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Analysis of Parking Situation in Rasht Using Multi-criteria Evaluation Method

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Site selection,
Parking space,
GIS,
fuzzy AHP.

Abstract

As a metropolitan area located in the north of Iran, Rasht is among the cities where the transportation network currently suffers from a major deficiency in parking space. Locating the activities without considering the parking use has gradually caused this issue to be emerged as an urban dilemma. In addition to identifying the existing situation of the parking spaces in the city in terms of the ability to meet the traffic demand, the present paper aims to optimally locate these spaces in the areas where the parking construction is required. For this purpose, an integrated set of effective measures is developed for assessing the current situation. Also, the fuzzy AHP questionnaire is used to collect expert opinions about the importance coefficient of the criteria selected in the research. The zoning maps are generated for the situation of selected criteria contributing to the location of parking spaces in the study area using the final weight of the criteria and the GIS software. Finally, the appropriate zones are located for the construction of parking spaces.

1. Introduction

Urbanization and the resulting urban growth have greatly influenced humans and the environment. The urban sprawl and traffic increase arise as a consequence of rapid growth of urban population beside the increased ownership of personal vehicles. The stationary traffic [1, 2] along with finding the right place to park are considered as part of the major urban issues [3]. One of the effective measures for reducing the traffic is to construct numerous public parking lots in order to prevent the long and inappropriate parking along the streets. The proper management of parking lots requires the establishment of strong links with the urban transport planning so as to predict and construct the required parking with the statistical accuracy by estimating the traffic volume in the city center [4]. The optimal location of parking spaces not only increases the parking efficiency, but also reduces the marginal parking, makes the traffic flow smooth and widens the streets [5]. However, the inappropriate site selection will intensify the traffic jams and increase the traffic volume of nearby streets.

One of the reasons for the current disorganized situation of parking in Rasht is the inappropriate site selection, lack of reasonable distribution, and the imbalance between the population and the parking spaces per capita, which has slowed down the traffic in the urban roadways. This issue acutely manifests itself in the high-density areas of the city with multiple urban uses, especially the office, business and leisure ones. On the other hand, owing to the implementation of development plans in this city such as the construction of high-speed BRT lines, city center sidewalk, and creation of traffic plan area, it is necessary to study the situation of existing parking lots and the parking location for addressing the urban traffic problems.

In recent years, due to the land constraints in large cities, especially in the city centers, it is of particular importance to study and locate the parking spaces for the optimal use of land and its added value. In this regard, many studies have been conducted in various cities of the world, including the study by Zhang et al. (2008) [6], Caicedo (2010) [7] on the relationship between the time of access to parking and the environmental pollution, Cheng et al.'s (2012) study [8] on the generation rate model and improved model setup considering further factors, such as the average turnover rate, parking space occupancy, service level, parking fees, and growth rate of automobiles.

Wang et al. (2013) [9] presented the policy and planning suggestions for the indoor and outdoor parking in Chinese cities. Ni et al. (2013) [10] investigated the development of a spatial model to minimize the social costs of parking. The studies of Ottosson (2013) [11] are the first one that calculates the price elasticity by time of day for on-street parking demand on a block level in the U.S. Li and Guo

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(2014) [12] evaluated the London parking reform with a matched-pair approach. Young and Miles (2015) [13] explained the spatial distribution of policy and usage of parking in Melbourne. Alkheder et al. (2016) [14] explored the problems of the Abu Dhabi smart parking management system, and Shaban and Pande (2016) [15] analyzed and classified the factors affecting the selection of parking in Qatar.

In Iran, this issue has been extensively studied using a set of site-selection criteria. However, these studies have been generally performed based on a small number of traditional and effective parameters such as land price. Therefore, the present paper attempts to consider an appropriate framework for the decision making by developing a comprehensive set of criteria affecting the location of urban parking, while overcoming the weaknesses mentioned in previous studies. Finally, the existing situation is comprehensively evaluated using this tool and the optimal sites for the urban parking are selected according to all effective parameters.

2. Methodology

This is a descriptive-analytical research in terms of method and nature and is an applied research in terms of research objectives. The required data was obtained from the both documentary data and field observations. In order to estimate the effective parking demand, all main and secondary roadways in the area were surveyed on the both directions. The questionnaire and face-to-face interview were also used to estimate the latent parking demand. After studying the theoretical foundations and determining the criteria affecting the site selection for the location of parking in the GIS environment, the study area was analyzed considering these criteria. For this purpose, after creating the hierarchical structure of the research, the expert opinions about the importance coefficient of criteria and sub-criteria were collected by the AHP questionnaire. Then, the importance coefficient was determined for each of the criteria and sub-criteria using the fuzzy AHP model. The basic maps of the comprehensive and detailed plans of Rasht were used to prepare the data layers required in the GIS environment. Figure 1 shows the research process.

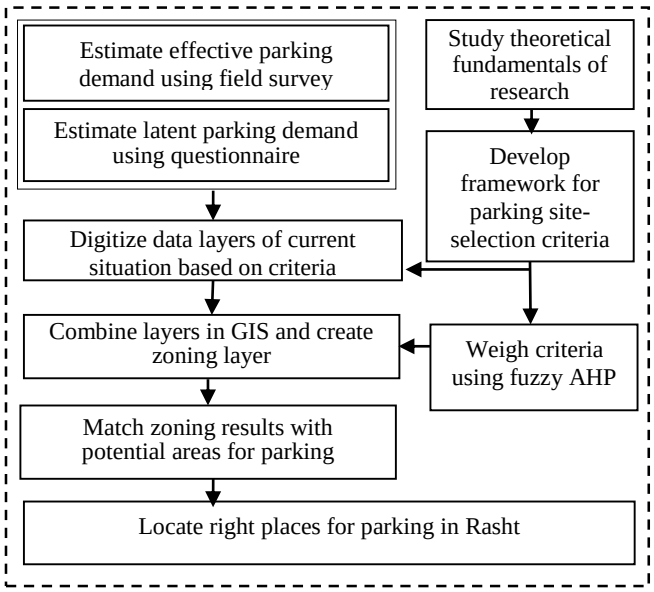

Figure 1. Research process

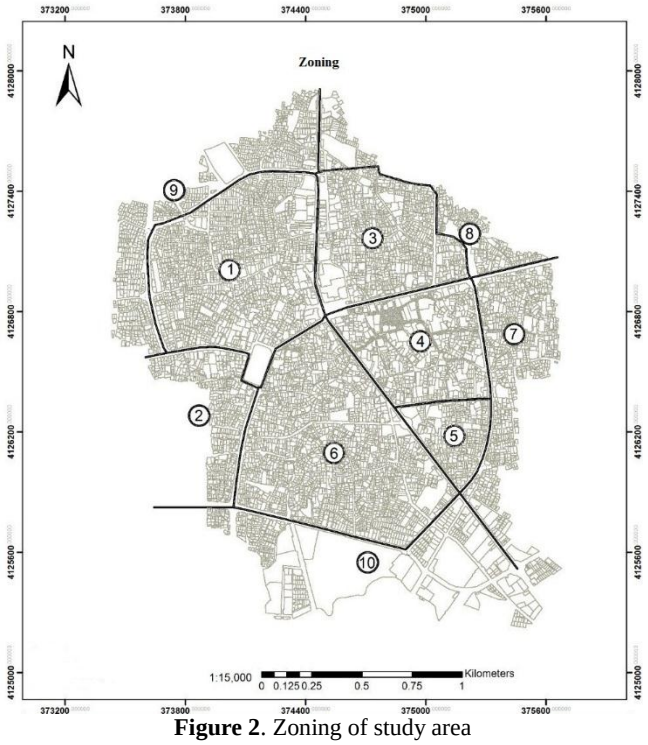

Figure 2. Zoning of study area

2.1. Parking Situation in Study Area

The study area of this research is located in the Rasht city center. This area consists of zones 1, 3, 4, 5 and 6, as shown in Figure 2. In this area, except for those located in the parking-prohibited area according to the driving rules, there are regular marginal parking.

2.2. Parking Site Selection Criteria

Locating the right place for a service function depends to a large extent on the factors that are evaluated when selecting a location for that function, and there are various effective factors in this context [16]. In this research, a framework of effective criteria was used for the location of parking lots as follows:

- Distance from travel attraction centers: including the distance from commercial, office, educational, recreational, cultural, tourism, and healthcare centers.
- Traffic: including the estimation of parking supply versus parking demand in the study area.
- Distance from roadways: including the distance from the first-class, second-class and third-class roadways.
- Land acquisition cost: analyzed in four groups: cheap, moderate, expensive and most expensive.
- Suitable parking uses: including the detailed parking, detailed training, detailed green space and barren land.
- Population: including the low density, moderate density and high density.

3. Results and Discussion

3.1. Using Fuzzy AHP Model to Determine Importance Coefficient of Research Criteria and Sub-criteria

A measure or criteria is required for assessing each issue. Choosing the right criteria allows to make a fair comparison between the options. However, this task becomes complex

when multiple criteria are considered to be assessed. Such complexity is increased when the multiple criteria are contradictory and dissimilar. This is the time when the assessment and comparison tasks go beyond a simple analytical state the mind can perform, and a robust scientific analysis tool would be needed. One of the robust tools for such situations is the multi-criteria analysis methods such as the Analytical Hierarchy Process (AHP) [17-19]. Since the actual phenomena are always fuzzy, ambiguous and inaccurate [20], the fuzzy AHP can be used for a range of values to express the uncertainty of decision makers [21]. The decision hierarchical tree of the present paper consists of the objective, criteria, and sub-criteria of the research, as shown in Figure 3.

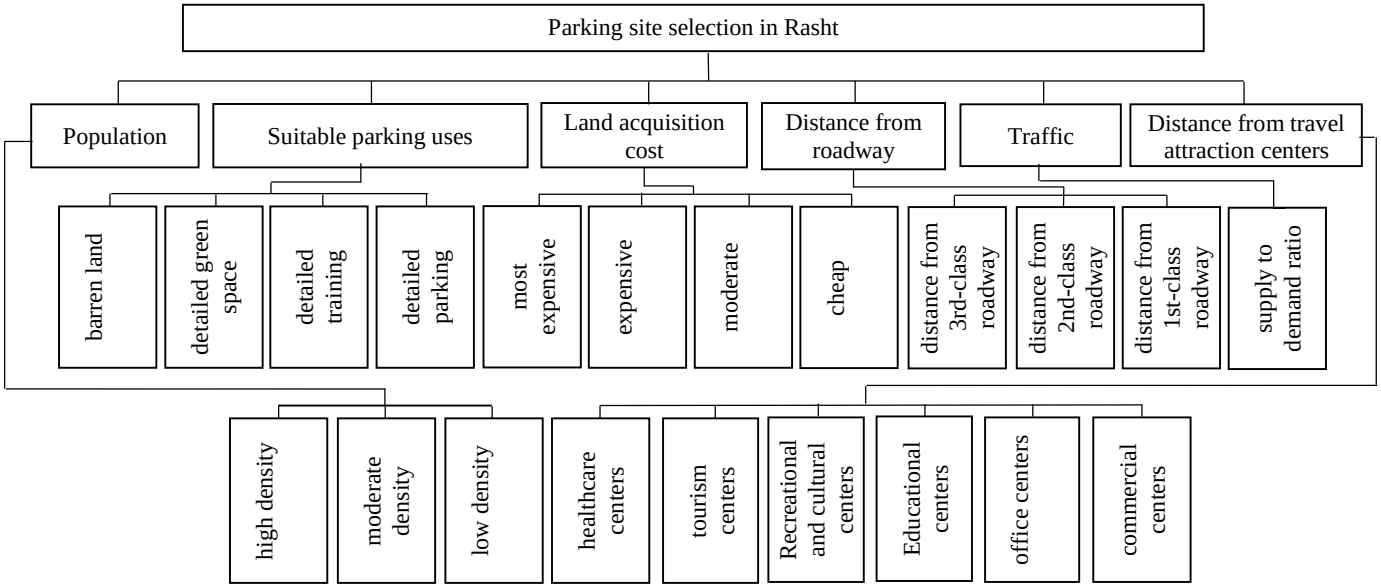

Figure 3. Research hierarchical structure

3.1.1. Weigh Criteria Using Fuzzy AHP

Based on the results of Table 1, the priority of level-2 criteria for organization and location of parking lots required in Rasht are:

1. Traffic
2. Distance from travel attraction centers
3. Distance from roadways
4. Population
5. Suitable parking uses
6. Land acquisition cost

Table 1. Priority of level-2 criteria for organization and location of parking lots required in Rasht

Organization and location of parking lots required in Rasht	weights
Distance from travel attraction centers	0.212
Traffic	0.291
Distance from roadways	0.189
Land acquisition cost	0.035
Suitable parking uses	0.095
Population	0.178

Based on the results of Table 2, the priority of the level-3 sub-criteria for the distance from travel attraction centers are:

1. Commercial centers
2. Healthcare centers
3. Office centers
4. Recreational and cultural centers
5. Tourism centers
6. Educational centers

Table 2. Priority of level-3 sub-criteria for distance from travel attraction centers

Distance from travel attraction centers	weights
Commercial	0.214
Office	0.134
Educational	0.092
Recreational and cultural	0.177
Tourism	0.198
Healthcare	0.185

Based on the results of Table 3, the priority of the level-3 sub-criteria for the distance from the roadways are:

1. 1st-class roadway
2. 2nd-class roadway
3. 3rd-class roadway

Table 3. Priority of level-3 sub-criteria for distance from roadways

Distance from roadways	weights
1st-class roadway	0.565
2nd-class roadway	0.333
3rd-class roadway	0.103

Table 4. Priority of level-3 sub-criteria for suitable parking uses

Suitable parking uses	weights
Detailed parking	0.405
Detailed training	0.188
Detailed green space	0.077
Distressed building - barren land	0.331

Based on the results of Table 4, the priority of the level-3 sub-criteria for the suitable parking uses are:

1. Detailed parking
2. Distressed building - barren land
3. Detailed training
4. Detailed green space

Table 5. Priority of level-3 sub-criteria for population

Population	weights
Low density	0.154
Moderate density	0.399
High density	0.447

Based on the results of the Table 5, the priority of the level-3 sub-criteria for the population are:
1. High density
2. Moderate density
3. Low density

Table 6. Priority of level-3 sub-criteria for land acquisition cost

Land acquisition cost	weights
cheap	0.496
moderate	0.342
expensive	0.161
most expensive	0

Based on the results of Table 6, the priority of the level-3 sub-criteria for the land acquisition cost are:
1. cheap
2. moderate
3. Expensive
4. most expensive

Table 7. Matrix of final weights of sub-criteria for organization and location of parking lots required in Rasht

Components	Final weights of criteria
Commercial	0.045
Office	0.028
Educational	0.019
Recreational and cultural	0.038
Tourism	0.042
Healthcare	0.039
Parking supply to demand ratio	0.291
1st-class roadway	0.107
2nd-class roadway	0.063
3rd-class roadway	0.019
Land acquisition- cheap	0.017
Land acquisition- moderate	0.012
Land acquisition- expensive	0.006
Land acquisition- most expensive	0
Detailed parking	0.038
Detailed training	0.018
Detailed green space	0.007
Distressed building - barren land	0.031
Low density	0.027
Moderate density	0.071
High density	0.08

3.2. Assessment of Current Situation of Research Criteria and Sub-criteria in Study Area

The objective of this stage is to identify the current situation of the study area from the perspective of the research criteria and sub-criteria. For this purpose, after reviewing the literature and utilizing the results of field surveys and urban land use maps, the layers of the sub-criteria effective in the site selection were rearranged in the GIS environment. Afterwards, the zoning map of each criterion was created by multiplying the weights obtained from the fuzzy AHP model. Then, the final map of the prioritization of the zones requiring parking construction was obtained by overlapping the zoning maps of the selected effective criteria (Figure 4).

3.3. Prioritization of Zones Requiring Parking Construction

At this stage, after overlapping the zones prepared for each effective site-selection criterion (Figure 4), the final map of the prioritization of the zones requiring parking construction was generated, as shown in Figure 5.

3.4. Overlapping of Proposed Sites and Existing Parking with Prioritization of Zones Requiring Parking Construction

Following the organization and location of the parking lots required in Rasht, the areas requiring parking were identified after reviewing the current situation in terms of the research criteria and sub-criteria (Figure 5), and the situation of existing parking lots was compared with the results of the study (Figure 6). Also, the overlap map of proposed sites and the potential points for the parking construction (which had no problem in terms of acquisition terms) were generated, as shown in Figure 7.

4. Conclusion

Site selection is considered one of the most important factors in the construction of an urban public parking. By selecting the appropriate criteria and analysis methods, it is possible to consider the problem of parking location at different city levels as well as possible. Since applying different site-location methods and models in different situations and locations may yield different results, the best method is the one that provides the best result according to the local conditions and constraints. Therefore, the appropriate tools such as GIS are increasingly used which can combine a large number of criteria and simultaneously perform the weighting. A review on the research works performed on the problem of parking facility location in urban areas, as detailed in the literature review of this work, indicates that several studies have been performed in certain cities. However, despite the special functions of the parking facilities, no study has yet been reported on the subject matter of parking facility location in Rasht using the methodology adopted in the present research. The research works presented so far have been mostly based on the library studies and questionnaire-based surveys, while this work undertook an accurate field survey on the demand for parking lots during different hours a day. Another distinctive feature of this study is that it considers the land price across the proposed location to address the cost-efficiency of the location. In the present paper, as a practical example of the combined use of the fuzzy AHP model in the GIS environment, 6 criteria and 18 sub-criteria were simultaneously weighted. Finally, after conducting the research operation process, the most suitable sites were selected for the deployment of public parking lots in Rasht.

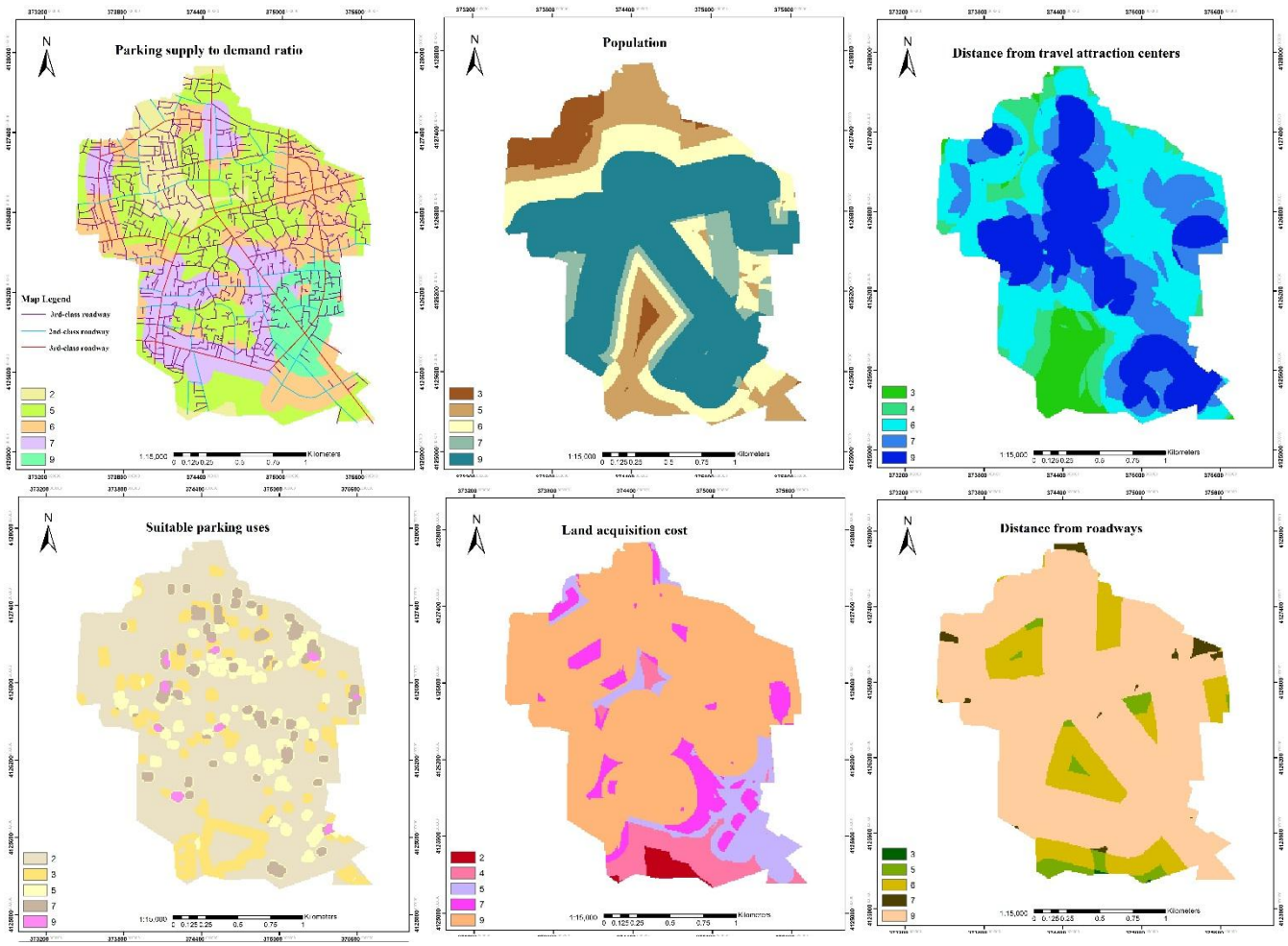

Figure 4. Zoning map of research criteria

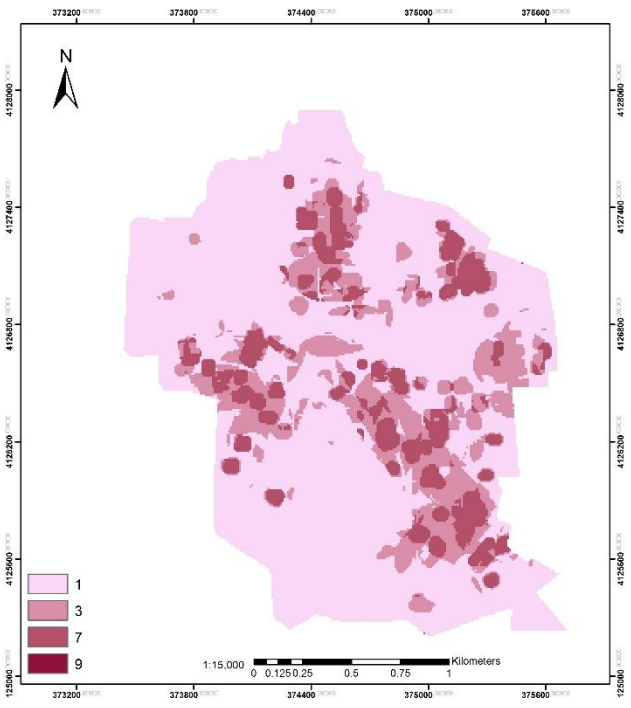

Figure 5. Prioritization of zones requiring parking construction

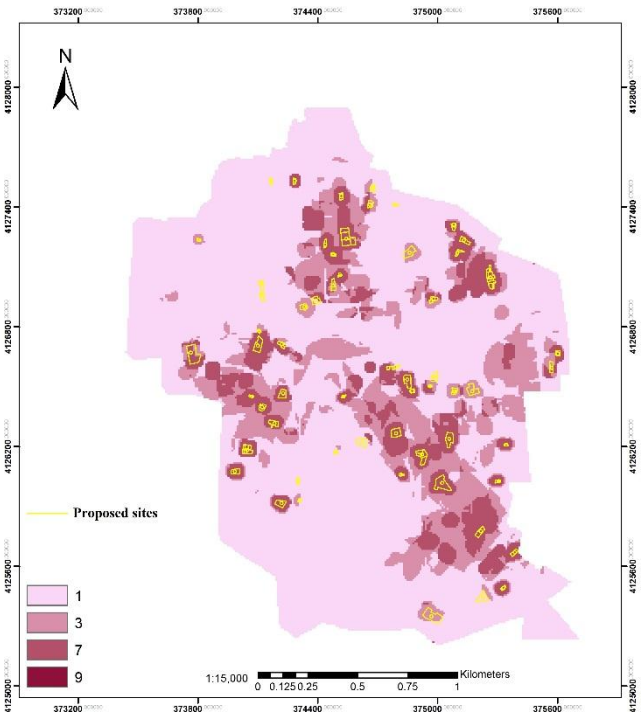

Figure 6. Overlapping of proposed sites with prioritization of zones requiring parking construction

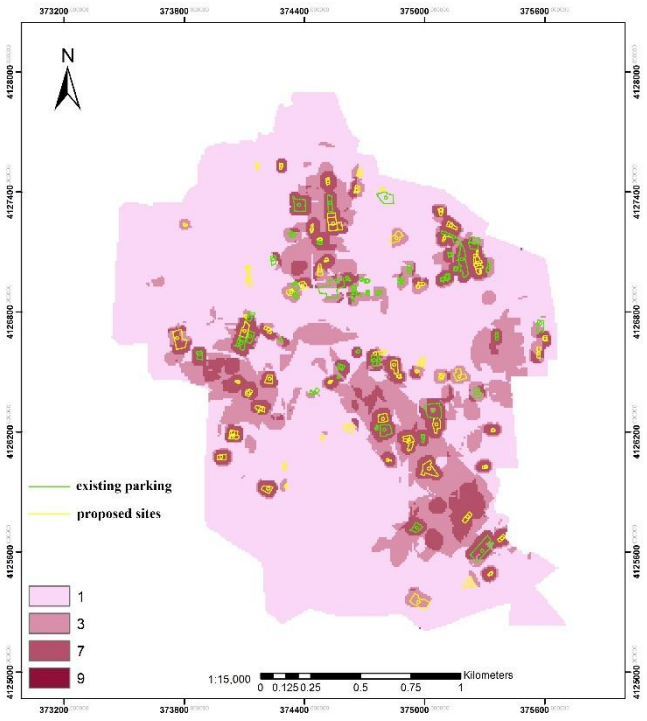

Figure 7. Overlapping of proposed sites and existing parking with prioritization of zones requiring parking construction

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