Developing Optimal Zones for Urban Parking Spaces by Arc GIS and AHP

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Abstract

Nowadays, finding a place for vehicle's parking space has become a big challenge especially, in downtown of metropolises. Parking places are as one of main part of the modern urban transportation system, having the crucial role of removing static traffic from streets, which can cause to reduce streets' parking spots, improve vehicles movement and increase the width of streets indirectly. Allocations of public parking spaces have been done in traditional way by visiting the location until few years ago without considering all effective parameters in allocation of public parking spots. The only parameter that has been considered, being the price of land. Geographic Information System (GIS) takes into account a suitable system for specifying optimum location to develop the public parking space. Using the GIS has the merit of increasing accuracy in comparison with the traditional method. This research presents proper method for locating of public parking place by consideration all effective parameters and by using GIS. The effective parameters have been weighed by AHP method. Then these parameters have been combined by fuzzy algebraic sum. This method has been used for locating suitable parking spots in region1 of Tehran as the case study.

Keywords: Allocation, Parking, GIS, AHP

1. Introduction

There have been immense advances in most aspects of technology, especially in the field of Transportation, therefore nowadays, locating Parking spaces play significant role in the modern urban transportation systems. Had we realized the significance of optimum allocation of parking spots in down town area, we would have deliberated on it much more meticulously. Parking spaces have the important role in decreasing static traffic from streets, is undeniable. This issue leads to reducing street parking spots, improving vehicle movement and increasing the width of streets indirectly. Parking management is a main compound of traffic management. Wrong and non-standard decision cause undesirable effect on urban traffic system, environmental degradation and prevent from economic development.

Proper allocation of parking is also intimately bound up with different parameters, with their different values and their importance. Locating of parking spaces with traditional ways and paper maps could not present correct and valid answers in such a way that consider all necessary elements but by using GIS and AHP could reach reliable answers. In this research municipal district, one of Tehran city has been chosen as case study for optimum allocation of parking spaces by consideration and weighting related parameters. The paper is structured as follows. Section 2 explains about case study for locating parking spots. Section3 introduces effective factors for allocating public parking spaces, which are required to allocate parking spots. In section4, parameters are surveyed and are weighed by AHP method. These weighed factors are combined together and are modeled in Arc GIS. In section5, GIS outputs are analyzed and by consideration outputs' analysis, suitable places for parking spots are introduced. Finally, Section 6 expresses the conclusions.

2. Case study

For practical definition of parking locating, using case study is obligated. So Tehran's district1 is chosen as a case study. The reasons for choosing this area are described as follows:

a. Tehran strategic situation and crucial role: not only is Tehran as Iran's capital and largest urban area and city but also, it is the largest city in Western Asia, one of the largest in Southern Asia, and the 19th largest city globally (Zia, Tony, 2010). Tehran population was estimated near 8.5 million (2012) (Zokai Ashtiani and et all. 2012). Moreover, it is the economic centre of Iran (Britannica). About 30% of Iran's public-sector workforce and 45% of large industrial firms are located in Tehran (Anthony H. Cordesman, September 2003). According to the head of Tehran Municipality's Environment and Sustainable Development Office, Tehran has a capacity for 700,000 cars but currently more than 3 million cars are on the roads in the capital (Zokai Ashtiani and et all. 2012). It can be conclude Tehran faces with traffic congestion problems and it affects on lack of parking spaces and access to them.

b. Tehran district1 commercial and residential situation and expensive land prices: The city of Tehran is divided into 22 municipal districts, each with its own administrative centers. The geographical boundaries of District1 (North of Tehran) is between mountain foots and Tehran plain, from the north to the 1800 meters elevation of Alborz mountain range, from the south to Chamran and Modarres Highways, from the west to Darakeh River and from the east to Fath Boulevard so that this district is situated in the most northern areas of Tehran. (Alireza Gharagozlou, Zahra jalili, Mojgan Hejrani Diarjan,

2006). In addition, it is the wealthiest region in Tehran with high buildings which have different applications such as residential, official, business and multi-applications. Most of high-classes shopping centers are located in this district, which are taken into account as trips absorption centers in rush hours. Besides, this area is the most expensive area in Tehran city and 65 percent of this region's residents are taken into account among of 5 percent of Iranian richest people. The average value of one square meter of residential unit is near 3500 $.By regard to describe this district, it can be concluded, suitable parking places allocation in this region can prevent of wasting vehicles' users and residents' time and expenses.

Fig.1. *Administrative divisions of the city of Tehran (Tehran municipality online site)*

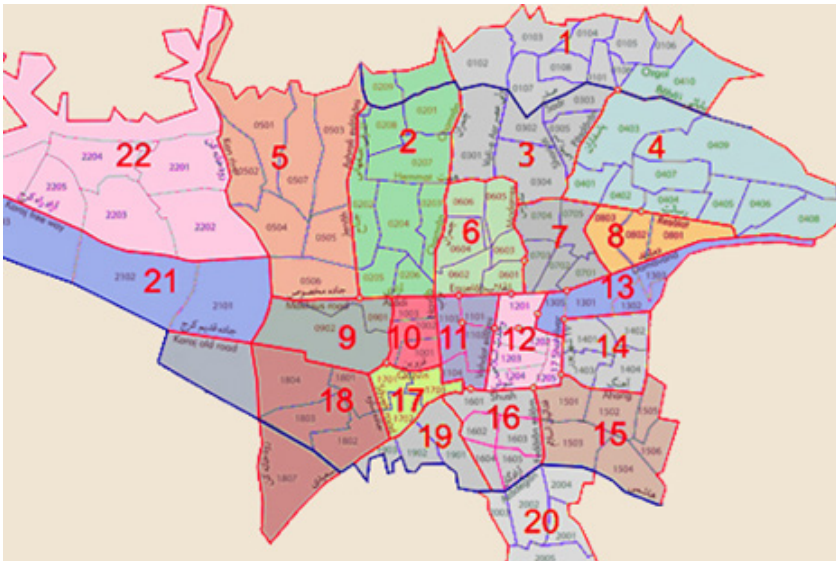

Fig.2. *Tehran geographical boundary of municipal district1 as case study*

3. Effective factors for allocating public parking places

In this part effective factors that has been mentioned as the most important factors for allocating parking spaces are presented.

3.1 Distance from travel absorption centers

This factor is one of the most important factors for allocating parking spots due to its advantages and disadvantages has for users' convince. Travel absorption centers include commercial centers like malls and shopping centers, administrative, entertainment, historical and medical centers. Distance from these centers should be in such a way that people reach their destination with minimum walking distance. The maximum acceptable walking distance between parking places and travel absorption centers has been shown according to cities population in table 1 (Weant, 2006). According to properties of region1 of Tehran city and considering this district maximum rational walking distance between parking places and travel absorption centers, being one kilometer. this research uses five buffers. (0-200m, 200-400m, 400-600m, 600-800m and 800-2000m).

3.2 Accessibility to passages

According to passages and roads operation, based on their transportation role and volume, this factor has been divided into 3 sections, arterial degree1, arterial degree 2 and local streets. Velocity in arterial degree 1 is 70 -90 km/h, in arterial degree 2 is 40-60 km/h and in local streets is 10-30 km/h(Brierley, 1997).

3.3 Accessibility to transportation terminals

Building parking spots near transportation terminals such as subway and bus stations are necessary and this factor is one of the most important factors for using public transportation. Because transportation terminals are taken into account as the big generation and absorption travel centers.

3.4 Price of land

Building parking with less cost has been always one of desirable choice for experts in transportation and urban planning, so price of land is one of the most important factors for allocating parking places. Experts and urban executives do their best to build parking spaces in lands with low price. In this research, price of land was divided into 5 groups, the cheapest lands, cheap land, land with average price, expensive land and the most expensive land.

3.5 limitative factors

There are some limitative factors for building parking space. Being 150 meters distance from intersections, avoiding from building near other parking places and avoiding of building vicinity of gas station, electricity posts, schools, administrative, entertainment, historical, medical centers and mosques are the most limitative factors, which should be considered by Urban mangers.

Table 1. *Maximum acceptable walking between parking and travel absorption centers (m)*

Type of parking / city population	Short term parking (less than half hour)	Long term parking (more than half hour)
Thin(less than 250 thousand people)	66 -120	200 - 320
Populous(more than 250 thousand people)	166 - 266	330 - 500

4. Surveying and weighting factors

In this section, all effective factors are weighed by AHP method. After that, these weighed factors were combined together and are modeled in Arc GIS.

4.1 AHP method

This method has been created at first in 1986 by Thomas L.Saaty. AHP is based on three main principals including dissection, comparison judgment and combination of priority steps. (Malczewski, 1999). Dissection and analysis principal needs to analyze and dissect hierarchically decision issues into different ingredients. Comparison judgment needs to compare hierarchically in binary system for existing elements in same surface and considering their roots in upper surfaces. Mentioned principals in AHP methods include three steps as follows:

Step1: Development of structural hierarchy process

Step1 is development of structural hierarchy process. In the first step of AHP method, is made hierarchically an analysis and dissection from decision issues into different ingredients. Creation of hierarchy process is the top most level, allocating of public parking spots, in this research. Afterwards, hierarchy levels go to level of more specialized. This process goes on until reach to levels of features, which are the lowest surfaces for making decisions. It should be noted, each level must be connected to its upper level. (Godsi pour, 2009). Structural hierarchy process for locating parking has been shown in figure3.

Step2: Factors dual comparison with together

In this step, each ingredient is compared with its related element since both elements are in same level. This comparison is made in a binary system. These weights can be estimated according to users' poll or experts' choices.

In this research, experts' opinion were combined with each other and by using the geometric mean, the results are converted to one. Table 2 shows the form, used in this research.

Table 2. *Dual comparison form, used in this research*

value	importance
9	Extremely Prefer
7	Very Strongly Prefer
5	Strongly Prefer
3	Moderately Prefer
1	Equal importance
2,4,6 and 8	Importance Between top options' distances

After calculating comparative importance, which is called comparative weight. Ultimate weight of each factor was estimated by compilation comparative weights, called absolute weight. Final weight of each parameter was obtained from sum multiplied criteria importance coefficient by parameters' weight in a hierarchy process.(Godsi pour, 2009).

By using special vector method, weight of each factor has been estimated. Table 3 shows value of each parameter rather than other parameter and final weight of parameters have been demonstrated in table 4.

Step3: survey of system compatibility

System compatibility rate can be computed in AHP. By consideration system compatibility, can judge about system validity. Acceptable inconsistency depends on decision makers and research accurcy. In this research, inconsistency values below 0.1 are acceptable. (Malczewski, 1999) Inconsistency coefficient of second level factors in AHP model is presented as follow:

Inconsistency coefficient= 0.098 <0.1 ok

Fig.3. *Structural hierarchy process of allocating of parking spots*

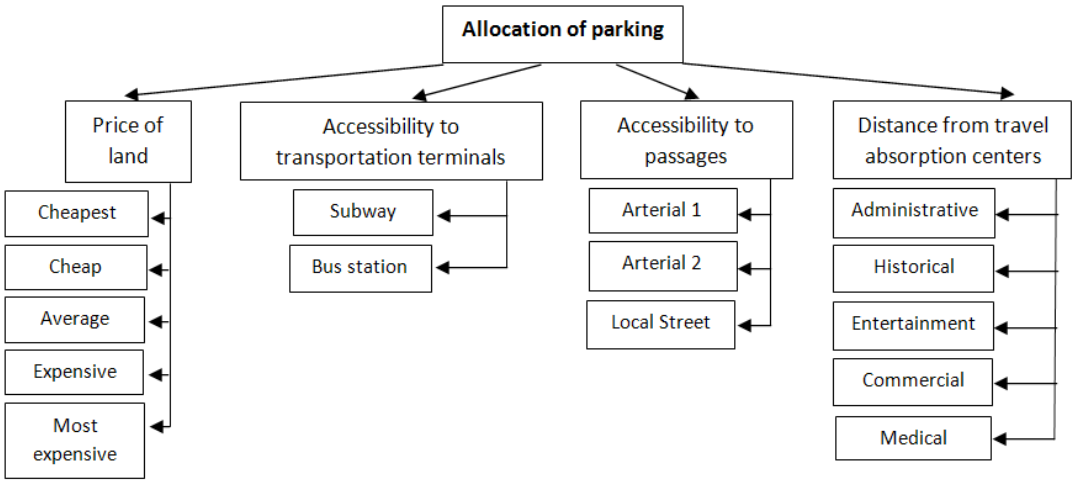

Table 3. *Dual comparison of second level factors in AHP model*

	accessibility to transportation terminals	Distance from travel absorption centers	Accessibility to crossing	Price of land
accessibility to transportation terminals	1	3	5	6
Distance from travel absorption centers	0.33	1	3	4
Accessibility to crossing	0.2	0.33	1	4
Price of land	0.17	0.25	0.25	1

Table 4. *Final weight of second level factors in AHP model*

Price of land	Accessibility to crossing	Distance from travel absorption centers	accessibility to transportation terminals
0.086	0.172	0.254	0.488

4.2 using fuzzy algebraic sum in combination of factors with together

According to Fuzzy theory, ingredients select numerical values between zero and one. In this research was used of Fuzzy method for combination factors. (An,P.Moon, 2001). Fuzzy algebraic sum is described according to formula 1: (An,P.Moon, 2001)

$$\mu\_combination = 1-(\prod_{i=1}^{n}(1-\mu_i)) \quad (1)$$

Where is weight of each factor that depends on its upper factor and is weight of each upper factor. By using this operator, Fuzzy membership values approach towards1. This operator is used when several factors boost their effects. In figure4 has been indicated Final combination of GIS layers in region1 for allocating parking spots

4.3 Data layer combination with use of fuzzy functions

In this stage the achieved layers from the previous parts would be combine according to the suitable fuzzy operators with each layer features in order to achieve the suitable final map as an output. For combination the safety sub-criteria and achieving the safety final fuzzy map, association function (Fuzzy And) was used because in parts whose each sub-criteria comprised no safety points, in the final Fuzzy map, would not include those parts. The related layers to sub-criteria are combined according to the table 3 weights. Then the fuzzy map of price of land, accessibility to crossing, distance from travel absorption centers and accessibility to transportation terminals combination would be achieved. In the final stage, for achieving the suitable places of the parking spaces, the fuzzy multiplication (Fuzzy Product) would be used. In that case, with multiplication the pixel weights of fuzzy map, the combination of above- mentioned parameters with corresponding pixel weights in safe places Fuzzy map, the final locating map would be achieved. Using multiplication operator (Fuzzy Product) would cause that the weights of secure places are zero or little would be zero or made less. Therefore the secure places would have more value to build. [Flak, M. A. and J. C. Barbaresso, 1982; Hauer, E. and B. N. Persuad, 1984; Wright, C. C. , C. R. Abbess and D. F. Jarrett, 1988]

5. Analyzing output data in GIS

Each part of district1 has been shown with special color in fig 2. Each color assigns with special weight about allocation of parking spots. Color changing from green to blue, from blue to orange, from orange to pink, from pink to grey shows weight changing and decreases of weight In other words, when any region weight decrease, this region is not suitable for locating parking spaces. The location with green color is the best place for allocating parking

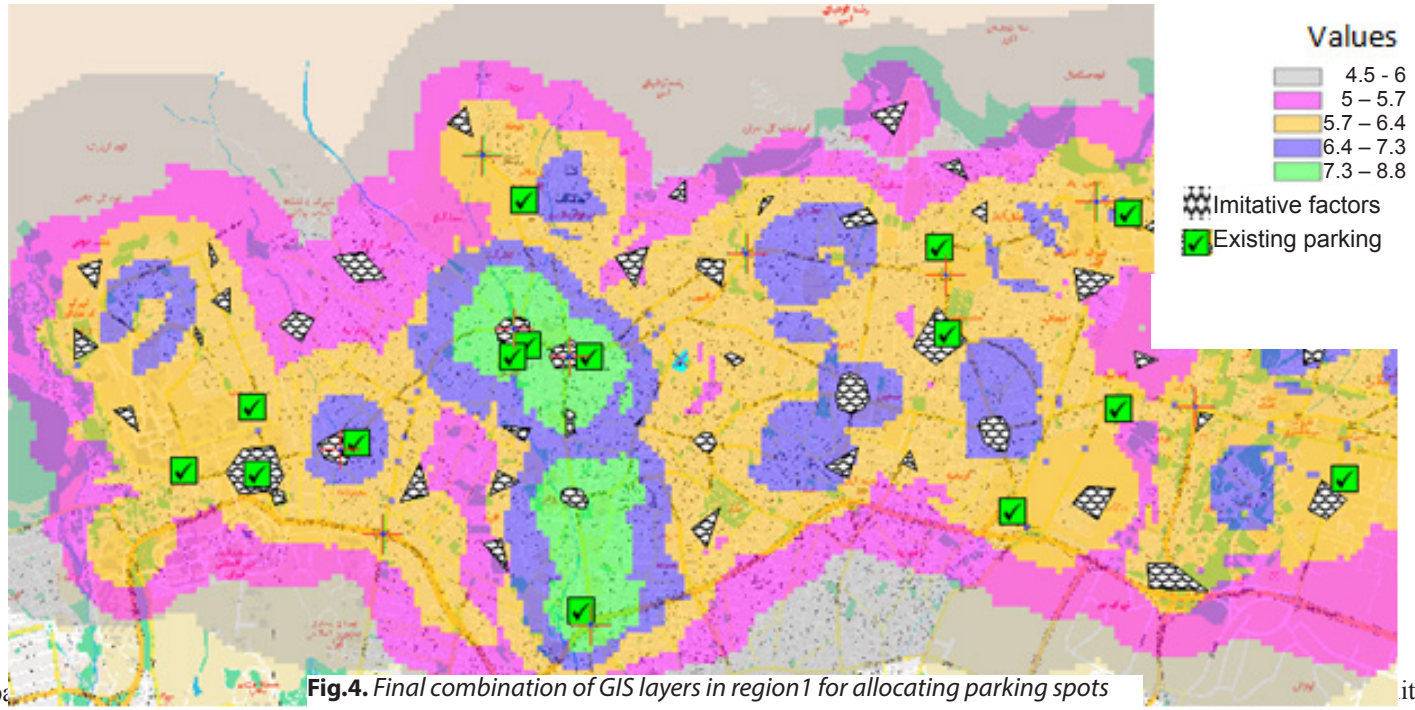

Fig.4. *Final combination of GIS layers in region1 for allocating parking spots*

to transportation terminals especially subway stations is more valuable than the other factors. Optimum location for parking spots is often in vicinity of subway stations. Some existing parking spots shows that they have been built in areas with low values of weight and even in the places that limitative factors have been prevented for building them. There are 14 existing parking place that 4 parking spots are in green and blue zones (33%). 8 parking spaces are in orange and pink zones(53%) which shows they have not built in suitable places. Tow parking spots are in limitative zones(14%).

6. Conclusion

For first time these effective and limitative parameters present in this research that have been weighed by AHP and have been combined with fuzzy algebraic sum together. Moreover, optimum zones have been specified for parking spots by GIS. Some existing parking spaces have not been built in suitable places. Moreover, some have been built in forbidden zones. By consideration this analysis, it can be concluded, most of parking places have been built without consideration experts' opinion, effective parameters and limitative factors, so moving parking places from unsuitable to appropriate zones would improve network users motivation for using them and enhance transportation quality.

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