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Parking site selection management using Fuzzy logic and Multi Criteria Decision Making

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Abstract

The construction of new service centers is very costly and the optimal site selection of these centers, one of the parameters for determining their degree of effectivencess, is of high importance. Public parkings are an example for these service centers. Population growth, sprawling of cities and increasing of vehicles result in heavy traffic and prolonged city trips.Utilizing public parkings can be regarded as an effective approach to abate traffic load in city centers, in that spaces designated for vehicles parking along the roads would be freed, and consequently the usable space of the roads would increase, which in turn would contribute to the smooth flow of traffic. In this paper, we describe an ideal method for parking site selection by the use of GIS, fuzzy logic and weighting criteria to determine proper parking sites. Suitable place for parking is selected for one of the high traffic regions of Esfahan city in Iran.

Keywords: parking site selection; weighting criteria; Analytical Hierarchical Process (AHP); fuzzy logic.

1. Introduction

By rapid growth of cities and towns, urban transport system such as vehicles, pedestrian crossing and streets, are playing a major role in transportation system and human beings, and it is apparent that by existence of quandary and problems in these transport system, the urban management system would be faced serious problems and consequently, living in these areas will be impossible. Suitable site selection for public parking spaces not only increases the parking efficiency, but it also decreases marginal car parking and so results in increase of streets' width and traffic fluency (Ghaziasgari, 2005; Karimi *et al*., 2006).

Transportation is one of the fastest growing of many fields in modern and developing urban areas. Nowadays, site selection of public parking lots in cities of Iran is done by a traditional method, in which this issue causes inefficiency of these parking lots and makes traffic problems. On these days, use Geographical Information System (GIS) for public parking site selection, has the ability to analyze many parameters simultaneously.

2. Determining the effective criteria in parking site selection

There are many parameters to determine site selection of parking lots. Considering civic construction and traffic critics views, effective parameters in parking site selection are classified into six main classes, which every class includes several subclasses. Table 1 shows the effective criteria and sub-criteria in parking site selections.

Civil engineering and traffic expert described that distance from absorbing excursion spaces and major streets are important parametes (Ghaziasgari Naeeni, 2005). People are no longer content spending entire days and weekends adding unnecessary miles to their vehicles, driving to businesses, restaurants, entertainment venues, and so on, that are scattered across broad areas. The response has been a shift in focus to the construction of multi-use high-rises and town centers, creating several opportunities for consumers and business owners to build on complementary uses and activities. In both mixed-use high-rises and town centers, housing, offices and retail are concentrated in one place, making it easier for consumers to get to a variety of destinations. Consequently, visitors entering the city and local residents moving in the city area will create traffic problems and this condition is worsens by lack of some services centre such as parking lots. The requisition of these regions for parking lot construction in such area is a major factor to determine minimum parking space. Therefore, a study has been conducted in Esfahan city in Iran with the objective is to determine the most suitable parking site using Geographical Information System (GIS), fuzzy logic and weighting criteria methods.

3. Methodology

The considered study area includes three traffic regions of Esfahan city, which is in center of Esfahan

Table 1. Efficient criteria in parking site selection

Criteria	Sub-criteria
Distance from absorbing excursion space	Trade, official centres, servicing, recreative, tourist, parks, educationl buildings and hospital
Attainment of major streets	Pedestrian and streets crossing, streets width
Construction	Premises value
Population	Population density
Efficient landuse for parking places	Ruined buildings, comprehensive parking, garages, comprehensive schools, stadium and green spaces, existing green spaces
Inappropriate usage	**Major trade and official centres, 50 meters hospitals buffer, historical centres and mosques.**

and one of the most crowded areas. Most of the historical buildings, mosques, official, trade and tourist centres are located in this part of the city.

In this study, process of determination the best suitable parking area was divided into three steps. Firstly, effective criteria for parking selection will be described by giving proper weightage and used in Multi Criteria Decision Making (MCDM). Analytical Hierarchical Process (AHP) approach was selected in this stage and after the selection criteria has been made, mathematical models were developed using results of Pairwise Comparison model. Secondly, the mathematical models were used in GIS for selected area. Finally, the best suitable parking area was searched using fuzzy logic.

3.1. Weighting criteria process

At this part after describing effective criteria and sub-criteria in parking site selection, a proper weight should be prescribed for this criteria. One of the major issues for decision- making is Multi Citeria Decision Making (MCDM) for criteria and sub-criteria. There are various methods for weighting criteria including Ranking method, Rating method, Pairwise Comparison, and Trade- off Analysis method. Ranking and Rating methods are used for short time, less expense and weighting criteria but if accuracy is a major factor, Pairwise Comparison and Trade-off Analysis will be used.

Among of above methods, AHP approach was preferred to other methods for weighting parking lots parameters, regarding to its double comparison for parameters, simplicity of using of this approach and its high accuracy. However, the major problem of this method is referred to a complete trust to critical outlooks; nevertheless, this problem has been sort out using AHP fuzzy approach (Ghaziasgari naeeni, 2005). The basic principle of both of these approaches are similar, therefore, the AHP approach has been explained firstly and in continuous, differences between AHP and AHP fuzzy approaches have been presented.

Table 4 shows the numerical values of judgments. The AHP method has been constructed on the foundation of three basics of analysis, comparison judgment and priority composition. Analysis basic needs analyzing decision-making problems to various elements regarding AHP scheme. It means that the first step is to create a tree structure for criteria and sub-criteria. The comparison judgment basic describe the comparability for existence of elements in an AHP structure level. These weights could be either calculated individually or an integration of critics judgments which has been employed in this study. After several numbers of double comparison and AHP, the results of comparisons were structured for parking site selection.

3.2. Models used in structure of public parking

According to the results of Pairwise Comparison

Table 2. Average of walking distances from tourist absorbing centres base on the population

	100000	100000- 250000	250000-500000	500000 >	Average
Trade centres	105	157	190	187	135
Official centres	137	167	223	217	160
Official centres	97	130	150	200	120

Table 3. Maximum walking distance from tourist absorbing centers

Population	Parking Type	
	Short time	Long time
> 250000	66-120 m	200-320 m
< 250000	166-266 m	330-500 m

model, equation 1 is shown the proper model for parking site selection.

$$F = (0.427\ f_1 + 0.235\ f_2 + 0.125\ f_3 + 0.046\ f_4 + 0.166\ f_5)\Pi C_j \quad (1)$$

Where, f_1= distance from absorbing excursion spaces, f_2 = attainment area, f_3 = premises value, f_4 = population density, f_5 = Layer preparation for the structure of parking and Cj = Inappropriate usage.

All of the parameters in equation1 are unstable and changeable. They are depends on criteria and sub-criteria. For example in equation, 2 show the sub-criteria of efficient used in parking site selection.

$$f_5 = 0.341Y_1 + 0.238Y_2 + 0.167Y_3 + 0.100Y_4 + 0.063Y_5 + 0.063Y_5 + 0.061Y_6 + 0.030Y_7 \quad (2)$$

Where Y_1 is comprehensive parking, Y_2 is ruined buildings, Y_3 is garages, Y_4 is comprehensive schools, Y_5 is comprehensive stadium, Y_6 is comprehensive green spaces and Y_7 is, existing green spaces.

3.3. Use of the models in GIS

At this part, after determining the effective parameters and sub-parameters in parking site selection and identified weighting criteria, they will be use in the study areas.

Table 4. Numerical values of judgments

	Comparison	Judgment
1	Comprehensive parking change to ruined buildings	3
2	Comprehensive parking change to garages	3
3	Comprehensive parking change to schools	5
4	Comprehensive parking change to stadium	5
5	Comprehensive parking change to comprehensive green spaces	7
6	Comprehensive parking change to existing green spaces	9
7	Ruined buildings change to garages	2
8	Ruined buildings change to schools	5
9	Ruined buildings change to stadium	5
10	Ruined buildings change to comprehensive green spaces	6
11	Ruined buildings change to existing green spaces	9
12	Garages change to schools	4
13	Garages change to stadium	3
14	Garages change to comprehensive green spaces	4
15	Garages change to existing green spaces	7
16	Schools area change to stadium	1
17	Schools area change to comprehensive green spaces	2
18	Schools area change to existing green spaces	4
19	Comprehensive stadium change to comprehensive green spaces	2
20	Comprehensive stadium change to existing green spaces	4
21	**Comprehensive green spaces change to existing green spaces**	**3**

Table 5. Standard of distance to street by fuzzy method.

Distance	0	120	200	320	800
Fuzzy logic	1	0.678	0.153	0.082	0.001

3.4. Selecting case study region for parking lot site selection by Fuzzy method

The basic concepts of this method are similar to AHP method, but contrary to the former method in which critics opinions were entered as an absolute number to the weighting procedure. In this approach, critic opinions are entered to the weighting procedure as a number base, which expresses a non-confidence to the critic opinions totally. This number base is entered to the weighting procedure, which is known as Byte and 0-255, which consists of consequence of models of second and third level. Table 5 shows the standard of distance to street by fuzzy method.

The ordered weighted averaging (OWA) operator, which was initially introduced by Yager (1988), has attracted much interest among researcher. Since then several applications of the OWA operators are reported in different areas, such as decision-making, expert systems, neural networks, group decision making and fuzzy systems and control. More applications of OWA are recently reported in multiple criteria decision-making and preference ranking.

The generality of OWA is related to its capability to implement different combination operators by selecting appropriate order weights. By specifying suitable order weights, it is possible to change the form of aggregation from the minimum-type combination through all intermediate types including the conventional weighted linear combination, to the maximum-type combination. This study focuses on the OWA method and IDRISI Andes in parking site selection.

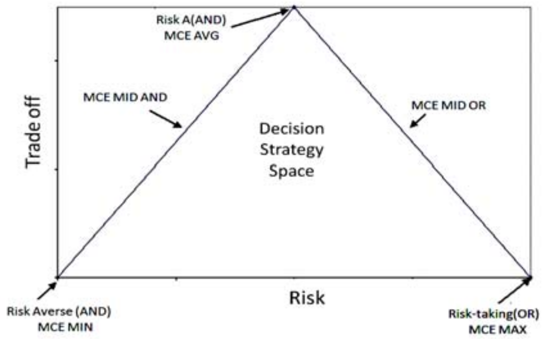

Figure 1. Decision Making by OWA

4. Results

4.1. Risk averse and MCE min

In this part, distance from absorbing excursion spaces is the most important and efficient factor. The existence layer in sub-classes is integrated by together and related map to main classes are prepared. At this stage, the parking site selection map was divided into seven classes and the results from this method are shown in Fig. 2 and Table 6. Regarding to the integration models in the region, seven items were selected for parking location. According to the results, the requisition of these regions for best, better and total sites are 174 m^2, 5389 m^2 and 5563 m^2, respectively.

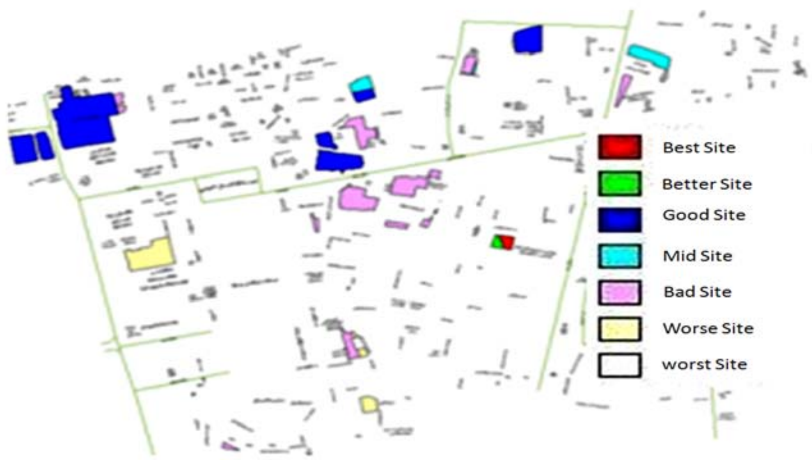

Figure 2. The best suitable parking site selection by OWA method, Risk averse and MCE min

Table 6. The result of OWA method for Risk averse and MCE min

Desirability	Best site	Better site	Good site	Mid site	Bad site	Worse site	Worst site
Minimum	115-123	108-115	95-108	70-95	40-70	1-40	0
Total	173	5389	14593	203920	131743	86456	50385
Average	43	598	810	1158	1568	847	1259
Maximum	130	2804	9954	39083	35365	11340	23196

Table 7. The result of OWA method for Risk Minimum and MCE MID

Desirability	Best site	Better site	Good site	Mid site	Bad site	Worse site	Worst site
Minimum	153-169	137-153	120-137	90-120	50-90	1-50	0
Total	14261	3261	8948	18184	698	26445	1397325
Average	4753	452	426	343	77	314	34933
Maximum	10439	999	2996	4001	276	7572	1397334

4.2. Risk Minimum and MCE MID

In this part, distance from absorbing excursion spaces and from major streets is an efficient criteria than other criteria and sub-criteria. The best suitable sites for parking are shown in Fig. 3 and also their results are indicated in Table 7. The results showed that the requisition of these regions for best, better and total area were 14261 m^2, 3261 m^2 and 16522 m^2, respectively, indicating that these areas can be utilized for multifloor public parking.

4.3. Risk Average and MCE AVG

In this part, the best suitable parking area was chosen using weighting criteria approach as shown in Fig. 4. Other suitable sites for parking and related results of OWA analysis also showed in Fig. 4 and Table 8. Based on the results of OWA method, the best suitable parking area was 14177 m^2 and for better sites was 3490 m^2.

4.4. Risk Maximum and MCE MID

Distance from absorbing excursion spaces, from main streets and Premises value is an important criteria where every site must be involved one of these criteria and sub-criteria. The best suitable parking area was chosen using weighting criteria approach as shown in Fig. 5. Other suitable sites for parking and related results of OWA analysis also showed in Fig. 5 and Table 9. Based on the results of OWA method, the best suitable parking area was 1543m^2, better sites was 17012m^2 and total was 18555m^2.

Figure 3. The best suitable parking site selection by OWA method, Risk Minimum and MCE MID

Table 8. The result of OWA method for Risk Average and MCE AVG

Desirability	Best site	Better site	Good site	Mid site	Bad site	Worse site	Worst site
Minimum	160-178	142-160	124-142	90-124	50-90	1-50	0
Total	15177	3490	15610	10075	12916	13526	1397325
Average	5059	174	678	296	258	287	34933
Maximum	10356	2394	4256	2868	4151	6136	1397334

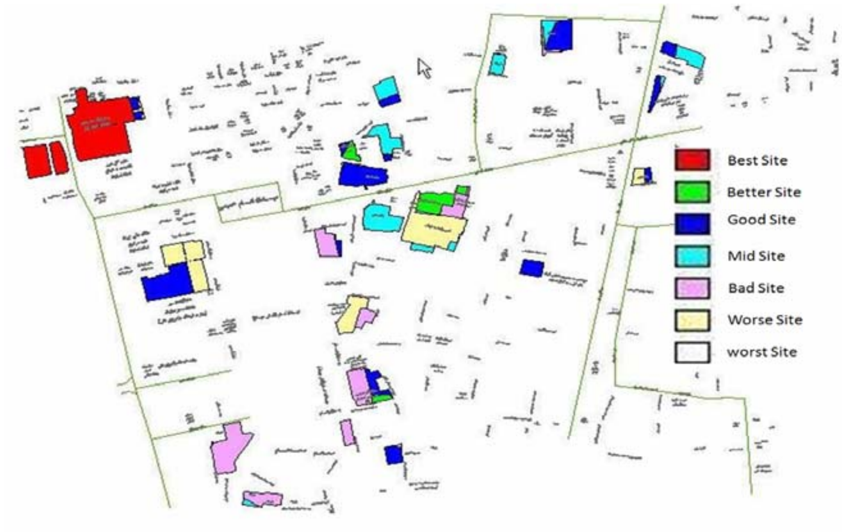

Figure 4. The best suitable parking site selection by OWA method, Risk Average and MCE AVG

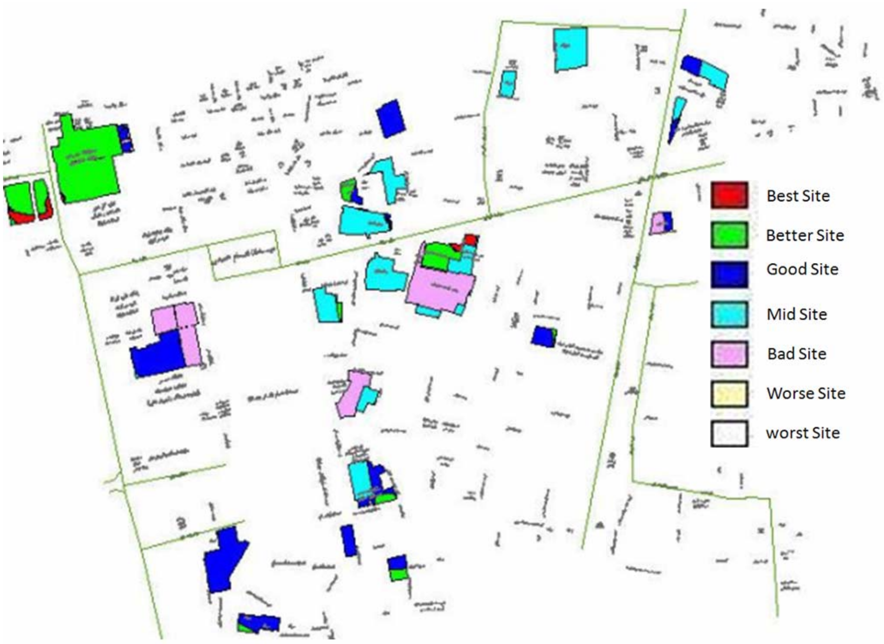

Figure 5. The best suitable parking site selection by OWA method, Risk Maximum and MCE MID

Table 9. The result of OWA method for Risk Maximum and MCE MID

Desirability	Best site	Better site	Good site	Mid site	Bad site	Worse site	Worst site
Minimum	175-193	152-175	133-152	100-133	50-100	1-50	0
Total	1543	17012	17627	20087	13525	0	1397325
Average	90	418	275	365	6136	0	34933
Maximum	542	11289	4197	3246	6136	0	1397334

Table 10. The result of OWA method for Risk- Taking (OR) MEC MAX

Desirability	Best site	Better site	Good site	Mid site	Bad site	Worse site	Worst site
Minimum	255-230	230-205	205-180	180-130	130-60	60-1	0
Total	26668	277	11145	22705	0	0	1397325
Average	2619	55	1592	756	0	0	34933
Maximum	11368	188	8666	6923	0	0	1397332

4.5. Risk- Taking (OR) MEC MAX

It is intended to find out the most appropriate location analysis is processing in GIS. For reclassification and format conversion, weight criteria are not important factor in this part. Therefore overlay method was employed in this study. Each site must have at least one criteria for suitability as a parking site. Fig. 6 shows the parking site selection based on OWA method and Table 10 shows the related results of the method. Based on the results of OWA method, the best suitable site for parking place is 26668 m^2.

5. Conclusions

Parking site selection performed using conventional approach, which does not have the ability for utilizing all of the effective citeria. Accourding to theresults of Overlay, OWA mthods and Fuzzy logic important results for parking site selection is as follows:

- The OWR method and weighting criteria and sub-criteria is bearing under consideration in Fazzy logic method that they are used in decision making in parking site selection. Among the available integration methods for parking site selection, OWA method has been prescribed as the best integration methods.
- Using this method in parking lot site selection instead of conventional methods, would cause increase in site selection process rate as well as its appropriate workability for constructed parking lot.
- The obtained results from OWA method in this study showed suitable sites based on main criteria weights are changeable in difference methods for decision making in terms of parking site selection management.

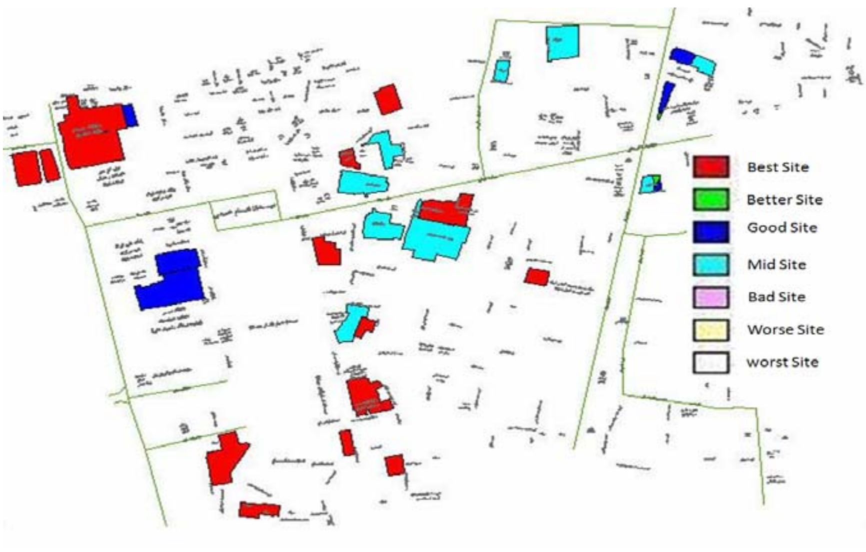

Figure 6. The best suitable parking site selection by OWA method, Risk- Taking (OR) MEC MAX

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