslararası Ulaşım Teknolojileri Sempozyumu ve Fuarı*, s. 409-419, 17-19 Aralık 2015.İstanbul, Türkiye.

[20] Das, A. M., Ladın, M. A., Ismaıl, A., and Rahmat, R. O., (2003) Consumers Satisfaction of Public Transport Monorail User in Kuala Lumpur, *Journal of Engineering Science and Technology,* 8(3), 272-283.

[21] Das, A.M., Yukawa S., Ismail A., Rahmat R. A O.K. and Ladin M. A., (2013) Comparative Analysis of Monorail System Between Kuala Lumpur Malaysia and Kitakyushu Japan, *Malaysian Universities Transport Research Forum Conference.*

[22] Ghafooripour, A., Ogwuda, O., and Rezaei, S., (2012) An Efficient Cost Analysis of Monorail in the Middle East Using Statistics of Existing Monorail and Metro Models, *Urban Transport XVIII: Urban Transport and the Environment in the 21st Century*, 18, 241.

[23] Hussien M., Sharawneh O., (2014) Comparison Between Monorail System and BRT System in Amman City, *The Fourth Jordan International Conference and Exhibition for Roads and Transport*. 1-15.

[24] Y. Li, Y. Xu, H. Yan, K. Wang, K., and N. Wei., (2015) Suspended Monorail Ssystem: A New Development of an Urban Rail Transit System with Low Passenger Capacity, *In Fifth International Conference on Transportation Engineering.* 3180-3186.

[25] 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. 400-409, 17-19 Aralık 2015, İstanbul, Türkiye.

[26] Hamurcu, M., Eren, T., (2016) Using ANP- TOPSIS Methods for Route Selection of Monorail in Ankara, *28th European Conference on Operational Research,* July 3-6, Poznan, Polland.

[27] 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.

[28] 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.

[29] Hamurcu M., Gür Ş., Özder E.H. and 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.

[30] Sadatuqu, T.M.N., Toshio, K., (2010) Study on the Influences of Public Transportation on Land and Building Use: The Case of Tama Monorail Line, *The City Planning Institute of Japan.* 98-102.

[31] Hamurcu, M., Eren, T., (2016) Analitik Ağ Süreci İle Ankara'da Kentsel Ulaşım İçin Monoray Teknolojisinin Seçimi*, 3rd International Symposium on Railway Systems Engineering (ISERSE'2016),* s. 85-96, 13-15 Ekim 2016, Karabük, Türkiye.

[32] Saaty, T. L. (1980) The analytic hierarchy process. New York: McGraw-Hill.

[33] Saaty, T.L., (1990) How to Make a Decision: The Analytic Hierarchy Process, *European Journal of Operational Research*, 48, 9-26.

[34] Badri, M. A. (2001). A combined AHP-GP model for quality control systems. International Journal of Production Economics, 72, 27–40.

[35] Dağdeviren, M., Yavuz, S., and Kılınç, N. (2009). Weapon selection using the AHP and TOPSIS methods under fuzzy environment. Expert Systems with Applications, 36(4), 8143-8151.

[36] Hwang, C. L., Yoon,K., (1981) Multiple Attribute Decision Making, in Lecture Notes in Economics and Mathematical Systems, 186, Springer-Verlag, Berlin.

[37] Shyur, H. J., Shih, H. S. (2006) A hybrid MCDM Model for Strategic Vendor Selection. *Mathematical and Computer Modelling*, 44, 749–761.

[38] Eleren A., Karagül M., (2007) Kuruluş Yeri Seçiminin Fuzzy TOPSIS Yöntemiyle Belirlenmesi, *Akdeniz Üniversitesi İ.İ.B.F. Dergisi,* 13, 280-295.

[39] Özbek, A., Eren, T., (2013) Çok Ölçütlü Karar Verme Teknikleri ile Hizmet Sağlayıcı Seçimi, *Akademik Bakış,* 36, 1-22.

[40] Matin H.Z., Fathi M.R., Zarchi M.K. and Azizollahi S., (2011) The Application of Fuzzy TOPSIS Approach to Personnel Selection for Padir Company, *Iran,Journal of Management Research*, 3(2), 1-13.

[41] Sepehr A., Zucca C., (2012) Ranking Desertification Indicators Using TOPSIS Algorithm, *Natural Hazards*, 62, (3), 1137–1153.

[42] Saremi H.Q., Montazer G.A., (2008) An Application of Type-2 Fuzzy Notions in Website Structures Selection: Utilizing Extended TOPSIS Method, *Wseas Transactıons on Computers*, 7(1), 8-15.

[43] İç Y.T., Yurdakul M., (2008) Çok Kriterli Karar Verme Yöntemlerini Kullanan Makine-Ekipman Seçim Çalışmalarında Bulanıklığın Sonuçlara Etkisinin İncelenmesi, *İsletme Fakültesi Dergisi*, 9(1), 125-140.

[44] Özer A., Öztürk M. ve Kaya A., (2010) İşletmelerde Etkinlik ve Performans Ölçmede VZA, Kümeleme ve TOPSIS Analizlerinin Kullanımı: İMKB İşletmeleri Üzerine bir Uygulama, *Atatürk Üniversitesi Sosyal Bilimler Enstitüsü Dergisi***,** 14(1), 233-260.

[45] Demireli E., (2010) TOPSIS Çok Kriterli Karar Verme Sistemi: Türkiye'deki Kamu Bankaları Üzerine Bir Uygulama, *Girişimcilik ve Kalkınma Dergisi,* 5(1), 102-112.

[46] Akyüz Y., Bozdoğan T. ve Hantekin E., (2011) TOPSIS Yöntemiyle Finansal Performansın Değerlendirilmesi ve Bir Uygulama, *Afyon Kocatepe Üniversitesi, İ.İ.B.F. Dergisi,* 13(1), 73-92.

[47] Özgüven N., (2011) Kriz Döneminde Küresel Parekendeci Aktörlerin Performanslarının TOPSIS Yöntemiyle Çözümü, *Atatürk Üniversitesi İktisadi ve İdari Bilimler Dergisi,* 25(2), 151-162.

[48] Soba M., Eren K., (2011) TOPSIS Yöntemini Kullanarak Finansal ve Finansal Olmayan Oranlara Göre Performans Değerlendirilmesi, Şehirlerarası Otobüs Dektöründe bir Uygulama, *Selçuk Üniversitesi İİBF Sosyal ve Ekonomik Araştırmalar Dergisi,* 15(21), 23-40.

[49] Yayar R., Baykara H.V., (2012) TOPSIS Yöntemi ile Katılım Bankalarının Etkinliği ve Verimliliği Üzerine Bir Uygulama, *Business and Economics Research Journal,* 3(4), 21-42.

[50] Tsou, C.H., (2008) Multi-objective Inventory Planning Using MOPSO and TOPSIS, *Expert Systems with Applications,* 35, 136-142.

[51] Shyur, H.-J., Shih, H.S., (2006) A Hybrid MCDM Model for Strategic Vendor Selection, *Mathematical and Computer Modelling*, 44, 749–761.

[52] Olcer, A. I., (2008) A hybrid Approach for Multi-Objective Combinatorial Optimisation Problems in Ship Design and Shipping, *Computers & Operations Research*, 35, 2760–2775.

[53] Abalı, Y.A., Kutlu B.S. ve Eren T., (2012) Çok Ölçütlü Karar Verme Yöntemleri ile Bursiyer Seçimi, *Atatürk Üniversitesi İktisadi Ve İdari Bilimler Dergisi*, 26, 259-272.

[54] Onüt, S., Soner, S., (2008) Transshipment Site Selection Using the AHP and TOPSIS Approaches Under Fuzzy Environment, *Waste Management*, 28 (9), 1552–1559.

[55] Özcan, E. C., Ünlüsoy, S. and Eren, T., (2017) A Combined Goal Programming–AHP Approach Supported with TOPSIS for Maintenance Strategy Selection in Hydroelectric Power Plants, *Renewable and Sustainable Energy Reviews*, 78, 1410-1423.

[56] Özcan, E. C., Ünlüsoy, S. ve Eren, T., (2017). ANP ve TOPSIS Yöntemleriyle Türkiye'de Yenilenebilir Enerji Yatirim Alternatiflerinin Değerlendirilmesi, *Selcuk University Journal of Engineering, Science and Technology*, 5(2), 204-219.