Optimal locating of residential towers using a GIS-based fuzzy approach

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Abstract
With respect to the increasing population of the cities and as a result of immigration to the urban areas, new concerns for the city traffic and residential problems have been arisen which the most important one is the construction of dense settlements in residential complexes.
This is due to the fact that cities and public services are distributed within the least space possible (for economical reasons) which upgrading these services is costly and time consuming,. On the other hand, settling a new population should be in a manner that traffic increase is minimized.
Therefore, tower construction is a new procedure which is suggested to prevent a part of such difficulties. However it has become a new urban traffic problem because an unsuitable locating of a tower with limited area and high residential concentration could result to sever traffic, service, environmental and abnormal social problems. Hence, finding a procedure to locate a suitable residential area is appealing. In this article we have tried to analyze parameters which are important in locating suitable areas for tower construction. These parameters may include region population, main street width, and distance of parking exit from the highway, proximity to green spaces and nearness to schools. The most important parameters will be selected and then using a GIS-based fuzzy logic approach, the best area for tower construction will be identified. The usage of a fuzzy procedure is due to the fact that locating a suitable tower construction area and its related parameters are not crisp urban planning issue. With the aid of a fuzzy system it is possible to achieve an optimum solution considering different uncertainties exist in urban site selection for tower construction. This paper concentrates on conceptual, logical and physical modeling of a prototype GIS-based fuzzy logic system to assist urban tower site selection problem.

1-Introduction
One of the most important cases of designing cities is replacing apartments with residential towers. If we want to have optimum designing for residential towers, there are some parameters affecting this issue.
In this paper the influencing parameters and statistical data have been gathered for tower construction site selection in Tehran. For the tower site selection, determination of degree of suitability for constructing tower is studied. Action to solve or reduce urban problems must be taken into account to prepare a comprehensive action plan to be consistent with the other urban actors [8]. Among a number of the influencing parameters four of them have been selected and formulated in a fuzzy inference system. They are "distance between outdoor of garage and the nearest main way of city", "number of population live in a circle around block with one Kilometer as its radius", "capacity of elementary schools exist in the same circle" and "width of street that outdoor of garage is opened in it". All these parameters have been determined for traffic reduction in Tehran.

After production of the GIS-based fuzzy system, a number of nominated sites have been identified for tower construction.

The methodology of the research is described in Section 2. The case study is elaborated in Section 3 and finally conclusions and recommendations for future research are explained in Section 4.

2-Methodology

Geospatial information is a subset of the information system for urban planning .More exactly; it is common to see software products actually named as a Geospatial Information System (GIS) to be presented in the comprehensive information system of any local authority. In addition to the geospatial database which is the core of a GIS product, four groups of functionalities of GIS are as follows [9]:

-A subsystem for geospatial data acquisition
-A subsystem for spatial analysis
-A subsystem for cartographic presentation
-A subsystem for data management.

The geospatial database needs to be regularly updated, and share information with another systems [9].GIS technology supports works that needs justification of which data and/or database exists or can easily be created [8].

The methodology of this project is illustrated in Figure 1.

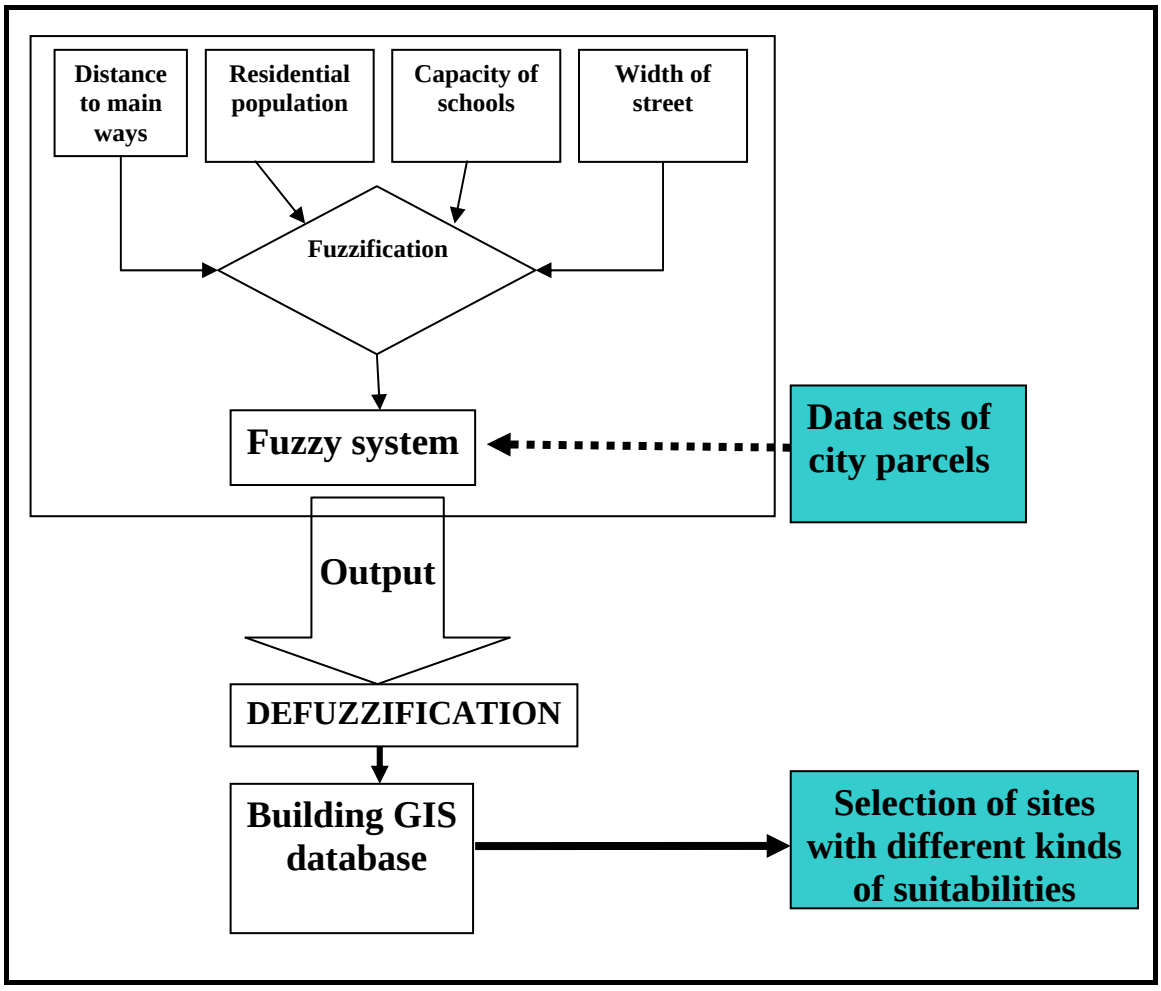

Figure1: Workflow of the proposed GIS-based fuzzy system for site selection of residential towers

2-1) Determining the parameters

One of the most important issues of urban planning is proper site selection of residential towers. Increasing population of cities and shortage of urban lands in order to construct new houses and increasing the importance of lands that have more accessibility to urban facilitates and tower constructions are among the most challenging issues in large cities. Accordingly urban planners are going to use residential towers in areas that have high cost of land, good natural conditions and more accessibility. This has benefits because proper use of urban land for residential purposes will be achieved.

There are some other subjects that have close relations to designing the best sites for residential towers. For example parameters such as increased public transportation vehicles, width of streets and accessibility to highways should be taken into account for proper urban traffic management.

Other problem is elementary schools for children between seven to twelve years old. Before constructing a new tower for residential purposes, the capacity of schools is known, so we should predict the number of students and take some considerations regarding the capacity of existing schools. If we do not take this issue into account, the parents will be faced with the problem of transportation of their children to school. This leads to one of the major issues causing urban traffic.

Accessibility to hospitals, green areas, commercial centers, cinemas and other facilities are some of the other parameters influencing residential tower site selection.

In this article we have studied the major influencing parameters and classify the entire nominated parcels into four classes, their titles are most suitable, suitable, weakly suitable and unsuitable.

The first phase of urban planning is problem recognition and definition, then decision to plan and description of the tasks [9].Therefore, in the first level we must recognize our parameters. Developed an initial set of site selection criteria for MUCS structure has been developed [15] so we consider these parameters and using some questionnaires, interviews and their analyses to categorize the influencing parameters into the primary and secondary parameters (Table 1).

Table 1 – The selected parameters influencing residential tower site selection

Type of parameters	Number	Parameters considered for residential tower site selection
Primary	1	Distance between outdoor of garage and main ways of city
	2	Population live in a circle around site with in 1 Kilometer as its radius
	3	Capacity of elementary schools exists in the same circle
	4	Width of street, the outdoor of garage open in it
Secondary	5	Capacity of public parkings exist in the area around the site
	6	Accessibility distance to parks and green areas
	7	Accessibility distance to nearest commercial centers
	8	Accessibility to medical centers and hospitals
	9	Land value
	10	Accessibility to facilitates and cultural centers (cinemas, theatre and …)

In this article we concentrate on the primary parameters.

2- 2) Fuzzy system for locating residential towers

A MATLAB toolbox has been developed for developing a GIS-based fuzzy system implemented in this research. The different stages of the system development are elaborated in this section.

2- 2- 1) Defining the input and output parameters

As mentioned before, among the mentioned parameters, four of them were selected considering the experimental investigations.

In the next stage, the linguistic parameters and their fuzzy range have been defined along with their charts. The implemented values are completely empirical and are based on the experience of different researches regarding tower construction and tower habitants [15].

When choosing these numbers it should be assumed that it is impossible to find a place where has a distance greater than one Kilometer from a highway or main street (Table 2).

Table 2 – Selected input parameters to be used in the fuzzy system

Title of input parameter	Input parameters
Way-dist	Distance between outdoor of garage and main ways of city
School-population	Capacity of elementary schools exists in the same circle
Width-St	Width of street, the outdoor of garage open in it
Population	Population living within 1 Kilometer

In the next stage, for each of the parameters a specific membership function has been defined. A trapezoidal component function has been used for all variables.

One feature of this function is a specific range which is usually in its middle the maximum weight is equal to 1.

The next variable is the population which elementary schools support and should be located within one Kilometer from the tower.

Table 3 indicates the chosen amounts for this variable. The other variables are the width of the street entering parking area and population within radius of one kilometer of the tower have been indicated in Tables 4, 5 and 6. In Tables 3 to 6, parameters A, B, C and D are trapezoidal parameters functions for each linguistic variable. The data used is illustrated in Figure 2.

Table 3 – Linguistic variables and their values for distances between outdoor of garage and main ways of city

Way-dist					
Values(Meter)	**Linguistic variable**	**A**	**B**	**C**	**D**
0 – 100	Short	0	0	50	100
50 – 300	Medium	50	150	250	300
200 – 1000	Long	200	800	1000	2000

Table 4 – Linguistic variables and their values for capacity of elementary schools exist in the same circle

School-population					
Values(person)	**Linguistic variable**	**A**	**B**	**C**	**D**
0 – 750	Bad	**500**	**500**	**500**	**750**
400 – 1850	Good	**400**	**900**	**1650**	**1850**
1400 – 3000	Very good	**1400**	**1900**	**2500**	**3000**

Table 5 – Linguistic variables and their values for width of street, the outdoor of garage open in it

Width-st					
Values(Meter)	**Linguistic variable**	**A**	**B**	**C**	**D**
0 – 15	Low	**7**	**7**	**7**	**10**
10 – 75	Normal	**5**	**15**	**25**	**75**

Table 6 – Linguistic variables and their values for population living within one Kilometer around site

Population					
Values(Person)	**Linguistic variable**	**A**	**B**	**C**	**D**
0 – 3000	Very good	628	628	628	3000
1500 – 15000	Not good	1500	5000	10000	15000

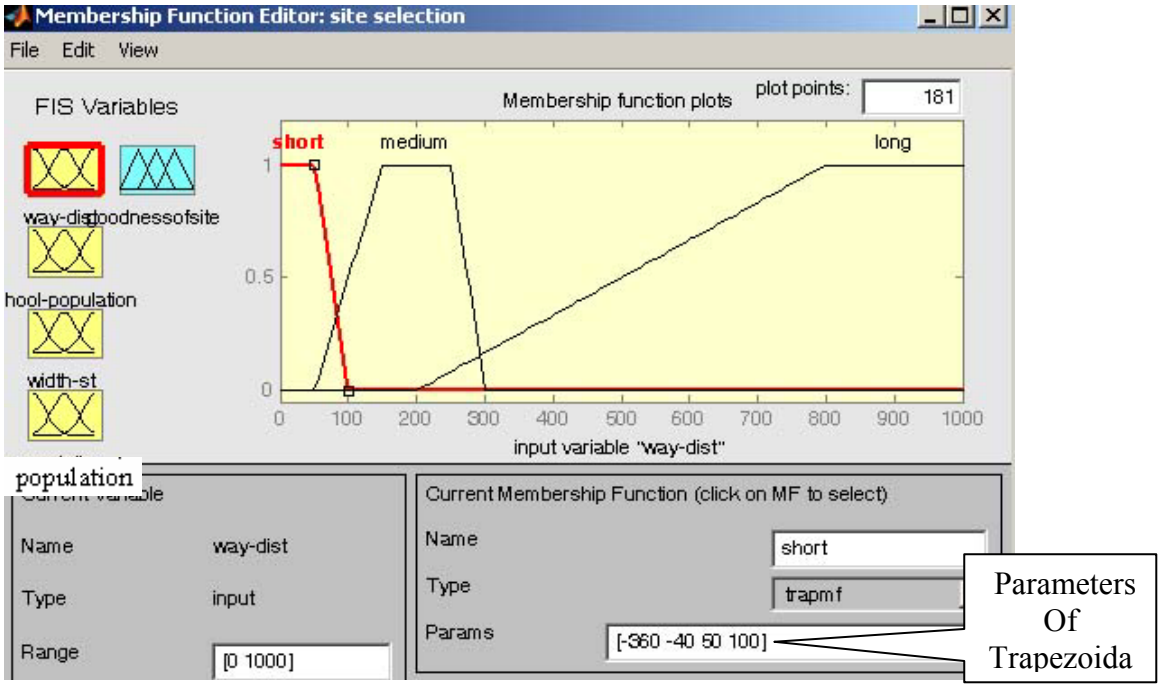

Figure 2 – A snapshot of MATLAB program to define an input parameter such as distance between outdoor of garage and main ways of city

The output is also divided into four intervals within the range of zero to one, which indicates that it is possible to examine any suitable land for tower construction and ultimately we can analyze its suitability with respect to its belonging to each class.
The four defined classes and the related values are provided in Table 7 as goodness of the selected sites.

Table 7 – Linguistic variables and their values for output parameter

Goodness of site	
Values	**Linguistic variable**
0 – 0.20	Most suitable
0.25 – 0. 5	Suitable
0. 5 – 0.75	Weakly suitable
0.75 - 1	Unsuitable

Selecting the ranges was completely arbitrary and in real conditions, depends on the range of the numbers which are usually defined in a specific area.

2-2-2) Defining the mathematical equations for the tower site selection problem

Now we have reached the stage to define the governing mathematical equations for the tower site selection problem. We could use the following thirty six laws.

Because there exists four input parameters which two of them attain three membership functions and the others have two membership functions. Therefore, we could define ($3 \times 3 \times 2 \times 2 = 36$) laws as the number of combinations.

The procedure for defining the laws is such that for each input parameters, one of the functions has been selected and the "AND" operator applied with another membership function of another parameter and ultimately one of the possible output parameters to this new assumption has been assigned. Table 8 introduces the laws used by fuzzy system. The defined laws and their corresponding membership functions have been employed in a MATLAB computer program. For presenting the suitability class, four sets of codes have been considered as follows:

Goodnessofsite = 1 if it is Most Suitable

Goodnessofsite = 2 if it is Suitable

Goodnessofsite = 3 if it is Weakly suitable

Goodnessofsite = 4 if it is Unsuitable

Table 8 –Rules applied for the residential tower site selection

No	Way-dist			School-population			Width-st		Population		Code of Goodness of site
	Short	Medium	Long	Unsuitable	Good	Very good	Low	Normal	Very good	Not good	
1	*			*			*		*		3
2		*		*			*		*		3
3			*	*			*		*		3
4	*				*		*		*		2
5		*			*		*		*		3
6			*		*		*		*		3
7	*					*	*		*		2
8		*				*	*		*		3
9			*			*	*		*		3
10	*			*				*	*		2
11		*		*				*	*		2
12			*	*				*	*		3
13	*				*			*	*		1
14		*			*			*	*		2
15			*		*			*	*		3
16	*					*		*	*		1
17		*				*		*	*		1
18			*			*		*	*		2
19	*			*			*			*	3
20		*		*			*			*	4
21			*	*			*			*	4
22	*				*		*			*	3
23		*			*		*			*	4
24			*		*		*			*	4
25	*					*	*			*	3
26		*				*	*			*	3
27			*			*	*			*	3
28	*			*				*		*	3
29		*		*				*		*	3
30			*	*				*		*	3
31	*				*			*		*	3
32		*			*			*		*	3
33			*		*			*		*	3
34	*					*		*		*	2
35		*				*		*		*	3
36			*			*		*		*	3

3) **Case Study**

Finally after developing the related fuzzy system, we want to exploit the system and achieve a result regarding the suitable places for tower construction. The study area is a site situated at Amirabad region in Tehran. First the map with 1:25000 scale of the area has been topologically structured using Arc/Info software, then the file has been exported to ArcView and finally the spatial database has been constructed. A buffer zone with one Kilometer radius have been selected around the site and the schools and residential population from the available information deduced. Also we could obtain the street width and the distance to the main street from the map have been obtained. These values should be entered in the toolboxes of a MATLAB environments based on the defined laws.

At this stage the result of fuzzy process has been used to find the best areas to build towers. So five new fields corresponding to the available information have been added. Four of them is related to input variables and the last one is for representing the output value. The output field has values between 0 and 1. If the output value is near 0, it is concluded that our polygon is not suitable and if the value is near to one, it is representing that the suitability of area has been increased.

At the end, we can classify all the polygons which have value for their new fields according to their outputs. This assist to perform queries on the results of fuzzy system as shown in Figure 4 .

It should also be noted that the fuzzy system offers only numerical output values and we have applied to fix these values with one of the linguistic variables of the system.

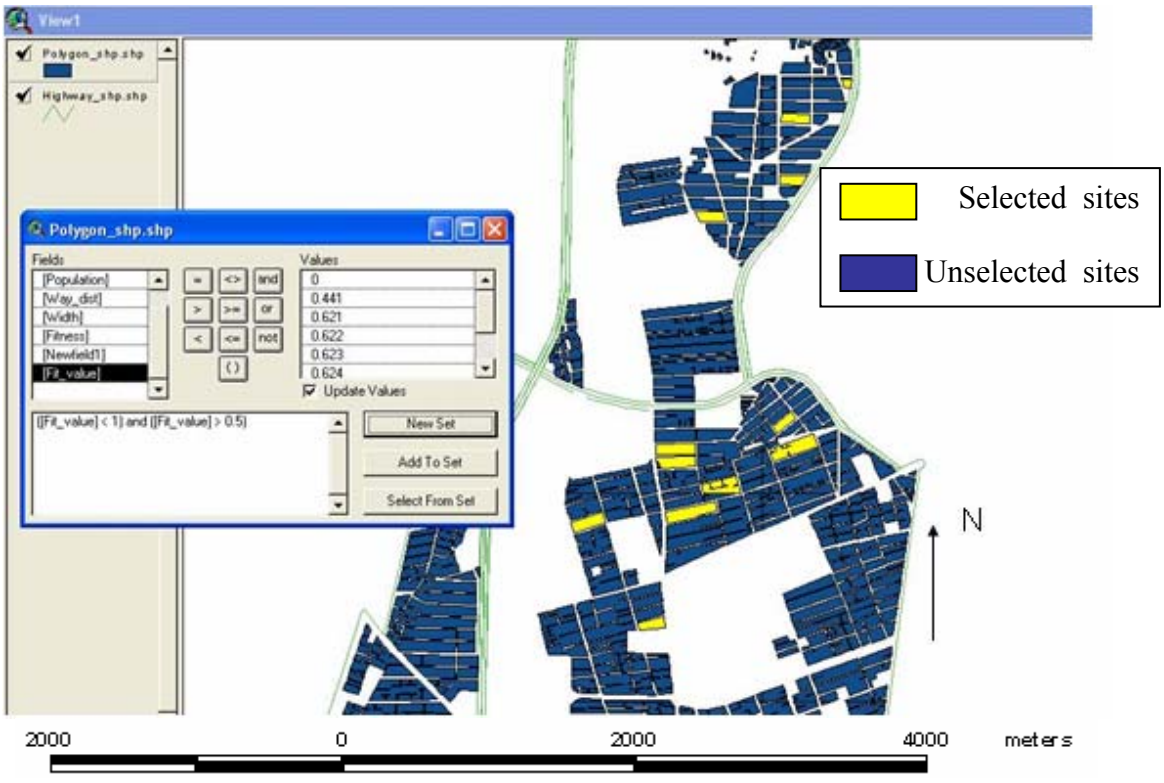

Figure 4 – The result of query to select the most suitable and suitable parcels for residential tower construction.

5-Conclusions and suggestions

The following conclusions have been achieved from the research and some recommendations are introduced:

1 – In this project only four parameters were considered for tower site selection, where in a real project, to achieve more precise results, all the influencing parameters should be considered.

2 – In municipal affairs, it is likely that in some special conditions, mass constructions of towers would be inevitable which regarding the mentioned parameters could be unsuitable. In this situation we could hope that private schools and general parking be constructed to solve the problems using GIS analysis.

3 –The property value is one of the very important parameters, however due to unavailability of the information in the research has been neglected.

4 - The fuzzy system will be used when we have uncertainty in our parameters and its values, so in this case study we used the named parameters and assigned range for them. However, using other parameters and their associated ranges may give different answers which studying their influences are the next steps of the research.

5 – In this project we have tested some of the functions of fuzzy toolbox of MATLAB and selected trapezoidal functions because they provided better results with respect to other functions exist.

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