Sigma J Eng & Nat Sci 35 (3), 2017, 535-543

Sigma Journal of Engineering and Natural Sciences
Sigma Mühendislik ve Fen Bilimleri Dergisi

Research Article

BIKE SHARING STATION SITE SELECTION FOR GAZIANTEP

Cihan ÇETİNKAYA[1]*

[1]*Gaziantep University, Department of Industrial Engineering, GAZIANTEP;* ORCID:0000-0002-5899-8438

Received: 30.06.2017 Revised: 02.08.2017 Accepted: 13.08.2017

ABSTRACT

Bike sharing is a traffic precaution service that bicycles are available for shared use to individuals for a short term. It is vital for this program to select the infrastructures scientifically. This study aims to determine the location of bike sharing station in Gaziantep by using fuzzy AHP and TOPSIS. Thus, firstly selection criteria are determined by the literature and municipal officials for siting bike stations. Then the criteria weights are calculated by using Fuzzy AHP to cope with uncertainty. Lastly, potential station sites are ranked using TOPSIS. The generally applicable model provides policy makers with the ability to decide on bike sharing siting.
Keywords: Bike sharing station siting, bike sharing, MCDA, Fuzzy AHP, TOPSIS.

1. INTRODUCTION

Traffic congestion is an ongoing problem of all countries and it seems to get more widespread. There are possible solutions but none of them is easy or cheap. In this context, bicycle sharing programs show up as the cheapest options which act as a subsidiary in traffic. The bicycle sharing program is that; the users can take the bicycles whenever they need them and leave them behind when they reach their destinations.

Since the first introduction of a bicycle sharing system in Amsterdam in the Netherlands in the 1960s, bicycle sharing systems have been receiving increased attention in recent years around the world, such as in Paris, France; Barcelona, Spain; Berlin, Germany; Washington, DC, USA; Montreal, Canada [1]. Many studies have also analyzed the impact of bike-sharing programs on mobility in cities. The percentage of trips by bicycle increased from 0.75% in 2005 to 1.76% in 2007 in Barcelona [2], from 1.0% in 2001 to 2.5% in 2007 in Paris [3] and from 0.5% in 1995 to 2% in 2006 in Lyon [4]. Noland and Ishaque [5], in a study of the OYBike in London, showed that 40% of users shifted from motorized modes.

According to the Bike Sharing World Map [6], there are 1.147 bike-share programs in operation and 362 being planned or under construction worldwide. When the statistics are examined for Turkey, there are 10 operating and 1 under construction bike sharing stations as can be seen in Figure 1; 2 in İstanbul, 2 in İzmir, Çanakkale, Sakarya, Eskişehir, Edirne, Antalya, Konya, Ordu (The other stations in the picture belong to Greece and Georgia, they seem to belong to Turkey in the map because they are close to borders). In this paper, we develop a scientific and

* Corresponding Author/Sorumlu Yazar: e-mail/e-ileti: cihancetinkaya@gmail.com, tel: (342) 317 26 11

decision-making me thod for determining the bike sharing station in Gaziantep. An important aspect of the city is that, the young population (15-24) in Gaziantep forms the %17.9 of the city-which is above the Turkish Republic young population ratio %16.4 [7]. The age profile of bike share users is typically younger than the general population average [8], [9]. Next section provides a review of the literature on bike sharing.

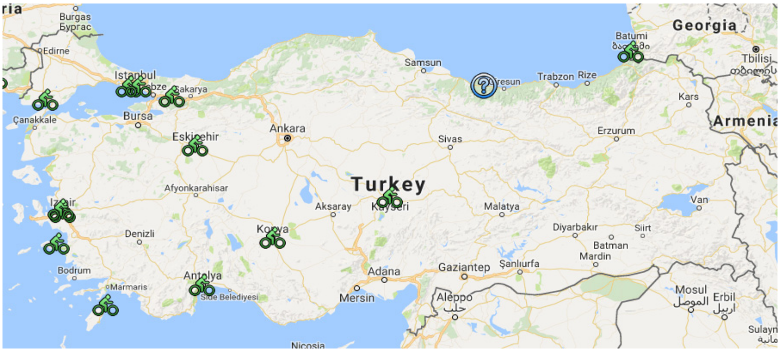


Figure 1. Bike sharing stations in Turkey [6].

1.1. Literature Review

Although the bike sharing program is a well-known topic nowadays, there is relatively little literature published on the strategic design of bicycle sharing systems. In this section we examine the "Bike Sharing Station Siting" papers that apply different solution techniques. The deployment of an interactive campus bicycle-parking map is proposed by Leigh et al. [10] for application on the Monash University campuses. Later, Lin and Yang [11] address the strategic planning of public bicycle sharing systems with service level considerations. The proposed model attempts to determine the number and locations of bike stations. A preference survey for estimating potential users and a model to determine the optimal area for locating bike rental stations by using GIS is proposed by Dell'Olio et al. [12]. Another GIS-based method is proposed by Palomares et al. [13] to calculate the spatial distribution of potential demand for public bicycle trips and to determine the potential area for locating bike stations. Then Larsen et al. [14] propose a GIS-based grid cell method for bicycle facility prioritization and location. A strategic design problem for bicycle sharing systems is proposed by Lin et al. [1] that also address incorporating bicycle stock considerations. In another interesting paper, Croci and Rossi [15] assess which attractors influence the use of bike sharing stations. This issue is very important when deciding the bike sharing station siting. Their main results suggest that the presence of metro and train stations, universities, museums, cinema and restricted traffic areas in correspondence of bike sharing stations significantly increase use. Afterwards, Liu et al. [16] propose a bike sharing network optimization approach by considering multiple influential factors. They use Artificial Neural Networks for predicting station demand and balance. An optimization method is proposed by Frade and Ribeiro [17] to design the bike sharing system such that it maximizes the demand covered and takes the budget as a constraint. The model determines the optimal location of the bicycle stations. In a recent study, Wang et al. [18] determine bike sharing station spots in Taiwan by using spatial-temporal analysis. As can be seen; in the limited literature of bike sharing station siting, mostly mathematical models or geographic information systems are used. To the best of our knowledge, MCDA techniques have not been used for this problem. Thus we apply a Fuzzy AHP-TOPSIS technique to determine the most suitable places for bike sharing stations. This paper contributes to the literature in two ways: (i) proposing a three step Fuzzy AHP-TOPSIS approach –fuzzy AHP is used to priori tize the criteria, fuzzy TOPSIS is used to rank the alternatives –, (ii) application of proposed approach to evaluate bike sharing station siting availability of each pre-determined alternatives.

2. STUDIES

2.1. Evaluation Criteria

An advisory board including a transportation engineer of Metropolitan Municipality who is responsible for bike sharing station siting and experts from Bicycle Association is constructed to determine and assess the criteria affecting the location of a bike sharing station. Also the authors are entrusted to search the literature and find the related criteria. After the interview with the engineers, experts and literature review, 13 different sub-criteria are determined under three groups (Figure 2).

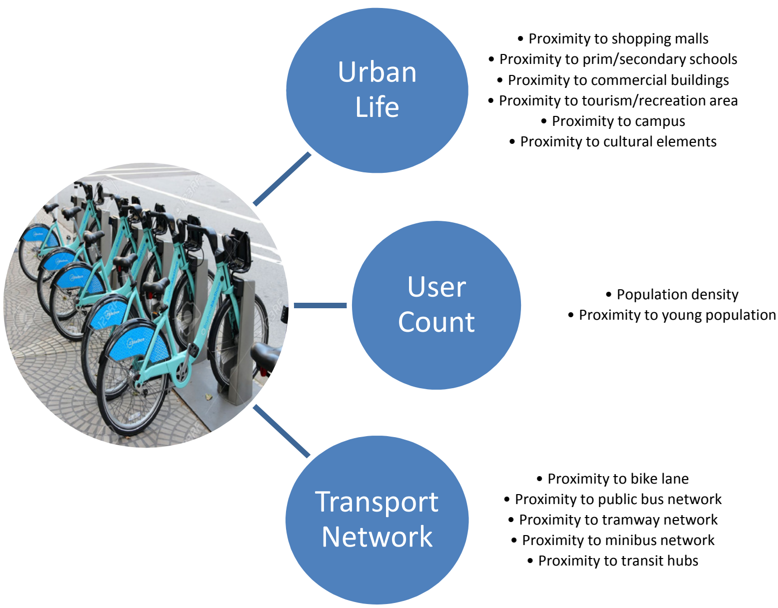


Figure 2. Bike sharing station siting criteria

Table 1 gives information about the criteria literature, the papers on the table either used the criteria in their study or defined a relation between criteria and bike sharing station siting. In addition, Table 2 defines the criteria briefly.

Table 1. Considered criteria and relation with literature

Authors	Urban Life Related Criteria						User Count Related Criteria		Transportation Network Related Criteria				
	C1.1	**C1.2**	**C1.3**	**C1.4**	**C1.5**	**C1.6**	**C2.1**	**C2.2**	**C3.1**	**C3.2**	**C3.3**	**C3.4**	**C3.5**
[19]	√		√	√		√			√	√	√	√	
[20]			√						√	√	√	√	
[21]			√							√	√	√	√
[22]							√			√	√	√	
[13]	√	√	√	√		√	√		√	√	√	√	√
[23]	√	√	√								√		
[15]					√	√				√	√	√	
[17]										√	√	√	
[24]			√	√		√				√	√	√	√
[PP]	√	√	√	√	√	√	√	√	√	√	√	√	√

Authors: **[19]** *The NACTO Bike Share Station Siting Guide* **[20]** *Pucher et al. (2011)*, **[21]** *Pucher et al. (2010 a),* **[22]** *Pucher et al. (2010 b)*, **[13]** *Palomares et al. (2012)*, **[23]** *Kim et al. (2012)*, **[15]** *Croci and Rossi (2014)*, **[17]** *Frade and Ribeiro (2015)*, **[24]** *Murphy and Usher (2015),* **[PP]** *Proposed paper.*

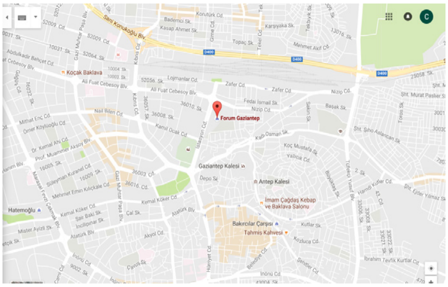
Below, you can see the descriptions of criteria that are used in this study.

Table 2. Description of each criterion

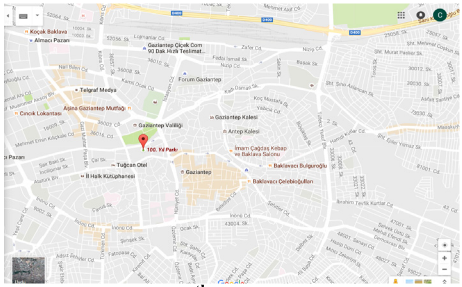
Main and Sub-criteria	Description
C1. Urban Life Related Criteria	
C1.1. Proximity to shopping malls	The bike station should be near to the shopping malls
C1.2. Proximity to prim/second schools	The bike station should be near to primary/secondary schools
C1.3. Proximity to commercial buildings	The bike station should be near to commercial buildings
C1.4. Proximity to tourism/recreation area	The bike station should be near to tourism/recreation area
C1.5. Proximity to campus	The bike station should be near to campus
C1.6. Proximity to cultural elements	The bike station should be near to cultural elements (museum, theatre, cinema)
C2.User Count Related Criteria	
C2.1. Population density	The bike station should be near to high volume of population/crowded neighborhood
C2.2. Proximity to young population	The bike station should be near to places that contain high percentage of young population
C3. Transportation Network Criteria	
C3.1. Proximity to bike lane	The bike station should be near to bike lane
C3.2. Proximity to bus transport network	The bike station should be near to public bus transport network
C3.3. Proximity to tramway network	The bike station should be near to tramway network
C3.4. Proximity to minibus network	The bike station should be near to minibus network
C3.5. Proximity to transit hubs	The bike station should be near to transit hubs

(Although it is hard to determine the places that mostly the young population lives, there are furnished apartments and residences for young people in specific areas of Gaziantep.)

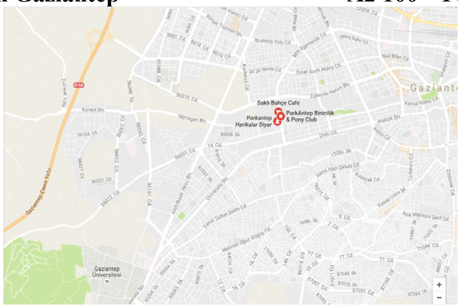
There are six alternatives for Gaziantep in this study. Alternatives are determined by Gaziantep Metropolitan Municipality after a small-scale survey performed by transportation engineers. Alternatives are spread among the city, their common feature is that; they are all crowded and they have a strong transportation infrastructure when compared to other districts of the city. The alternatives are shown on the map in Figure 3.



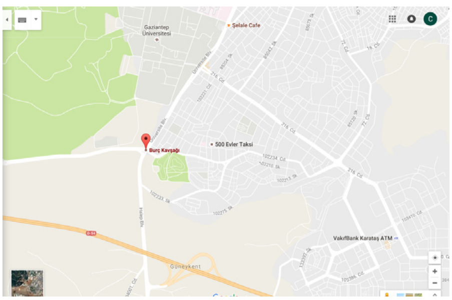
A1 Forum Gaziantep



A2 100th Year Culture Park

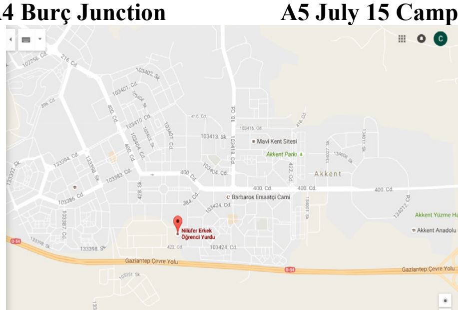


A3 Wonderland



A4 Burç Junction

A5 July 15 Campus



A6 Karataş Male's Dormitory

Figure 3. Bike sharing station alternatives

2.2. Methodology

After determination of the criteria, the weights of each criterion that will be used in evaluation process are assigned by using the FAHP method. In this phase, above mentioned experts are asked for forming an individual pairwise comparison matrix according to the scale given in Table 3. Superdecision software is used to create the hierarchic structure of the evaluation criteria. It is noted that the inconsistency ratio, which means the user makes the evaluations consistently, is smaller than 0.1. Geometric means of these values are found to obtain the pairwise compassion matrix on which there is a consensus.

Table 3. Fuzzy comparison scale, Kabak et al. [25]

Linguistic scale for importance	Abbreviation	Triangular fuzzy scale	Triangular fuzzy reciprocal scale
Equal importance	**EI**	(1, 1, 1)	(1, 1, 1)
Weak importance (of one over the other)	**WI**	(2, 3 ,4)	(1/4, 1/3, 1/2)
Strong importance	**SI**	(4, 5, 6)	(1/6, 1/5, 1/4)
Demonstrated importance over the other	**DI**	(6, 7, 8)	(1/8, 1/7, 1/6)
Absolute importance	**AI**	(8, 9, 10)	(1/10, 1/9, 1/8)

Following questions are asked to the expert team: "Which criterion is considered more important and how much more important when selecting a bike sharing station site?" The experts select one criterion and then determine the degree of importance according to Table 3. The same questions are asked for each criterion. The pairwise comparison matrices for main criteria and urban life related sub-criteria are given in Tables 4 and Table 5 with their calculated weights. All calculated scores of the criteria weights are defuzzified through COA (center of area) defuzzification method [26]. (To decrease complexity, the other analyses for sub-criteria are obtained but they are not given in the text.)

Table 4. Weights and pairwise comparison matrix of main criteria

	C1			***C2***			***C3***			***Weight***		
	l	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***
C1	1.00	1.00	1.00	0.25	0.33	0.50	0.17	0.20	0.25	0.09	0.105	0.129
C2	2.00	3.00	4.00	1.00	1.00	1.00	0.25	0.33	0.50	0.205	0.258	0.325
C3	4.00	5.00	6.00	2.00	3.00	4.00	1.00	1.00	1.00	0.517	0.637	0.745

Table 5. Local weights and pairwise comparison matrix of urban life related sub-criteria

	C11			***C12***			***C13***			***C14***			***C15***			***C16***			***Weight***		
	l	***m***	***u***	***l***	***m***	***u***	***L***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***	***l***	***m***	***u***
C11	1.00	1.00	1.00	0.25	0.33	0.50	1.00	1.00	1.00	0.25	0.33	0.50	0.17	0.20	0.25	1.00	1.00	1.00	0.05	0.06	0.07
C12	2.00	3.00	4.00	1.00	1.00	1.00	4.00	5.00	6.00	1.00	1.00	1.00	0.17	0.20	0.25	2.00	3.00	4.00	0.14	0.17	0.20
C13	1.00	1.00	1.00	0.17	0.20	0.25	1.00	1.00	1.00	1.00	1.00	1.00	0.12	0.14	0.16	1.00	1.00	1.00	0.06	0.06	0.07
C14	2.00	3.00	4.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.17	0.20	0.25	2.00	3.00	4.00	0.11	0.13	0.15
C15	4.00	5.00	6.00	4.00	5.00	6.00	6.00	7.00	8.00	4.00	5.00	6.00	1.00	1.00	1.00	4.00	5.00	6.00	0.41	0.49	0.56
C16	1.00	1.00	1.00	0.25	0.33	0.50	1.00	1.00	1.00	0.25	0.33	0.50	0.17	0.20	0.25	1.00	1.00	1.00	0.05	0.06	0.07

Weights of sub-criteria are defuzzified by COA method and crisp weights are obtained after the normalization. Final weights obtained by FAHP are shown in Table 6. According the results, the most important factor of bike sharing station siting is "proximity to bike lane" with 0.327 as expected. Other factors can be seen in Table 6 below.

Table 6. Weights of criteria obtained by fuzzy AHP

Main and Sub-criteria	Weights	Main and Sub-criteria	Weights
C1. Urban Life Related Criteria		**C3. Transport Network Related Criteria**	
C1.1. Prox. to shopping malls	0.037	**C3.1.** Prox. to bike lane	0.327
C1.2. Prox. to prim/second school	0.018	**C3.2.** Prox. to public bus network	0.072
C1.3. Prox. to commercial building	0.007	**C3.3.** Prox. to tramway network	0.023
C1.4. Prox. to tourism/recreation	0.014	**C3.4.** Prox. to minibus network	0.04
C1.5. Prox. to campus	0.051	**C3.5.** Prox. to transit hubs	0.151
C1.6. Prox. to cultural elements	0.007		
C2. User Count Related Criteria			
C2.1. Prox. to density	0.065		
C2.2. Prox. to young population	0.189		

After determining the weights, TOPSIS method is applied to rank the alternatives. The TOPSIS method is based on the concept that the most preferred alternative should have the shortest distance from the positive ideal solution and have the longest distance from the negative ideal solution [27], [28]. The readers can find the detail formulation of applied TOPSIS method in Hwang et al. [29]. Scores and ranking are determined by using TOPSIS as shown in Table 7.

Table 7. Final ranking based on Fuzzy AHP-TOPSIS

	A1	A2	A3	A4	A5	A6
$S_i -$	0.107	0.131	0.09	0.105	0.057	0.063
$S_i +$	0.071	0.062	0.07	0.064	0.141	0.094
$C_i *$	0.601	0.679	0.564	0.622	0.289	0.401
Rank	3	1	4	2	6	5

$S_i -$: The separation of each alternative from the ideal solution /$S_i +$: The separation from the negative ideal solution /$C_i *$: The relative closeness of the alternative A_i with respect to A_+

According to Table 7, the best location for a bike sharing station is A2, while the worst location is the A5. Possible reasons for A2's high ranking are its "proximity to bike lane, and proximity young population. If one location is to be selected, then A2 should be chosen because it possesses the highest C_i value. Above table is calculated by taking the weights of each criterion into consideration. If it is assumed that each criterion has equal weights we find the results as shown in Table 8.

Table 8. Final ranking based on TOPSIS (Equal Weights)

	A1	A2	A3	A4	A5	A6
$S_i -$	0.098	0.083	0.064	0.08	0.047	0.061
$S_i +$	0.048	0.05	0.058	0.052	0.1	0.072
$C_i *$	0.672	0.624	0.522	0.607	0.317	0.461
Rank	1	2	4	3	6	5

$S_i -$: The separation of each alternative from the ideal solution /$S_i +$: The separation from the negative ideal solution /$C_i *$: The relative closeness of the alternative A_i with respect to A_+

According to Table 8, the best location for a bike sharing station is A1, while the worst location is the A5. Possible reasons for A1's high ranking are its compatibility to all types of criteria especially the urban related criteria group. If one location is to be selected, then A1 should be chosen because it possesses the highest C_i value.

3. CONCLUSION

In this study, bike sharing station problem of Gaziantep is taken into account, a fuzzy AHP and TOPSIS model is proposed to solve the problem. As a result, Alternative 2, namely "100th Year Culture Park" seems as the best option. Possible reasons for A2's high ranking are its "proximity to bike lane, and proximity young population. This model can be applied on any city based on different expert opinions to establish a decision support tool for policy makers. Future research can be proposing a set covering problem for multiple bike stations in Gaziantep to minimize the travel distance to obtain a bicycle. From another perspective, the effects of bike sharing stations on traffic can be examined to encourage the bike sharing system.

Acknowledgments

We would like to thank Ömer Demirdirek -who is a transportation engineer in Kayseri Metropolitan Municipality- and Yusuf Katarcı -who is the leader of Bicycle Association in Gaziantep- for their valuable contributions.

REFERENCES

[1] Lin J.R., Yang T.H., Chang Y.C., 2013, A hub location inventory model for bicycle sharing system design: Formulation and solution, *Computers & Industrial Engineering*, 65, pp. 77–86.

[2] Romero C., 2008, Spicycles in Barcelona, *PowerPoint Presentation by City of Barcelona at the Spicycles Conference*, Bucharest, Romania, December 2008. http://spicycles.velo.info/Portals/0/FinalReports/Barcelona_Final_Report.ppt.

[3] Nadal L., 2007, Bike sharing sweeps Paris off its feet, *Sustainable Transport*, Issue 19, pp.8–12.

[4] Bonnette B., 2007, The implementation of a Public-Use Bicycle Program in Philadelphia, *Urban Studies Program, Senior Seminar Papers, Pennsylvania University*.

[5] Noland R. B., Ishaque M. M., 2006, Smart bicycles in an urban area: Evaluation of a pilot scheme in London, *Journal of Public Transportation*, 9(5), 71–95.

[6] The Bike-sharing World Map, www.bikesharingworld.com, Access date: 28.07. 2017.

[7] TSI, 2015, Turkish Statistical Institute, Gaziantep Population http://www.nufusu.com/il/gaziantep-nufusu, Access date: 28.07.2017

[8] Fishman E., Washington S., Haworth N., 2013, Bike Share: A Synthesis of the Literature, *Transport Reviews*, 33:2, pp. 148–165.

[9] Gutierrez J.G., Torres J.R., Iniestra J.G., 2014, Dimensioning of a Bike Sharing System (BSS): A study case in Nezahualcoyotl, Mexico, *XVIII Congreso Panamericano de Ingeniería de Tránsito, Transporte y Logística* (PANAM 2014), pp. 253–262.

[10] Leigh, C., Peterson, J., Chandra S., 2009, Campus Bicycle-parking facility site selection: exemplifying provision of an interactive facility map, *Surveying & Spatial Sciences Institute*, pp. 389-398. ISBN: 978-0-9581366-8-6.

[11] Lin J.R., Yang T.H., 2011, Strategic design of public bicycle sharing systems with service level constraints, *Transportation Research Part E*, 47, pp. 284–294.
[12] Dell'Olio L., Ibeas A., Moura J.L, 2011, Implementing bike-sharing systems, *Proceedings of the Institution of Civil Engineers - Municipal Engineer*, Volume 164 Issue 2, pp. 89–101.
[13] Palomares J.C.G., Gutiérrez J., Latorre M., 2012, Optimizing the location of stations in bike-sharing programs: A GIS approach, *Applied Geography*, 35, pp. 235–246.
[14] Larsen J., Patterson Z., EI-Geneidy, A., 2013, Build It. But Where? Use of Geographic Information Systems in Identifying Optimal Location for New Cycling Infrastructure, *International Journal of Sustainable Transportation*, Volume 7, Issue 4, pp. 299–317.
[15] Croci E., Rossi D., 2014, Optimizing the position of bike sharing stations, The Milan case, *CERE Working Paper*, 68, http://dx.doi.org/10.2139/ssrn.2461179.
[16] Liu J., Li Q., Qu M., Chen W., Yang J., Xiong H., Zhong H., Fu Y., 2015, Station Site Optimization in Bike Sharing Systems, *IEEE International Conference on Data Mining*, pp. 883–888.
[17] Frade I., Ribeiro A., 2015, Bike-sharing stations: A maximal covering location approach, *Transportation Research Part A*, 82, pp. 216–227.
[18] Wang J., Tsai C.H., Lin P.C., 2016, Applying spatial-temporal analysis and retail location theory to pubic bikes site selection in Taipei, *Transportation Research Part A*, 94, pp. 45–61.
[19] The NACTO *Bike Share Station Siting Guide*, http://nacto.org/wp-content/uploads/2016/04/NACTO-Bike-Share-Siting-Guide_FINAL.pdf Access date: 28.07.2017
[20] Pucher J., Garrard J., Greaves S., 2011, Cycling down under: a comparative analysis of bicycling trends and policies in Sydney and Melbourne, *Journal of Transport Geography*, 19 pp. 332–345.
[21] Pucher J., Dill J., Handy S., 2010a, Infrastructure, programs, and policies to increase bicycling: An international review, *Preventive Medicine*, 50, pp. 106–S125.
[22] Pucher J., Buehler R., Seinen M., 2010b, Bicycling renaissance in North America? An update and re-appraisal of cycling trends and policies, *Transportation Research Part A*, 45, pp. 451–475.
[23] Kim D.J., Shin H.C., Im H., Park J., 2012, Factors Influencing Travel Behaviors in Bikesharing, *91th Annual Meeting of the Transportation Research Board and Publication in the Transportation Research Record Series* (Revised paper).
[24] Murphy E., Usher J., 2015, The Role of Bicycle-sharing in the City: Analysis of the Irish Experience, *International Journal of Sustainable Transportation*, 9:2, pp. 116–125.
[25] Kabak, M., Burmaoğlu, S., Kazançoğlu, Y., 2012, A fuzzy hybrid MCDM approach for professional selection, *Expert Systems with Applications*, 39: 3516–3525.
[26] Raut, R.D., 2011, Evaluation of supplier selection criteria by combination of AHP and fuzzy DEMATEL method, *International Journal of Business Innovation and Research*, 5 (4): 359–392.
[27] Çetinkaya, C., Özceylan, E., Erbaş, M., Kabak, M., 2016, GIS-based Fuzzy MCDA Approach for Siting Refugee Camp: A Case Study for Southeastern Turkey, *International Journal of Disaster Risk Reduction*, 18: 218–231.
[28] Eraslan, S., Çağman, N., 2017, A Decision Making Method By Combining TOPSIS and Grey Relation Method Under Fuzzy Soft Sets, *Sigma Journal of Engineering and Natural Sciences*, 8: 53–64.
[29] Hwang, C.L., Lai, Y.J., Liu, T.Y., 1993, A new approach for multiple objective decision making, Computers and Operations Research, 20: 889–899.