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Review Article

IDENTIFYING PUBLIC PARKING SITES USING INTEGRATING GIS AND ORDERED WEIGHTED AVERAGING APPROACH IN SANANDAJ CITY, IRAN

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Abstract
In this study, the integration of GIS-based ordered weighted averaging as used to spatial site selection of parking lots in Sanandaj city located in the west of Iran. For this purpose, the effective parameters were selected including distance from attractions, street width, population density, distance from roads, land price, and land use were selected based on literature review and expert opinion. The layers of the parameters were prepared in the GIS environment, and the relative weights of factors were gained using analytical hierarchy processes. Then, the ordered weighted averaging method was used to aggregate all maps and creat the suitability map. The zoning of suitable lands finally was determined using the zonal land suitability (ZLS) method and the most suitable sites were suggested in the study area. The results indicate that 234,887 m^2 (16.14%) of the study area has high suitability for construction parking sites mostly located in the northern and southern parts of the city. In conclusion, the combination of GIS with powerful aggregation and suitability analysis methods has a strong ability to integrate and analyze various spatial data simultaneously, in particular in site selection studies.

Key Words: GIS, Car Parking sites, Site selection, OWA, Iran

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INTRODUCTION

The rapid growth in urban population and business activities has significantly affected facilities and infrastructures in many large cities (Ahmadi Baseri et al 2012). Urban transport systems play a major role in daily human life. Without enough execution of transport systems, the urban management system would face serious problems in urban areas (Aliniai et al 2015). Thus, essential urban substructures have been created to control traffic and decrease transportation costs. The most prominent examples of urban substructures are streets, underpasses, overpasses, public parking and the development of public transportation (Eskandari & Nookabadi, 2017).

One of the most imperative factors in the achievement and effectiveness of urban land utilizes, (for example, business, managerial, recreational, instructive and administration focuses) is advantageous access to parking facilities (He et al., 2015; Davis et al., 2010).

Public parking as an urban substructure is a standout amongst the best pieces of the urban transportation framework in decreasing traffic at street corners. Accessible parking areas, as a significant part of the transportation system, have an indispensable undertaking in giving spots to removing still traffic from the urban transportation, with a subsequent reduction in crowding and traffic densities (Jelokhani-Niaraki and Malczewski, 2015a; Bingle, 1987). The absence of parking spot in city centers implies drivers spend quite a while finding a reasonable parking spot and maybe making them drive further for this reason.

The location of public parking lots close to urban streets is a useful measure in reducing traffic resulting from vehicles parked on-street for long periods. Street parking intensifies the traffic of the transport fleet, together with increasing air pollution, noise pollution and fuel consumption, as well as accelerating vehicle depreciation (Nakhaei et al., 2010;). Indeed, parking vehicles along streets, especially in central metropolitan areas, reduces passage capacity, decelerates vehicles and increases accidents. In this regard, an effective way to allocate adequate parking space would be of great interest to managers, urban planners and traffic control authorities.

The construction of public multistory parking lots is associated with increasing the efficiency and achieving the desired goals when all the useful parameters in the construction of public parking spaces are taken into account. One of the most critical parameters is their location. Inadequate parking space and inappropriate dispersal not only causes inefficiency but also increases urban traffic, thereby exacerbating the duration of city trips and increasing air pollution. In the comprehensive plans prepared for the city of Sanandaj, parking is one of the types of urban land uses evaluated in traffic studies and communications networks. The major drawback is that practically parking location studies, such as estimating parking demand, parking supply, etc., are investigated using mathematical and statistical relationships. In other words, in studies of comprehensive plans, the emphasis is on needs assessment, and they do not place much importance on the location of the parking lot.

In the past, site selection was carried out using traditional methods based almost purely on some factors like land price and proximity to market places, which resulted in the inefficient use of existing parking capacity. Additionally, the processing of numerous data by traditional means requires a considerable time and sometimes may not yield the desired results (Shahabi et al., 2011). Finding a suitable place for parking lots should increase efficiency and reduce the overall cost of construction. For solving this problem, it is necessary to employ new systems that can simultaneously analyze various parameters in parking site selection, and present clear results.

Geographic Information System (GIS) provides appropriate analytical tools for spatial analysis and planning. Boolean Logic, weighted linear combination (WLC), and fuzzy logic are the most often used approaches of overlay methods. Boolean operations standardize all criteria with the value of zero to one and give the final map in this value. WLC has more flexibility than the Boolean method. In this approach it is possible to compensate for certain factors (Ishizaka and Nemery, 2013). Several studies have been accomplished on parking site selection, which used various methods like aggregation methods such as boolean logic, overly, and weighted linear combination (Kazazi Darani, Akbari Eslami, Jabbari, & Asefi, 2018; El-Zonkoly & dos Santos Coelho, 2015; Jelokhani-Niaraki & Malczewski, 2015b; Aliniai, Yarahmadi, Zang Zarin, Yarahmadi, & Bakhtiari Lak, 2015; Neisani Samani, Karimi, & Alesheikh, 2018, TANG & REN, 2009a, Tang & Ren, 2009b; Mirzaei, Kazemi, & Homaee, 2016; Gao, Tao, Xu, Wu, & Kwaku Baah, 2018; Farzanmanesh, Ghaziasgari Naeeni, & Makmom Abdullah, 2010).

Ordered weighted averaging (OWA) is one of the most suitable aggregations and a relatively new multi-criteria evaluation methods. OWA is a combination method that is analogous to WLC but which considers two sets of weights. Unlike the Boolean logic where the intersection (AND) operator represents the lowest risk while the union (OR) represents the highest risk in decision-making, the OWA method can obtain a full spectrum of risk scenarios bounded between the intersection (AND) and the union (OR) operators (Malczewski, 1999). Researchers have employed OWA for several studies such as land-use suitability, urban water management, natural resource management, and landfill site selection (Bottero et al. 2013; Zhang et al. 2012; Malczewski, 2006; Rahman et al., 2012; Jelokhani-Niaraki & Malczewski (2015a) and (2015b)). However, a few studies such as Aliniai & Bakhtiari Lak (2015), used OWA as the suitable aggregation method for parking site selection, and previous studies have mostly exploited other approaches simultaneously.

The aim of this study is to prescribed public parking lots using combination GIS and ordered weighted averaging method in Sanandaj city. Sanandaj is the capital of Kurdistan province located in the west of Iran. The rapid growth that has taken place in most of Iran's populous cities has also taken place in Sanandaj and is accelerating. Today, traffic in this city has become a severe problem for the city council and managers, as every day many people spend a long time in urban traffic and suffer from resulting physical and psychological pressure. Indeed, most of parking lots in the city have been constructed in small parts, and standard criteria have not been considered before construction, result in rising severe traffic problems. The problem of parking is not only in the central areas of the city where market activity prevails but also in residential areas due to increased building density without sufficient parking space. Side problems due to insufficient parking space in every area of the city include increased urban traffic, air pollution, heat island formation, relatively expensive transportation costs and wasted time, capital and even citizens' health. In this regard, the importance of resolving the problem has increased, and more endeavor is required for the solution. Hence, the present work aims to locate suitable sites for the construction of public car parking in Sanandaj City, by using GIS and powerful suitability analysis methods and to consider the useful parameters simultaneously in order to take a step toward solving the parking and traffic problem. This study also in going to disclose current parking location heterogeneity and create a balance between providing sufficient parking and minimizing the amount of land used for parking lots.

Case Study

The study area is Sanandaj city the capital of Kurdistan province in the west of Iran. (Figure 1 shows the location of the study area. The population of the city is based on the population and housing census of the year 2016, equal to 412,767, which is more than one-third of the total population of the province. Among the eight regions of this city, four central districts were analyzed for analysis. The leading cause of Sanandaj's traffic is the commercial activities in the city center, so urban plans are essential to solve this issue. The historic areas and central parts of the city, including the bazaar, located in Regions 3 and 4, and the parts with heavy traffic are in Regions 9 and 10.

Methodology

To find the most suitable site for public parking, based on the literature review and expert points six criteria including public attraction centers, population density, accesses, distance from passages, land use and the land value corresponding sub-criteria were determined. After this determination, criteria maps were prepared using ArcGIS software. The relative weights of factors were measured using Analytical Hierarchy Processes and the map layers were combined by using an OWA approach) (Yager, 1988). Eventually, for land zoning according to area constraints, the method of Zonal Land Suitability (ZLS) was applied and the most suitable sites were suggested.
A detailed description of how the layers were prepared is below:

Preparing the criteria maps:

Public attraction centers

The most important factor is the distance between parking site and attraction places. This distance should be as short as possible. Suitable distances are shown in Table 1. Map of suitable distances is shown in Figure 2 below.

Table 1. Suitable distances from attractions

Attraction	Suitable distance (m)
Commercial and services	150-300
Officials	150-300
Other uses: recreational, pilgrimage.	200-350

Land value

Given the high price of land in the city center, property value can be influential when choosing the optimum place for parking. The cost of the building determined this criterion according to an expert valuation (Figure 3).

Population density

The map of the population density in the study area is shown in Figure 4.

Access

Access depends on street width and passing traffic and therefore the classification of street has been done into 4 layers. The map of this criterion for the study area is shown in Figure 5.

Distance from passages

Passages with different levels of access are divided into three classes, based on their traffic and access to parallel and unauthorized parking.

First-class passages

These passages have a heavy traffic load and a high fine for parallel or unauthorized parking. They are considered just for traffic so they do not have any marginal parking. These passages include arterial ways and second-class main and adjunct arterial ways.

Second-class passages

These passages have a lower traffic load and lower fines than first-class passages. In addition, marginal parking is not allowed during traffic jams. These passages include first-, second- and third-class local streets.

Third-class passages

These passages have an average traffic load and fines are from low to average, occasionally including no fines. A specific band is considered marginal parking in these passages. They include first- and second-class local streets.
Suitable distances from these three passage types are shown in Figure 6.

Appropriate or inappropriate usage

Different usages of lands can be utilized in a more efficient way to build public parking. GIS classifies urban lands with different usages, under two classes for building parking:

Appropriate usages for parking
Bare land, garages, useless places, yards of big schools, current green spaces and buildings with low structural quality or useless places.
Inappropriate usages for parking
Main commercial centers, cultural centers such as mosques, official centers, hospitals, tourist centers and the boundary of these areas and high-quality buildings. Also, The limitations are clinical, cultural, official and military areas, which are highlighted in Figure 7 below.

Weighting
After the criteria were determined, they were weighted to determine their relative importance, so that a criterion with a higher level of importance take more weight than a less important criterion. Analytical Hierarchy Process (AHP), which is used in multi-criteria decision making analysis, was chosen for this study. In order to interpret the matrix, it is necessary to define the ratio of importance between the factors in the rows and the factors in the columns. This ratio was evaluated by expert's opinions in the range shown in Table 2. At the end of the study, each factor was used as a layer in the analysis process.

Table 2. Point intensity of relative importance scale

Definition	Level of importance
Equal importance	1
Normal importance	3
High importance	5
Very high importance	7
Extraordinary importance	9

(Do and Kim, 2012)

Combination of criteria
The layers of criteria and sub-criteria were integrated using the OWA method. This method allows control of the position of risk and compensation arising in MCE, by which it is possible to control the desired level of risk and weight the effect degree of factors in the final efficiency map.

Locating and land-use planning the area by ZLS
OWA created map of suitability levels for parking sitting. There are two approaches for finding locations on the final map. The first approach is to use levels of desirability as a threshold to determine each location's desirability or undesirability, which results in a Boolean map (0 illustrates unsuitable levels and 1 illustrates suitable levels). In the second approach, the threshold is not determined by the level of suitability or unsuitability, but also by the general quality of the land. In this case, all locations are ranked based on their desirability degree, which makes a fuzzy map and makes range between 0 to 255. In this study, the second approach – ZLS - was used to find suitable locations for building a public parking lot through macro (site select) ability. The resulting proportional map was expanded from 0 to 225 to run ZLS. To run this code, it is necessary to create a macro file with the "iml" suffix, before running the macro code in IDRISI software. After entering inputs and running the code, two tables and two maps will be displayed. The first map will be specified automatically by a macro named SITEID, which will be used as a definition file to extract location statistics. The second map will be specified by the user while running the macro. The first table includes the average desirability point, range of points and standard deviation points, and the second determines the area of locations in hectare. According to the purpose of this study, decision making or land-use planning includes locating suitable places for building public parking in a study area with a minimum area of 500 m^2.

RESULTS AND DISCUSSION
A land suitability map for parking sites was obtained after combining all the maps using the OWA method. Figures 8 and 9 show the limited places and final suitability map respectively. The figure shows a range from 0 to 255, with values from 54 to 214 in the resulting map of the study area. For more accurate classification, the final map was classified by a ZLS approach. The minimum desirability threshold was considered to be 180, with a minimum area of 500 m^2. Figure 10 indicates the classified land suitability map for building parking, including 5 classes from very unsuitable to suitable. According to the figure, the area with very high suitability for building public parking located mostly in the north-west and the east of the city.
The area and percentage of the suitability classes are shown in Table 3. As can be seen, 23.4 hectares of the study area (16.14%) has very high suitability for public parking. High suitability, average suitability, low suitability, and unsuitable areas cover 18.7, 29.4, 3.1 and 32.84 percent of the study area respectively. Fields study was conducted in places where classified at high level of suitability to compare the obtained results, and it showed good consistency.

Table 3. Suitability classes for parking site selection in the study area

Area (m^2)	class
464291	Unsuitable
234887	Suitable
267562	Moderate -high suitability
417737	Moderate suitability
44799	Low suitability

Spatial analysis of the resulting areas indicates that a high percentage of land close to crowded streets is suitable for building parking. Going away from these areas, the suitability for parking decreases. The majority of these areas are close to official-commercial centers and main passageways.
Although building public parking has a high impact on solving the traffic issue in the study area, it is a not only possible solution. Locating and building non-marginal parking, along with managing marginal parking, is an option. Since most attraction places such as commercial, religious and cultural sites located in the city center, it would be better to change and relocate such sites as commercial to less crowded places.
The results of this research indicate that using GIS can incorporate different levels of complexity of the decision problem. Regarding this case, weighting plays a crucial role. Decision-makers may not arrive and agree at the same weights for the criteria and sub-criteria. This may lead to different results for final maps and can affect the final decision. However, it must be noted that the presented methods are only tools to aid decision-makers and are not the decision itself.
Various indicators have been used in this study for selecting public parking sites, and these indicators were made in a Geographical Information System (GIS) structure. These parameters were categorized into two groups' namely physical infrastructure criteria (distance from attraction centers, street width, and distance from roads) and social-economic criteria (real estate value, population density, and appropriate land use). As same as this research, similar studies were conducted and considered various criteria such as physical infrastructures, social and economic criteria. For instance, Jelokhani-Niaraki & Malczewski (2015b), Aliniai & Bakhtiari Lak (2015) and Farzanmanesh & Makmom Abdullah (2010), investigated physical substructures and social and economic criteria and the sub-criteria to select the best sites for car parking in distinctive regions. Furthermore, some resources like Kazazi Darani, Akbari Eslami, Jabbori & Asefi (2018) have considered some environmental criteria such as air pollution. Nevertheless, due to the shortage of data access, the environmental criteria have been ignored in this paper.
Meanwhile, the Ordered Weighted Averaging was used to create the parking suitability site selection map. This method is one of the most popular approaches in multi-criteria decision

analysis. GIS-based Multi-criteria Decision Analysis (MCDA) techniques involve the use of geographical data, weights, and an MCDA aggregation function that combines spatial data and weights of criteria to evaluate locations (Jelokhani-Niaraki & Malczewski, 2015b) and OWA is a generic method that can be applied in a wide range of situations and for various types of data. Several authors offer the GIS-OWA approach to urban planning and management (Asproth et al, 1999; Mendes, 2000; Mendes and Motizuki, 2001) due to the fact that OWA method provides a user-friendly environment in which the full range of decision strategies can be generated and examined. Although, opting a suitable site for public parking has been considered in a lot studies such as Kazazi Darani & Asefi (2018), Gao & Kwaku Baah (2018), Palevicius & Vengrys (2013), Farzanmanesh & Makmom Abdullah (2010) and Tang & Ren (2009a) & (2009b) by diverse methods, a few studies have accomplished the OWA method for selecting public parking sites such as Aliniai & Bakhtiari Lak (2015) and Jelokhani-Niaraki & Malczewski (2015a) & (2015b).. For instance, Aliniai et all (2015) have deduced that the OWA method can make a flexible situation in the site selection process in distinct risk levels and criteria. They have proven that using this method for public parking site selection, can be achieved a variety of results in terms of accuracy, reliability, and prioritization of criteria. In general, the results of their study are highly correlated with the selected criteria and the case study, so it is clear some low-risk methods such as Boolean and OWA are the most reliable approaches to opt parking's site locations. Moreover, Jelokhani-Niaraki & Malczewski (2015b), has presented a Web-based group GIS-MCDA procedure and tool operationalized by an OWA-based approach to address the issue of parking site selection in Tehran. In this study, the OWA method has shown numerous strengths for solving parking site selection in Tehran, it is also subject to a number of limitations.

CONCLUSION

In this study, GIS was used to locate the most suitable sites for public parking in Sanandaj City, considering six specific criteria. To indicate suitable places for building public parking, the central parts of the city were zoned and reviewed for locations that allow the possibility of building public parking. The spatial distribution of these locations gives users the best access and helps organizations such as the municipality to apply the best management method.

As mentioned above, the purpose of this study is not only to locate suitable places for building public parking but also to indicate the efficiency of OWA in comparison with other methods of overlay evaluation. OWA, which was used in this study, controls the level of risk and competition. In other words, the OWA approach allows decision-makers to explore different decision strategies based on their attitudes between risk and trade-off.

During the selection of the criteria of this study, factors such as accessing required data, expenses and time taken to gain data were considered. The flexibility of this method allows researchers to add more factors in coming studies. In addition, this method increases the speed of the process of choosing appropriate places for building public parking, along with its suitability. It is recommended to utilize parameters like the ability to compress, earth slope and developing and compressing infrastructure in studies about locating public parking.

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Conflict of Interest:

The authors declare that they have no conflict of interest.

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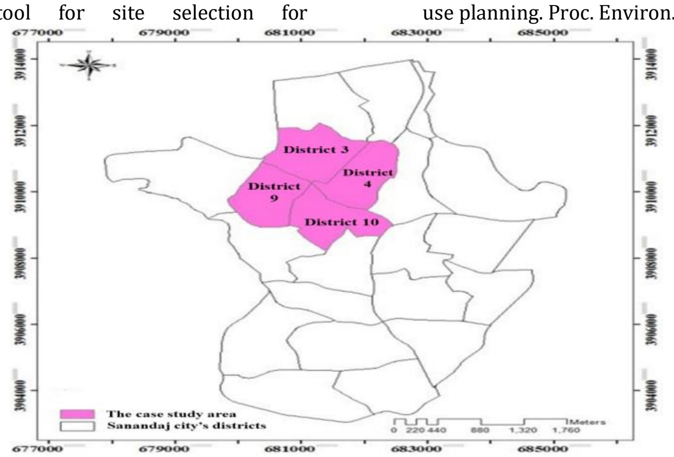

Fig1. Introducing the case study area

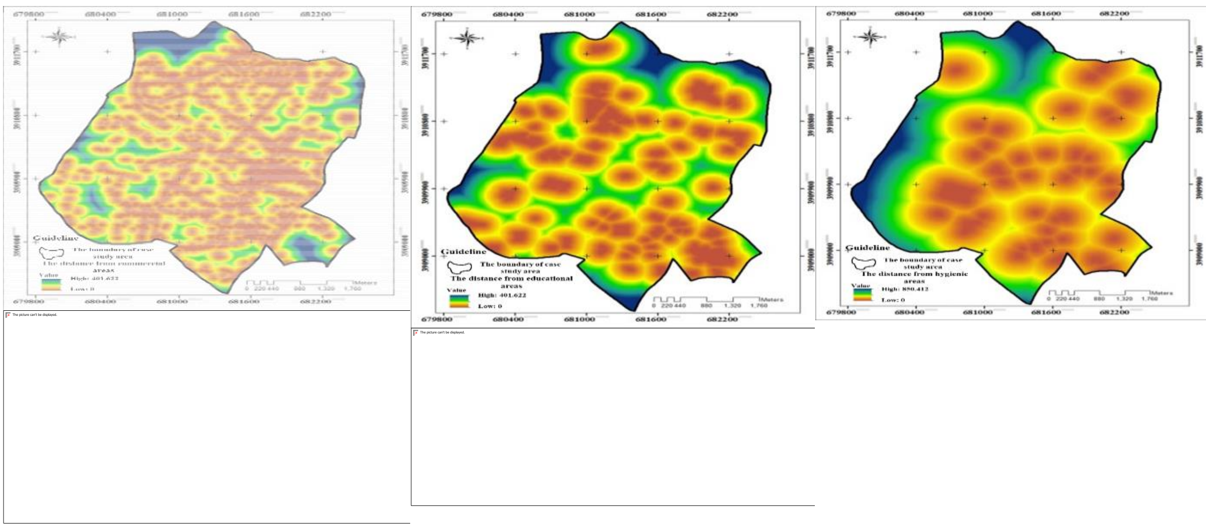

Figure 2. Distance from attractions (attractive places)

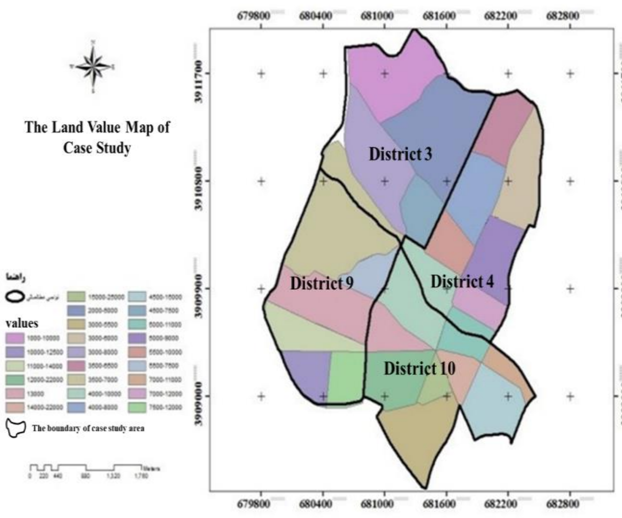

Figure 3. Land value (property value)

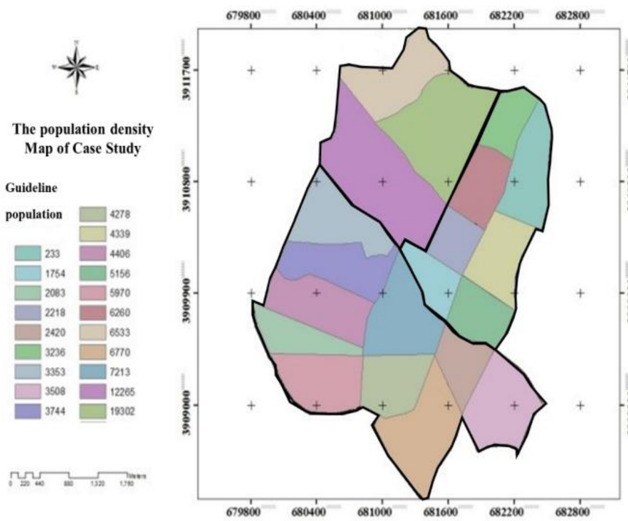

Figure 4. Population density

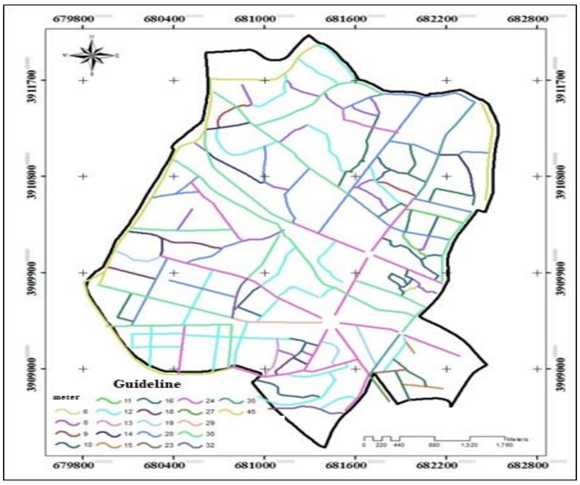

Figure 5. Street width

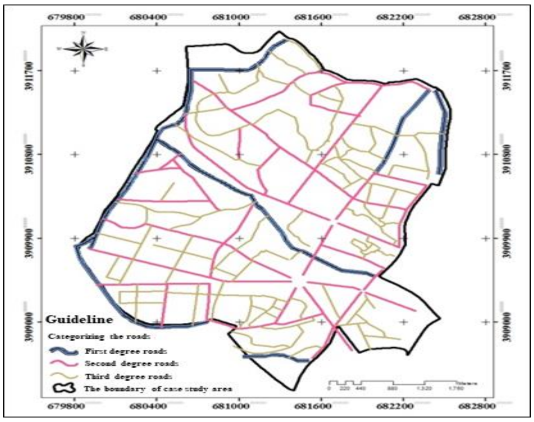

Figure 6. Classified streets

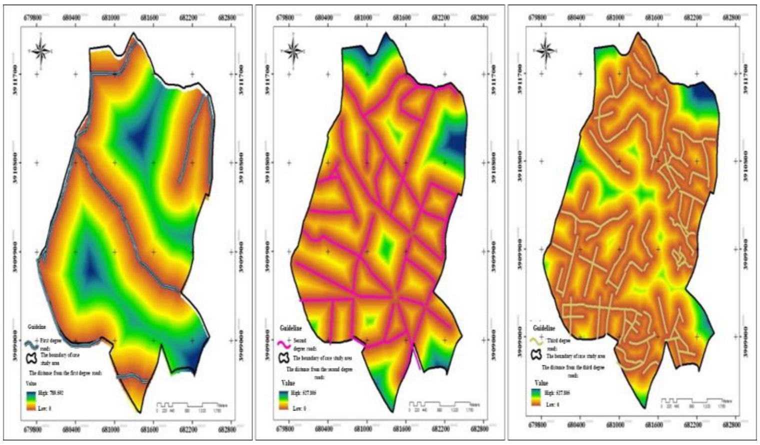

Figure 7. Distance from streets

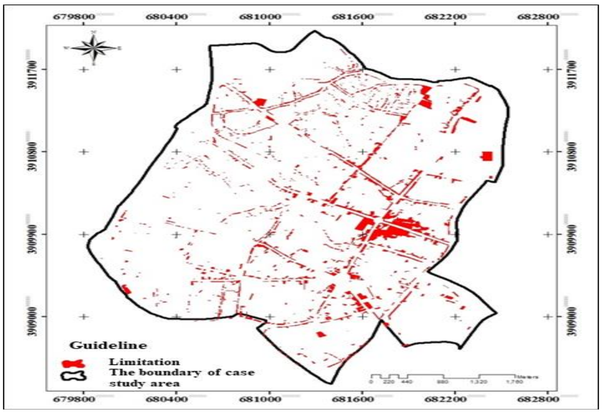

Figure 8. Limited places for public parking

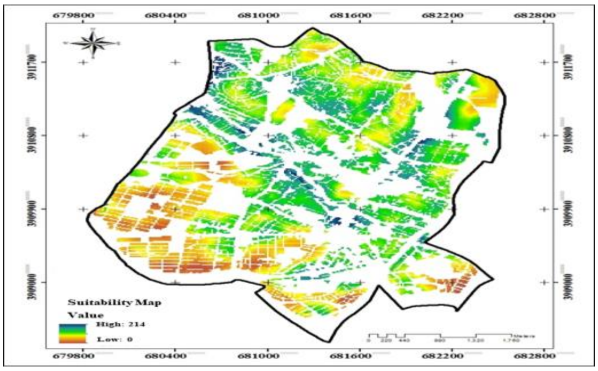

Figure 9. Final fuzzy map

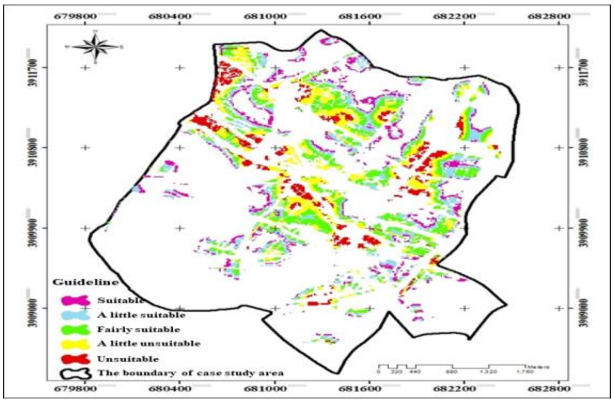

Figure 10. Final classified map using ZLS

Table 1. Suitable distances from attractions

Attraction	Suitable distance (m)
Commercial and services	150-300
Officials	150-300
Other uses: recreational, pilgrimage.	200-350

Table 2. Point intensity of relative importance scale

Definition	Level of importance
Equal importance	1
Normal importance	3
High importance	5
Very high importance	7
Extraordinary importance	9

(Do and Kim, 2012)

Table 3. Suitability classes for parking site selection in the study area

Area (m^2)	class
464291	Unsuitable
234887	Suitable
267562	Moderate -high suitability
417737	Moderate suitability
44799	Low suitability