Public Parking Site Selection using GIS

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ABSTRACT

Nowadays by the increase of the population, most of the large cities suffer from the lack of public parking spaces. Public parking spaces as one of the important parts of a modern urban transportation system, plays an important role in decreasing the load of heavy traffic.
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. At the moment in most of the cities, public parking site selection is done by traditional methods or just visiting of the site. In this traditional method, considering all of the effective parameters in site selection is almost impossible and site selection is done by just considering some limited factors like land price. Therefore, in some cases this causes the selected site for parking to fall in area so far from tourist absorbing centres, or far from crowded streets, and finally the heavy traffic in city.
Geographic Information System (GIS), as a science of analysis of spatial and attribute data, is an efficient tool to find optimum place for public parking. In this field of studies use of GIS results in decrease of field visit and increase of accuracy and reliability of results. In this paper, we introduce an optimum method for parking site selection by the use of GIS and considering almost all of the effective parameters simultaneously.
In this article, effective factors are considered from two main points of view including parking efficiency and the problem of providing required land for parking especially in cities central regions. Then, conceptual model of parking site selection is presented. Suitable place for parking is also selected for one of the high traffic regions of Shiraz city in Iran. Different methods for information and layer integration are used and finally these methods are compared and the most suitable one is proposed.

Keywords: public parking site selection, GIS, multi criteria decision making, AHP, Fuzzy logic, Index overlay

Introduction:
By rapid growth in inhabited cities and towns, urban transport system such as vehicles, pedestrian crossing and streets, are playing a major role in transporting goods 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.

As regards, public parking lots, as a major part of modern urban transportation system, have a vital task in providing some places for extracting motionless traffic from urban transportation system, and as a result make a decrease in crowding and traffic densities. Appropriate site selection of these centres will tend to their workability increment and street parking reduction. Nowadays, site selection of public parking lots in Iran towns and cities is done by a traditional method, in which this issue causes inefficiency of these parking lots and even makes traffic problems.
Thereafter, it is necessary to employ new systems which have the ability to analyze a lot of parameters simultaneously, in parking site selection. One of these systems is known as Geographical Information System (GIS). Currently, GIS abilities are utilized in various fields [5,6]. Municipal service centres site selection, is one of the GIS usage in urban management. Of the applied works about parking field, Weant studies could be cited. He performed studied in relation to requirements of some cities in USA, to new parking lots by using GIS [1]. In addition, Kligman studies can be mentioned. He accomplished some studies on the role of parking lots in residential status optimization by using GIS in Newton city [2]. The aim of the present study is prescribed as public parking lots site selection using GIS, in which its case study is five traffic regions of Shiraz city and for this, study results of Shiraz transportation master plan have been used [7].

2. Execution method

In order to carry out parking site selection in GIS environment, firstly, the case study and effectiveness parameters must be determined. After this stage, these parameters should be weighted and information layer ought to be prepared and integrated regarding to each layer weight. Figure (1) depicts the diverse stages related to parking site selection [4].

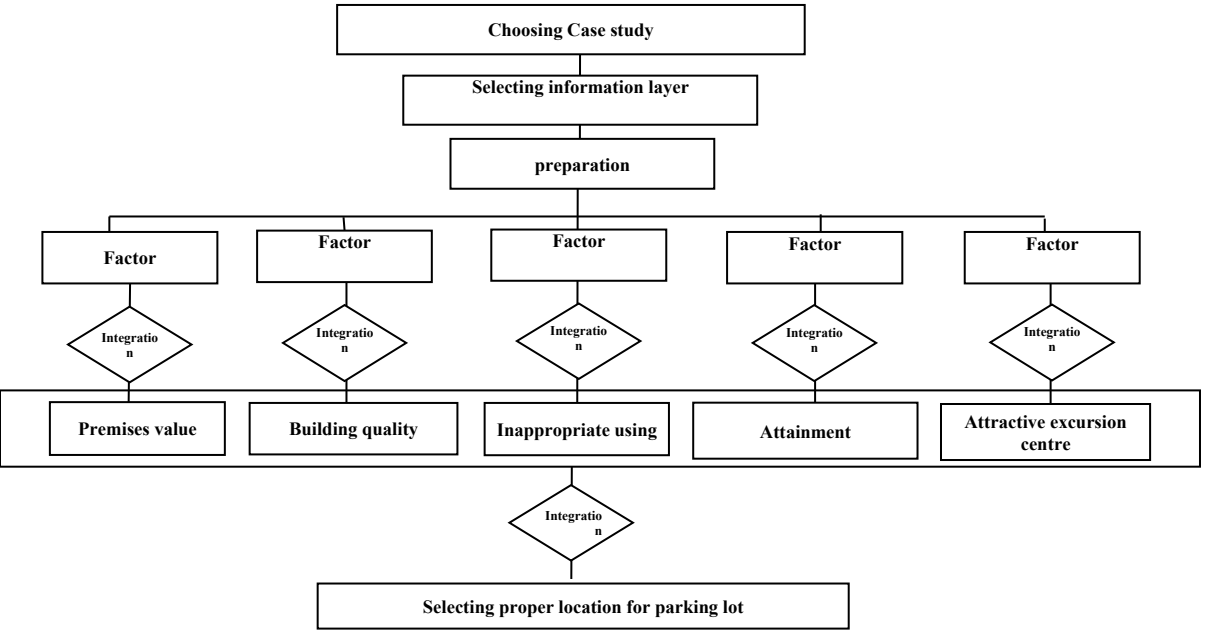

Figure 1. Various stages of parking lot site selection using GIS

3. Selecting case study region for parking lot site selection

The considered case study for this research includes five traffic regions of Shiraz city. Shiraz is located in western south of Iran. Existence of historical centres in this city, have made thousands of tourists to visit the city each year. Consequently, entering these

visitors to the city would make traffic problems and lack of some services centre such as parking lots.
Shiraz city consists of 156 traffic regions, which by Transportation Master Plan studies, traffic region of 21, 26, 28, 29 and 60, have the most requirement for public parking lots. On the whole, the requisition of these regions for parking lot construction, equals to 3600 parking spaces [7]. For that reason, these regions were chosen as the area studies in the present work.

4. Determining the effective parameters in parking site selection

considering civic construction and traffic critics views, effective parameters in parking site selection are classified into five main classes, which every class includes several sub-classes [8]. Main classes are as:

- distance from absorbing excursion spaces:

  It is known as the most significant factor in parking site selection, which consists of trade, official, servicing, recreative and tourist sub-classes.
- Inappropriate usage:

  this class in formed by integration of pedestrian crossing and streets, major trade and official centres, 50 meters hospitals buffer, historical centres and mosques.
- Attainment:

  This class includes streets information layer with attainment level of 1, 2, 3 and 4, in which the street categorization was applied in 4 levels regarding to the passing traffic and streets width
- Premises value:

  This class consists of building code number (plaque) information layer, which every building code number has been classified into 5 divisions of very expensive, expensive, medium, inexpensive and very cheap.
- Construction quality

  This class includes building code number (plaque) information layer, which every building code number has been classified into 3 parts of ruined buildings, maintainable buildings and new constructed buildings.

5. Weighting criteria and sub-criteria

At this part after describing effective criteria in parking site selection, a proper weight should be prescribed for these criteria. There are various methods for weighting but among these methods, Analytical Hierarchical Process (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. But 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. Regarding that 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.

5.1. Analytical Hierarchical Process

This method was proposed by a researcher called Saatyon on the basis of human being analysis of fuzzy matters. The Analytical Hierarchical Process 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 is alluded to double comparison for existence elements in an AHP structure level, in which the elements of each level are compared to the elements of the mentioned level on the basis of table (1) and afterwards their relative importance are calculated. These weights could be either calculated individually or an integration of critics judgments, which in this status, in order to composite different critics opinions, responses are converted to a unique response using geometric average [9].

Table 1.Numerical values of judgments

Importance of a criteria to another one	Huge appropriateness	Significant appropriateness	High appropriateness	Slight appropriateness	Equal appropriateness	appropriateness between former spaces
Numerical value	**9**	**7**	**5**	**3**	**1**	**2,4,6,8**

After numbers double comparison, the produced comparisons are structured in a matrix form, called comparison matrix. In this matrix a_{ij} component is actually the results of i^{th} criteria comparison with j^{th} criteria regarding to the table (1). For calculating each criteria weight of each level, the specific vector method has been used [9].

5.2. Analytical Hierarchical Process 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 triangular fuzzy number which consists of three respective weight numbers from double comparison table [3].

4.3. Weighting results using AHP method

Concerning the foresaid explanation about AHP and AHP fuzzy methods, firstly, all of the site selection criteria were categorized in three different levels, which the main criteria were placed in the first level and their sub-criteria were put in the following levels. Then, these criteria were weighted using both methods and the results of AHP fuzzy are tabulated in tables 2 to 4 and in table 5 the parameters for tables 2 to 4 are presented.

Table 2. Weighting results of third level criteria

Distance from	Appropriate model
Trade centres	$C = 0.523c_1+0.354c_2+0.080c_3+0.043c_4$
Servicing centres	$D = 0.507d_1+0.325d_2+0.115d_3+0.053d_4$
Official centres	$E = 0.507e_1+0.325e_2+0.115e_3+0.053e_4$
Recreative centres	$F = 0.490f_1+0.363f_2+0.107f_3+0.040f_4$

Table 3. Weighting results of second level criteria

criteria	Appropriate model
Tourist absorbing centres	$g_1=0.324C+0.276D+0.243E+0.157F$

Attainment	$g_2=0.479l_1+0.358l_2+0.119l_3+0.044l_4$
Premises value	$g_3=0.388m_1+0.297m_2+0.198m_3+0.074m_4+0.043m_4$
construction quality	$g_4=0.388n_1+0.297n_2+0.198n_3$

Table 4. Weighting results of first level criteria

criteria	Appropriate model
Parking site selection	$G=0.482g_1+0.275g_2+0.158g_3+0.085g_4$

Table 5. Introducing tables parameters of weighting results

criteria	Sub-criteria
Trade centres	c_1=0 to 160 c_2=160 to 300 c_3=300 to 420 c_4=420 to 520
Servicing centres	d_1=0 to 40 d_2=140 to 260 d_3=260 to 360 c_4=360 to 450
Official centres	e_1=0 to 140 c_2=140 to 260 c_3=260 to 360 c_4=360 to 450
Recreative centres	f_1=0 to 120 f_2=120 to 220 f_3=220 to 320 c_4=320 to 400
Tourist absorbing centres	C=trade centres D=servicing Centres E=official centres F= recreative centres
attainment	l_1=first level l_2=second level l_3=third level l_4=forth level
Premises values	m_1=very cheap m_2=inexpensive m_3=medium m_4=expensive m_5=very expensive
Construction quality	n1=ruined buildings n2= maintainable buildings n_3= new constructed
Parking site selection	g_1=tourist absorbing centres g_2=attainment g_3=premises values g_4= Construction quality

6. Layer preparation

Intended for finding out the most appropriate location analysis in raster networks, raster layers related to various parameters should be prepared. To perform this work, common methods in data processing in GIS, like vector structure to raster structure conversion, map preparation for network analysis, reclassification and format conversion were used. At this stage, at first, the operation is begun from lower levels until reaching to the first level, but since the tourist absorbing centres are different in their requirements for parking lots (the bigger of centres, the more requirement for parking lots), for this reason at the outset, for each tourist absorbing centres, regarding to the civic construction standards and according to its usage and area, a number was presumed as above mentioned centre requirement, which after normalization of this number for all of the tourist absorbing centres and multiplying this number to the third layer level weights, the third layer would be prepared. In order to calculate walking distances from tourist absorbing centres, network analysis was used in this research, because the walking path is conformed on the attainable network. In the end, because of the multiplicity of the tourist absorbing centres in the region, around 400 raster layers were prepared [4].

7. Models used in parking site selection and their evaluation

At this moment, all of the information layers are prepared and for finding the parking appropriate location, integrating the prepared layers, using information integrated models is sufficient. In this article for finding parking site selection, overlay index integrated model, fuzzy product operator, fuzzy sum operator and fuzzy Gamma operator have been

applied, and in continuous the outcomes of these methods have been compared and the proper model has been chosen.

7.1. Information integration

Firstly, the existence layer in each class (sub-classes) is integrated by together and related map to main classes are prepared. At this stage in order to integrate sub-classes and creating main classes, the overlay index integrated model has been used. In figure 1 (A to D), obtained main classes are shown.

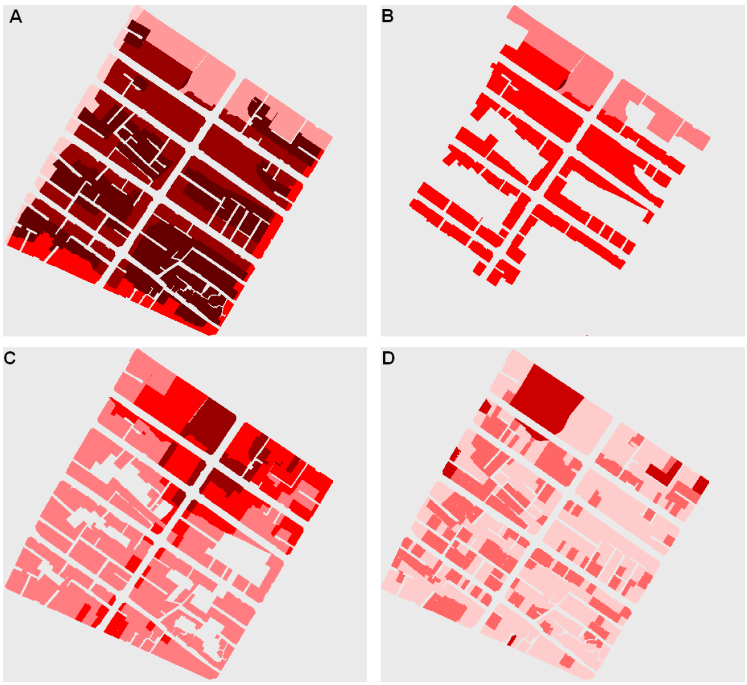

Figure 1. Premises value layer(A), Attainment layer(B), Tourist absorbing layer(C) and Construction quality layer(D)

In continuous, related layers to main classes are integrated on the basis of above mentioned information integrated model [4]. In the figure 2 (A to D) the proper parking location are shown regarding to their priority.

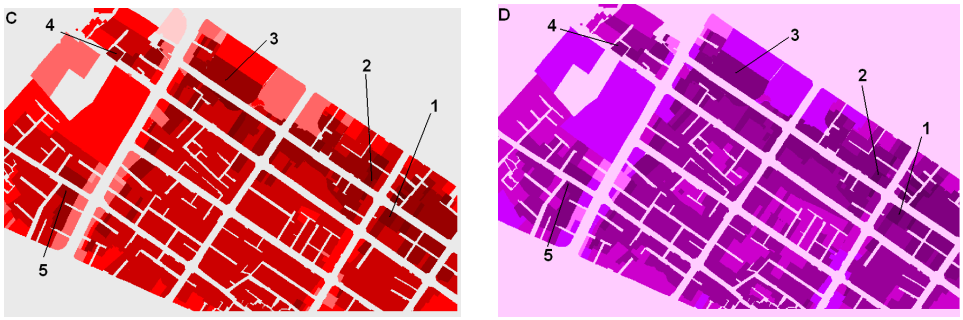

Figure 2. Integration results using fuzzy product(A), Integration results fuzzy Gamma(B), Integration results using index overlay(C) and Integration results using fuzzy sum(D)

7.2. Evaluation of integrated model results

Regarding to the integration models in foresaid region, five items were selected for parking location. These five items were similar locations in four methods, but their priorities in various layer integration methods are different. Meant for comparing these methods, the first item of each method has been compared to the first item of the other methods. In this comparison, the position of selected location in every of major site selection criteria, are tabulated in table (6). In this table for each criterion five statuses of excellent, proper, medium, poor and worst is considered.

Table 6. Comparing of information integration methods

Integrated model	Premises value	Construction quality	attainment	Tourist absorbing centre
Fuzzy product	Proper	Excellent	Excellent	Poor
Fuzzy gamma	Proper	Proper	Proper	Proper
Fuzzy sum	Proper	Medium	Proper	Excellent
Index overlay	Proper	Medium	Proper	Excellent

Regarding to figures 10 and 11, the results of index overlay method and fuzzy sum are similar and the reason is referred to the non-weighting of fuzzy to the layers. Fuzzy product, has approximately ignored the tourist absorbing centres and chose its selected location by appropriateness of the others parameters, whilst tourist absorbing centres is known as the most important parameter for parking site selection. Fuzzy Gamma has chosen the tourist absorbing site selection in proper scale, while index overlay and fuzzy sum models have chosen this parameter in excellent scale. Thereafter, it could be resulted that index overlay and fuzzy sum methods are appropriate methods for parking site selection.

8. Conclusions

Currently, site selection of parking lots is performed using conventional approach, which does not have the ability for utilizing all of the effective parameters for site selection simultaneously, and besides the time consuming process is presumed as its worst shortcoming, which is tended to inappropriate workability for constructed parking lots. This approach would increase trend in using proper tools, which have the ability to integrate a lot of spatial data simultaneously. For that reason, in the present study, an appropriate method has been proposed for parking lots site selection by GIS. The most important results of using this method meant for parking site selection is as follows:

- 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 weights from AHP and AHP fuzzy in this study have a slight difference. Since the difference between main criteria weights are sizeable, therefore the influence of using AHP fuzzy in weighting is not considerable, therefore, AHP method could be used for parking site selection.
- Among the available integration methods for parking site selection, fuzzy product has been prescribed as the weakest method and overlay and fuzzy sum methods have been prescribed as the best integration methods.

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