International Journal of Academic Research in Accounting, Finance and Management Sciences
Vol. 3, No.4, October 2013, pp. 18–26
ISSN: 2225-8329

www.hrmars.com

Locating of Bicycle Stations in the City of Isfahan Using Mathematical Programming and Multi-Criteria Decision Making Techniques

Mahsa GHANDEHARI[1]
Vahid HAMIDI POUYANDEH[2]
Mohammad Hossein MOSHREF JAVADI[3]

[1,2,3]*Department of Management, University of Isfahan, Isfahan, Iran*
[2]*E-mail: hamidi.vahid@yahoo.com (Corresponding author)*

Abstract *There are several factors that necessitate the use of bicycle as a non-motorized transportation vehicle. Some of these factors include: Increase of the air pollution, many vehicles traveling simultaneously and creating massive traffic in the urban streets, decrease in the citizens' physical activities, and danger of peoples' health. The favorable distribution of bicycle stations that act as the mediator between users and bicycles can play an important role in the increase of bicycle usage. This is the reason that present study was aimed to find the best locations of bicycle stations through mathematical programming and multi-criteria decision making techniques. In order to implement such study, the appropriate criterions of location have been weighted through analytical hierarchy process (AHP), in which final weights of the proposed locations have been calculated through SAW method. In the next step, the combination model has been developed and the final location of bicycle stations has been determined. The results of this study indicated that there were four main factors that influenced the bicycle stations location that some of them had their own sub-factors. These factors included closeness to the bicycle path, transportation and networks, demand, and use type. The resulted locations from combination model indicated reliability of the model.*

Key words Locating of bicycle, Multi-Criteria Decision Making, Mathematical programming, Goal programming

DOI: 10.6007/IJARAFMS/v3-i4/271 URL: http://dx.doi.org/10.6007/IJARAFMS/v3-i4/271

1. Introduction

Every planning effort for cities should be placed on the framework of sustainable development (Rybarczyk and Wu, 2010). The sustainable development refers to which development that considers the present needs with respect to the future generation's abilities for satisfying their needs (Behzadfar and Golrizan, 2008). Transportation is an important and determinant parameter in the all aspects of urban life. This is why the transportation system should be designed so exactly that is coordinated with sustainable development criterions. In order to design a sustainable transportation network, it is necessary that the alternative situations of transportation are accessible (Rybarczyk and Wu, 2010). The use of modern systems of urban transportation is important in the cities with higher levels of urban traffic and air pollution. It is should be remembered that the massive investment of creating and establishing such transportation systems such as metro is one of the limitations of its actualization. In order to achieve these goals, it is necessary to prioritize and design the effective and efficient cases that do not need many costs and its implementation is necessary in the urban transportation network. This is why that it is necessary to study and consider non-motorized transportation vehicles such as bicycle (Hataminejhad and Ashrafi, 2009). The bicycle stations are developed for expanding and improving bicycle culture as a mediator between bicycles and users (Batenipor, 2011). If these stations are established in the desirable locations and has good distribution, it is possible to solve the problem of citizens' access to the bicycle stations. The use of appropriate criterions and related methods of decision making will results in a sound choose in terms of stations location. The multi-criteria method is one of the comprehensive decision making methods that leads to improve decisions quality

through making decision process more clarity and rationalizing and improving its process (Wang and Triantaphyllo, 2008). Finding the best location of bicycle station leads to better use of non-motorized vehicles such as bicycles and walking. The growth of bicycle culture among peoples not only increase their health and happiness, but also decreases air pollution and traffic. This is why that the issue of bicycle and its study has been considered as an important research field by authors and researchers. Also several studies have been done in terms of bicycle that some of them have been indicated in this section. Palomares et al. (2012) employed GIS-based method for measuring the distance distribution of potential traveling demand that find the location of bicycle stations, determine the capacity of the stations, and also define the demand characteristics for stations.

The results of this study have been compared with many of the location-designation modeling approaches. This comparison results in minimizing face resistance and maximizing coverage. The later approach was better for the purpose of this study. Also the number of references has been decreased in both two cases. Based on these results, increase in the stations number leads to less improvement in the coverage population decrease and access to the stations. The reason is that distance construct of the proposed network has an important role in the use of bicycle station. Vogel et al. (2011) in his study that has been entitled “an introduction to bicycle sharing system through data mining: examining the operation style” analyzed the comprehensive operational data from bicycle sharing system for concluding the bicycle operation styles. They used data mining for achieving an insight about complex styles of bicycle operations in the stations. The operation style show imbalance in the bicycles distribution and also leads to a better perception of system structure. The constructed data mining process supports planning and exploiting the decisions for designing and managing bicycle sharing systems. Goetzke and Rave (2011) examined the effective factors on the use of bicycle. They developed a model for bicycling based on the resulted data from a poll about movement and relocation across the country. The results of their study indicated that the effects of social network increases probability bicycling for purchasing and the destinations of leisure traveling not to school and office. Additionally, it is perceived that the bicycle infrastructures are only important for purchase and mission travels. Finally, it is seemed that traveling by bicycle is independent from every policy making variable. Taghvaei and Fathi (2011) studied how to select the appropriate and sound criterions of bicycle paths in different areas with respect to the geographic position and its effective factors. The results of their study revealed that paying attention to the designing quality of bicycle path and also considering appropriate criterions for bicycle paths leads to increase the use of bicycle as an urban non-motorized transportation vehicle and citizens’ leisure. The reason is that the most important factors are considered in the path designing such as citizens’ security and relaxation.

Tahanian and Pakbaz (2010) used Fuzzy-AHP for finding the best location of bicycle stations and then compared their results with the findings of first six month of 2010. Their results indicated that the Fuzzy-AHP can be considered as an appropriate criterion in finding a favorable location of bicycle location and also urban transportation paths. Mokhtari Malekabadi (2010) examined the bicycle and its role in the sustainable transportation system in the city of Isfahan through questionnaire, interview, observation, and correlation coefficient. He also found about 15 locations for bicycle in this city. The results of his study indicated that there is a significant relationship between better access to the bicycle stations and the use of bicycle as a transportation vehicle. Also the results of his study revealed that the number of bicycle stations, bicycle paths designing, and other considerations are not sufficient and the bicycle has not considered as a sport-leisure instrument and has not good position for doing urban traveling and decreasing urban traffics. As indicated in the later section, every studied that have been done in terms of bicycle employ different methods that each of them have their own weaknesses and strengths. This is why that the authors of this study seek to locate the bicycle stations through combining mathematical programming and multi-criterion decision making techniques so that achieve a comprehensive model for achieving their strengths and eliminating their weaknesses. Therefore, the purpose of this study is to locate the bicycle stations. In order to achieve this goal, the following goals have been developed.

1. Determining the goals and criteria of stations location;
2. Determining the proposed locations for establishing bicycle stations;
3. Developing a mathematical model for defining the stations;
4. Determining the most appropriate stations and their locations.

The literature review of this study and research methodology of study has been indicated in the following sections and then findings and conclusion have been presented.

2. Literature review

2.1. Bicycle

The bicycle is a vehicle that has two wheels and is driven by human direction. Some definitions are based on the considerations such as frequency, size, and priority of the wheels (Sadeghi, 2012). Sivarc is the first one that drive bicycle in the history. He constructs a wooden bicycle in 1690 that its wheels are related to each other. This bicycle had not any running pedal and its movement is done by driver's efforts (Alinasab and Forodi, 2011). The bicycle has been considered as a leisure vehicle in the beginning of its invention. The demand for bicycle has been decreased in the beginning of 20th century and appearance of automobile invention as a competitor of bicycle. The issues such as creating a healthy city and sustainable development leads to some changes in the use of personal automobile in the 1980s and then the use of bicycle as a part of urban transportation has been formalized. Bicycle was entered to Iran before 2th world war. It was considered as an expensive vehicle in the beginning of its introduction in Iran and only wealthy peoples could purchase it. The import of bicycle to Iran was increased after 2th world war and also its price was decreased during this period. Rapid growth in the number of automobile in Iran in the beginning of 1970s and the lack of necessary security for cyclists and lack of the government's attention to the different levels of planning leads to decrease the importance of bicycle as a vehicle. Nowadays, bicycle is considered as a public vehicle because of lack of access to the automobile and motorcycle (Gharib, 2004).

2.2. Facilities location

The location is an activity that is done for choosing the most appropriate place for an especial application that analyzes the capabilities and abilities of a region from different aspects such as appropriate and sufficient land and its relationship with urban applications (Pirmoradi, 2012). The study of location theories is started from 1909 by Alfred Weber's efforts for determining the location of a store so that minimize total distance between store and customers. The theory of facilities location and its applications has been attended by authors and researchers in different areas and also several models have been developed and introduced in this area. The issue of facilities location can be grouped from different aspects (Aminbashian, 2010).

2.3. Multi-Criteria Decision Making

Decision making refers to the selection of an option (an appropriate one) from different alternative options in the conditions that there is more than one criterion in the selection process. This situation refers to the multi-criteria decision making. Generally, the methods of multi-criteria decision making methods can be grouped in two overall sets including multi-criteria decision making and multi-purpose decision making methods. The first methods are related to the strategies and alternatives that are small, limited, and numerable (Ansari, 2010). In such models, the decider considers several purposes rather one in the decision making process. These models are used in the problems that the decider wants to design and find an ideal solution (NorbakhshBaghbadrani, 2010). On the other hand, the second type of the solutions is related to the strategies and options that are big, unlimited, and innumerable (Ansari, 2010). In these models, the decider seeks to select the best alternative with respect to the goal and considering the criteria (NorbakhshBaghbadrani, 2010). The analytical hierarchy process (AHP) is one of the multi-criteria decision making methods that can be combined with mathematical programming methods. This is considered as one of the most important and more applicable methods of ranking and multi-criteria decision making.

2.4. Analytical Hierarchy Process

The analytical hierarchy process is one of the most comprehensive designed systems of multi-criteria decision making. This technique formulates the problem in a hierarchical manner and also paves the ground for considering different quantitative and qualitative criteria in the problem. This process provides the possibility of considering different options in the decision making process and also the possibility of sensitivity analysis on the criteria and sub-criteria (Ghodsipor, 2005).

2.5. The Simple Additive Weighting method

This is one of the historical methods that can be used in the multi-criteria decision making so that can find the best option with regard to the predetermined vector of criteria weights importance (Asgharpor, 1998). This process has been described in the following section.

$$A^* = \left\{ A_i \left| \max_i \frac{\sum_j w_j r_{ij}}{\sum_j w_j} \right. \right\} \quad (1)$$

2.6. Mathematical Programming

The mathematical programming refers to the construction of mathematical models of the natural conditions in order to determine the best structure of the systems with respect to the considered purposes and their limitations (Taha, 1998). The algebraic form of this technique has been showed in the formula 2.

$$Max\ Z = \sum_{j=1}^{n} w_j x_j \quad (2)$$

Subject to.

$$\sum_{j=1}^{n} a_{ij} x_j (\leq = \geq) b_i \quad i = 1, \dots, m$$

$$x_j \geq 0 \quad j = 1, \dots, n$$

2.7. Goal Programming

Charnes and Cooper introduced this method for the first time in 1960. As the name of this method shows, the decider seeks to determine a goal for every purpose. The overall style of goal programming has been indicated in the following section.

$$Min\ Z = \sum W_i (d_i^+, d_i^-) \quad (3)$$

Subject to.

$$\sum a_{ij} x_j + d_i^+ - d_i^- = b_i$$

$$x_j, d_i^-, d_i^+ \geq 0$$

X_j: decision variables;
W_i: goals weight;
d_i^-: negative deviation from goals;
d_i^+: positive deviation from goals;
a_{ij}: technical coefficients;
b_i: resources;
Z: weighted sum of the variations from goals.

Goal programming seeks to minimize the weighted sum of the deviations from goals as much as possible and also seeks to enter the related variables to the goal function if the controls of positive and negative variations are important for planner. If both two variations are favorable for planner, their variables are entered to the goal function (Shahin and AhmadiAzar, 2012).

3. Research methodology

This study is an applied research from purpose perspective and is a descriptive-survey one from research methodology perspective. This study has been done in the city of Isfahan. The data collection method in such studies is library method. Also the experts' viewpoints are collected in some cases. In order to do this, the municipality responsible officers' viewpoints were collected. In order to determine the criteria and sub-factors' weights, the paired-comparison questionnaire can be used. In order to analyze the data, several software such as: Expert Choice, Excel, and Lingo were used. The appropriate criteria and goals of the bicycle stations location can be achieved through library studies and interview with experts. The proposed places for establishing new bicycle stations were resulted from interview with municipality officers. Also the weight of

every criteria and sub-criteria can be calculated by Expert Choice. The alternatives' weight or proposed places can be calculated through SAW method. In the final step, it is possible to develop the final model and find the best location of the bicycle stations through the resulted weights from past step and the existing limitations. The final solution can be calculated by Lingo. The parameters of the combinative model have been indicated in the following section.

$$Min\ Z = d_1^+ + d_2^- \quad (4)$$

Subject to.

$$\sum_{i=1}^{n} w_i x_i + d_1^+ - d_1^- = U \quad (5)$$

$$\sum_{i=1}^{n} c_i x_i + d_2^+ - d_2^- = C \quad (6)$$

$$\sum_{i=1}^{n} x_i = N \quad (7)$$

$$d_{ij} * y_{ij} \geq L * y_{ij} \quad (8)$$

$$d'_{ij} * y'_{ij} \geq L * y'_{ij} \quad (9)$$

$$y_{ij} \leq x_i \quad (10)$$

$$y_{ij} \leq x_j \quad (11)$$

$$y_{ij} \geq x_i + x_j - 1 \quad (12)$$

$$y'_{ij} = x_j \quad (13)$$

$$x_i, x_j, y_{ij}, y'_{ij} \in \{0,1\} \quad (14)$$

d^+_1: the positive deviation from first goal (maximizing the station's utility);
d^-_1: the negative deviation from first goal (maximizing the station's utility);
d^+_2: the positive deviation from second goal (minimizing the costs of stations establishment);
d^-_2: the negative deviation from second goal (minimizing the costs of stations establishment);
W_i: the weight of the station;
C_i: the costs of station establishment;
U: the amount of first goal;
C: the amount of second goal;
X_i: binary variable that will be 1 if the station is established and it will be 0 if the station is not established;
X_j: binary variable that will be 1 if the station is established and it will be 0 if the station is not established;
Y_{ij}: is a dependent variable to X_i and X_j. If X_i=X_j=1 then its value will be 1 and otherwise it will be 0;
d_{ij}: distance between two proposed stations;
d'_{ij}: distance between two proposed stations;
n: the number of propped stations;
L: the minimum distance between two stations;
y'_{ij}: is a dependent variable to the X_j. If X_j= 1 then its value will be 1 and otherwise it will be 0.

The 4th formula seeks to minimize the unfavorable deviations. The 5th formula seeks to maximize the utility of the stations. The 6th formula seeks to minimize the costs of stations construction. The 7th formula refers to the number of necessary stations. The 8th formula indicates that the distance between proposed stations should not be more than a predetermined value. The 9th formula indicates that the distance between proposed stations with existing station should not be less than a predetermined value. The 10th and 13th formulas refer to the dependency of y_{ij} and y'_{ij} variables with respect to the X_i and X_j. The 14th formula refers to the binary of X_i, X_j, y_{ij}, and y'_{ij}.

4. Findings

After doing library studies and examining the articles and thesis in this area and interviewing with experts, four criteria have been developed that some of them have their own sub-criteria. These include closeness to the bicycle path, transportation and networks, demand, and use type. The public transportation criteria consists of three sub-criteria including good access to the main arteries, public transportation network (such as bus), and the number of automobile parking. The use type consists of three sub-criteria including administrative area, trade area, and residential area. The demand consists of three sub-criteria including the number of schools, the number of historical and attractive locations, and the number of parks and leisure areas. The hierarchical tree of this study has been showed in the figure 1.

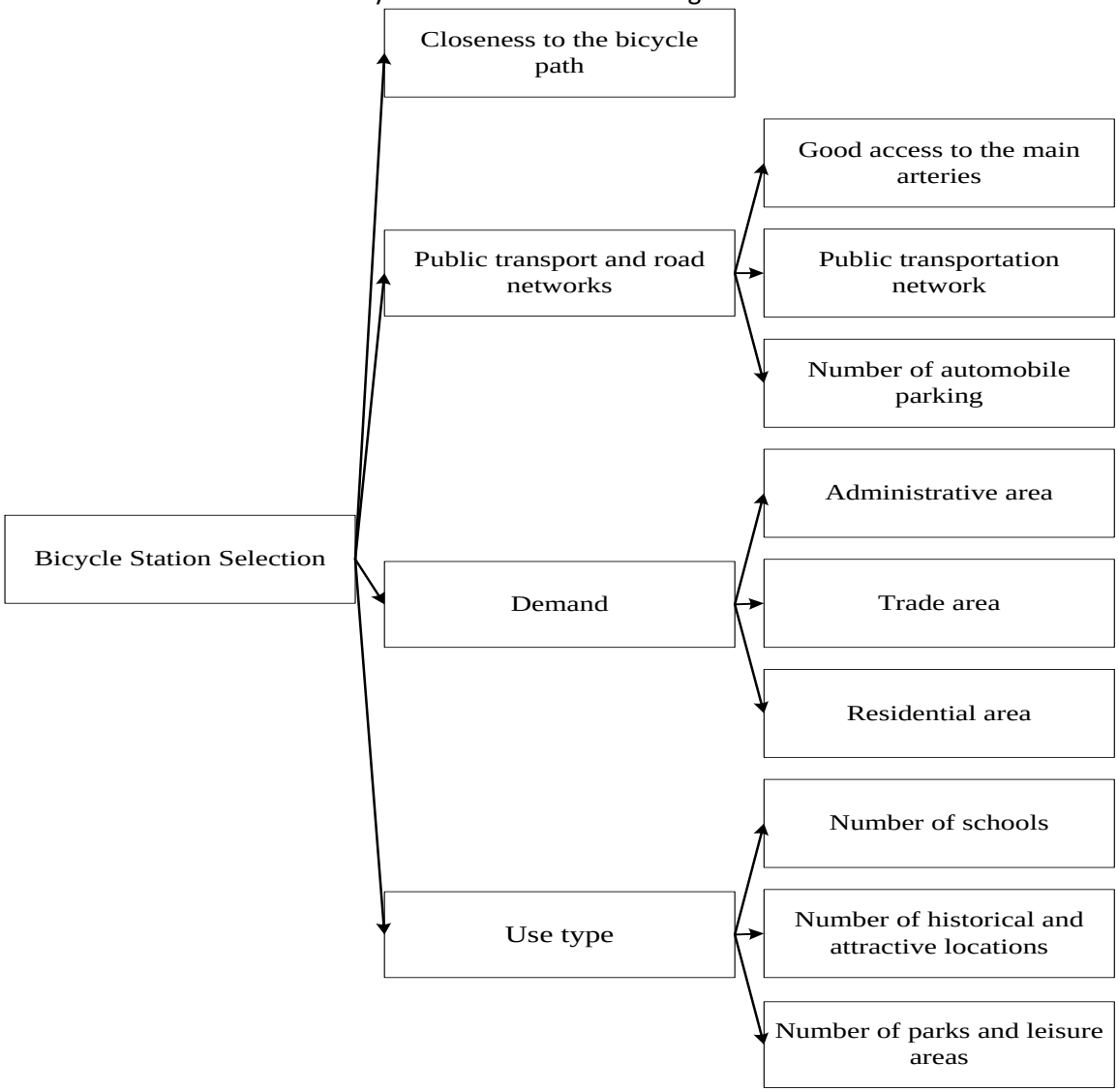

Figure 1. Hierarchical tree of criteria and sub-criteria

In the next step, the proposed bicycle stations have been recognized through urban map from city regions and interviewing with municipality officers. There are several effective factors in selecting the proposed locations such as the sufficient land for station establishment, geographic position of the proposed location, geographic position of the existing stations, and natural obstacles.

After interviewing with municipality officers, “maximizing utility of the stations in every region” and minimizing the costs of station establishment” have been considered as the main purposes. After recognizing criteria and the alternatives, it is necessary to extract the overall and local weights in order to use in the mathematical model. Also it is necessary to provide the municipality officers with paired-comparison questionnaire for determining the criteria and sub-criteria weights through resulted criteria and sub-criteria.

In order to this, Expert Choice has been employed. The resulted weights of criteria and sub-criteria have been indicated in table 1.

Table 1. Weights of criteria and sub-criteria

Criteria	Local Weight	Sub-Criteria	Local Weight	Global Weight
Bicycle path	0.3136	-	-	0.3136
Public transport and road networks	.1586	Good access to the main arteries	0.2692	0.0427
		Public transportation network	0.5188	0.0823
		Number of automobile parking	0.2119	0.0336
Use type	0.1901	Administrative area	0.2174	0.0413
		Trade area	0.4545	0.0864
		Residential area	0.3280	0.0623
Demand	0.3375	Number of schools	0.4743	0.1600
		Number of historical and attractive locations	0.1910	0.0644
		Number of parks and leisure areas	0.3346	0.1129

In order to achieve the criteria weights in comparison to the criteria and sub-criteria, the SAW method has been employed. In order to this, it is necessary to normalize the data. In the next step, the authors multiply the normalized data with criteria and sub-criteria weights so that calculate the final weight.

After doing the past calculation, the weight of every proposed location can be calculated that they should be used in the problem model. It is possible to determine the best regions of bicycle stations through solving this problem. The results of this problem solving have been indicated in table 2.

Table 2. The final locations for construction of bike stations

Area	Number of proposed location	Geographic Position of proposed location
1	Three	Intersection of Beheshti Street, Abbas Abad Street and Saeb Street
2	Two	Shahidan street, Next municipality of region 2
3	One	Intersection of Ostandari street and Farshadi street
4	One	Intersection of Bozorgmehr street and HashtBehesht street
5	Five	ChaharBaghBala, Nazar Intersection
6	Four	Intersection of Imam Sajjad street and Khalili street
7	One	ShahidChamran Highway, Eshragh street
8	Two	Kaveh Street, next to the Kaveh passenger terminal
9	Two	Intersection of Atashgah street and Behesht street
10	One	Intersection of Soroush street and Askarieh street and SaghireIsfahani street
11	Four	Imam Khomeini Highway, East Sharif street
12	Two	Intersection of Baharestan street and Mofatteh street
13	Four	Highway ShahidHabibullah, Zayandehroud passenger terminal
14	Three	Intersection of Zeynabieh street and AmanSamani street

5. Discussion and conclusion

The bicycle and its importance in the urban transportation in many of Iran's cities are not attended considerably. The rental bicycle stations as a component of urban services is the mediator between users and bicycles is determined to develop the culture of bicycling across the city of Isfahan. If these stations are established in the appropriate locations can leads to the citizens' tendency to use the bicycles. The use of appropriate decision making criteria and methods can leads to better location of the bicycle stations. This is why the authors of the present study seek to find the best location of bicycles stations through mathematical programming and multi-criteria decision making techniques in the city of Isfahan. For this purpose, several steps have been passed. In the first step, the appropriate goals and criteria of location have been developed

through library and interviewing experts. In the second step, several points of every municipality regions have been recognized as bicycle stations through interviewing municipality officers. In the final step, every proposed points received a weight through MCDM methods and then the final scores of every point has been calculated through Lingo with respect to existing limitations and resulted weights from previous step. Four criteria have been developed including closeness to the bicycle paths, public transportation network, the type of use, and demand. Also two main purposes have been considered as main goals including maximizing the utility of stations in every region and minimizing the costs of station establishment in every region. Several points have been candidate in every urban region based on the Isfahan city map and the location of existing stations. The best locations of bicycle stations have been recognized through solving the model in all of the 14 urban regions.

There are several limitations and problems in every research. Some of the problems and limitations of this study have been indicated in the following section.

- Lack of sound information in some areas that the authors are forced to use quality information in order to do paired-comparisons
- The use of statistics of an especial time period for doing calculations because of lack of updated statistics and information
- The location of bicycle stations with respect to considering the existing conditions and lack of attention to the urban development.

Because the present study only considers the location of bicycle stations and the number of allocated bicycles for every station is not studied in the present study, it is suggested that the future authors employ methods such as simulation and line theory for achieving precise information about transportation of every station in order to determine the number of bicycles that are needed in every region. Also it is suggested that other studies are done in terms of bicycle stations paths through outputs of this study and the GIS information. The authors of this study used interview for finding the proposed primary points and its criteria have been considered for determining the primary locations, it is suggested that the future authors use another methods. For example, it is suggested that the future studies acquire the utility and traffic information of different regions and then consider some of these points as proposed points. The model of this study is a hard model, it is suggested that the future authors employ the creative methods for determining the best location of bicycle stations and then compare its results with findings of our study.

References

1. Alinasab, M.A., Forodi, Sh., (2011). The Sustainable Urbanism Paradigms with Focus on the Bicycle, Report, No. 68, pp. 77-87.

2. Aminbashian, J., (2010). The Location of Hierarchical Coverage in a Multi-period Time Period with respect to the Increasingly Demand Trend, (the Case of Maintenance Centers of CNG), M.A. Thesis of Industrial Engineering, Faculty of Industrial Engineering and Systems, Isfahan University of Technology.

3. Ansari, M. R., (2010). Determining the Favorable Maintenance Plan through Combinative Approach of MCDM-GP, M.A. Thesis of Industrial Management, Department of Management, Faculty of Administrative Sciences and Economics, University of Isfahan.

4. Asgharpor, M.J., (1998). Multi-criteria Decision Making, firs edition, Tehran, Publications of University of Tehran.

5. Batenipor, N., (2011). Designing the Bicycle Stations in Kish Island based on the User-based Approach, M.A. Thesis, Department of Art, Kish Branch, University of Tehran.

6. Behzadfar, M., Golrizan, F., (2008), The Sustainable Transportation, International Monthly of Road and Building, No. 55, pp. 16-28.

7. Gharib, F., (2004). Study the Feasibility of Establishing Walking and Bicycle Paths in the Areas of Tehran Ghadim, Journal of Beautiful Arts, No. 19, pp. 17-58.

8. Ghodsipor, H., (2005). Analytical Hierarchy Process, Tehran: Publications of Amirkabir University of Technology.

9. Goetzke, F., Rave, T. (2011). Bicycle Use in Germany: Explaining Differences between Municipalities with Social Network Effects. Urban Studies. 48, (2), 427-437.

10. Hataminejhad, H., Ashrafi, Y., (2009). The Bicycle and its Role in the Sustainable Urban Transportation: The Case of Bonab City, Journal of Research in Human Geography, No. 70, pp. 45-63.

11. MokhtariMalekabadi, R., (2010). The Geographical Analysis of the Bicycle Role in the Sustainable Transportation System in the city of Isfahan, Journal of Regional and Urban Studies and Researches, No. 3, Issue. 9, pp. 101-122.

12. NorbakhshBaghbadrani, A., (2010). Defining the Wheat Import Model under the Uncertainty Conditions (the Mathematical Fuzzy Multi-criteria Programming), M.A. Thesis, Department of Economics, Faculty of Sciences and Economics, University of Isfahan.

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, 235-246.

14. Pirmoradi, A., (2012). Finding the Best Location of Firing Station through It and GIS, Journal of Artificial Intelligence and precise Instruments, Vol. 6, No. 3. Pp. 13-18.

15. Rybarczyk, G., Wu, Ch. (2010). Bicycle facility planning using GIS and multi-criteria decision analysis. Applied Geography, 30, 282-293.

16. Sadeghi, Z., (2012). An Introduction to the Non-motorized Transportation across the World, The Transportation and Traffic Assistant of Isfahan Municipality, The Planning and Studies Administration, pp. 5-7.

17. Shahin, A., Ahmadi Azar, M., (2012). Determining the Optimum Combination of the Customers based on the Kano through Goal Programing: The Case of Isfahan Alzahra Hospital, Journal of Health Information Management, Vol. 9, No. 4, pp. 525-538.

18. Taghvaei, M., Fathi A., (2011). The Criteria of Location and Designing the Bicycle Stations in the city of Isfahan, Journal of Applied Sociology, No. 22, Issue. 43, pp. 135-152.

19. Taha, H., (1998). An Introduction to Operation Researchers, Linear and Dynamic Programming, translated by Mehdi Bazargan to Persian, Tehran: MarkazeNashreDaneshgahi Publications.

20. Tahaneian, A.R., Pakbaz, A.A., (2010). Prioritizing the Bicycle Stations Locations through Fuzzy-AHP and Statistical Comparison, pp. 1-15.

21. Vogel, P., Greiser, T., Mattfeld, D.Ch. (2011). Understanding Bike-Sharing Systems using Data Mining: Exploring Activity Patterns, Procedia Social and Behavioral Sciences, 20, 514-523.