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ORIGINAL ARTICLE

Provision of an integrated analysis model by combining AHP decision-making technique and GIS for identification and management of land use changes

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The urban land use is one of the basic concepts of urban planning knowledge and, in fact, the foundation for its formation, and it is so important that some urban planners in advanced countries regard it as urban planning. In recent decades, rapid changes in land use in the suburbs of major cities of Iran, especially in Tehran as the capital, have been accompanied by significant consequences such as environmental pollution and poor urban growth. Unfortunately, an important part of these changes was non-normative and unscheduled. The study aimed to provide an integrated analysis model by combining the AHP decision-making technique and GIS to identify and manage land use changes. In this study, the required model indicators including population, employment, land prices and use were obtained and its raw data were extracted. Using the selected model, we analyzed the data and finally we obtained a map and a table to show the intensity of the changes in the study area. The results can help predict land use changes in future research.

Keywords: Integrated analysis; AHP decision technique; GIS; use change management

Introduction

Due to human activities and natural phenomena, the face of the earth is always changing. The speed and variety of this change in urban environments is more than other areas. Therefore, for optimal management of urban areas, awareness of the land use change ratio is considered necessary. Today, due to high land value and natural resource constraints, predicting future land use changes is of great importance to managers, environmentalists and other researchers. In order to organize the land use changes, it is necessary to apply expert knowledge in the form of a system in such a way that the user can consider the effect of various environmental, economic, social and political factors on land use change. In recent decades, rapid changes in land use in the suburbs of major cities of Iran, especially Tehran as the capital, have been associated with important consequences such as environmental pollution and poor urban growth (Zaheri, 2008). Unfortunately, an important part of these changes was improper and unscheduled. The study of land changes and degradation in previous years and the feasibility and prediction of these changes in the coming years can be an important step in planning and optimal land use and controlling the improper changes in the future.

Subway as one of the main infrastructure of the city is an effective means of organizing city development. Subway station as a new element in the physical space of the city consists of a space that in the simplest state can be limited to one or more inputs and outputs. But since each of these stations gradually affects a range of environments around them, today, in the development planning of stations, with regard to their functional characteristics and their advantages, are considered as a single coordinated set with interactions with the area around them.

For example, Sadeghiyeh Subway Station in Tehran, which is located at the beginning of Tehran Subway Line 2, has a large station complex. The lands and properties located near the station have changed their use since its opening. In this project, it is tried to find the reasons for the changes by examining the changes in these lands, in order to have a correct and proper planning for such particular lands in the future plans of the city.

Theoretical principles

The city will continue to grow and develop, use and analyze existing resources, and expand through the land development and use change. Incorrect and contradictory patterns of land use can have a long-term financial effects on the value of land, buildings and other improvements, and can also put additional pressure on public roads and infrastructures. Sudden land

development combined with inertial sources or vacant lands may result in excessive use of public funds for the provision of services and other public needs. Land use planning is established to identify, describe and express the priorities of urban land use based on physical characteristics and land constraints, characteristics of areas and neighborhoods, the right place to locate different activities and land use from the economic aspects and access to services and public infrastructure and communication between the highways and generally the entire transport system.
Development of public transport facilities has become a way to improve access, community support, achieve regional goals, improve the quality of life, and support the financial success of private and public investment in public transport.
Obviously, the integrated planning of urban transportation system and land use in the city in the long term can be of great help in reducing intra-urban travel and eliminating many of them in cities by intelligent and optimal land use distribution in the city and location of economic activities, employment, education and shopping, and access to various administrative services in the city that are accessible with the shortest path and spending the least time and energy, and even on the scale of walking in residential neighborhoods. The subway as one of the main infrastructures of the city has the ability to attract various social groups and is an effective means for organizing city development (Hejazi, 2008). Studies in this area, and in particular the experiences of developed countries, indicate planning and encouragement to bring about the functional focus of uses around stations in the form of station complexes. Land use planning is one of the important categories that can play a special role in organizing and regulating the establishment of various activities and living in cities, while also forming the main core of urban planning, and this type of planning is successful only when it can identify the real factors and processes of land use and provide useful and practical ways to guide it towards the desired developmental goals (Shen, 2009). In this regard, the role of land as an important tool in identifying the objectives of national, regional, and urban policies is very sensitive. Discovering and identifying land use changes are the most important issues of urban planning and management. This issue is important in terms of urban planning and organization and social justice in the city, and in terms of equality and inequality in the distribution of taxes and value added in the city. Land use planning in contemporary times is more flexible than before due to the study of various aspects of the land, including the economic, social, physical, access. In addition, the new approaches to land use planning using evaluative models and evaluation of each of these aspects compared to each other, taking into account the objectives of the valuated plan and according to the value determined for each indicator, determines its effect in the process of presenting the plan. With these interpretations and taking into account the high success rate of the new approaches in the presentation and implementation of land use plans and analysis of the manner and extent of the effect and impression of the aspects and dimensions of the plan on the basis of software systems, the research attempts to compare and analyze the changes in land use in a given time using new approaches and utilizing information analysis software to ultimately utilize the results derived from them into a set of factors affecting land use and the effectiveness of each of them.

Background

Verburg et al. (2004) used a spatial statistical model to analyze land use change patterns in the Netherlands, and most changes in the national level was the development of industrial and commercial-industrial areas. The most important factors influencing these changes were access factors, state spatial policies at the national level and the effects of location and neighborhood.
Braimoh and Onishi (2007) in a study entitled "identifying the causes of land use change in the urban area of Lagos, Nigeria", considered factors such as access to roads, population, neighborhoods, and state spatial policies as the most important factors affecting land use change in this region. The table shows the main causes of land use change and the variables used for each factor in this study (Braimoh and Onishi, 2007). Zheng et al., (2012) in a study on land use change in the Changqinng of China, divided land use with different physical, environmental, economic, social and political dimensions, and divided the main factors affecting its changes into spatial and non-spatial factors (Zheng et al., 2012).

Experiences of station-based complexes and land-use planning focusing on subway

London subway: This subway started with about 400 km and 280 stations at first with private sector moves, which intended to improve the poor neighborhoods, then it was supervised by a semi-public system that dramatically reduced major investment problems, urban economy and transportation with the cooperation of the private sector.
Kesington station-London: Kesington underground station in High street is an ideal example of how a subway system can be part of a comprehensive shopping mall. That is, the subway system can be used as part of the local culture and to meet various needs by constructing the station complexes instead of just having a transport function.
Seoul subway: Seoul subway has 266 stations with 10 lines and 287 km length. The distance between trains at peak hours is 2.5 to 5 minutes and the train speed is between 30 and 36 kilometers per hour. It displace 6.7 million passengers a day. The subway system now accounts for 36% of total displacement. In the downtown, anyone can walk to the subway station i.e. with less than 500 meters. In South Korea, private sector funds are used to build station complexes. The main reasons for this are: first, the reduction of operational investment by private financing; second, the use of efficiency, creativity and technology of the private sector, and third, proper operation of the subway system and station complexes. The construction of the subway in Seoul increases the price of land and the percentage of land use, this price increase depends on the distance from the station, so that after 2 years from the opening of the Seoul subway line 5 to 200 meter radius of the stations, the property is increased by 14.7% to a radius of 500 m, 13.4% increases to 1000 m and 11.5%, meaning the closer the property is to the station, the more expensive it is.

McPherson Square Station - Washington: A 13-story building consisting of administrative and commercial centers is located around this station which is in the downtown of Washington. The building is connected to a subway station through an underground tunnel, built on 18,000 square feet (about 1,700 m^2) of land, and is located in an area that has become an administrative district and is one of the most expensive regions of the city. Before the construction of the Subway Station in 1977, this area was the place for selling vulgar books and other forms of illegal entertainments. The subway accelerated the redevelopment of this part of Washington DC.

Methodology

The data required for this research is collected through desk study. By referring to scientific centers and libraries in various organizations, theoretical and scientific resources have been collected. The data collection tool was observation and completion of spatial questionnaires (field surveys). The collected and processing data are analyzed by the software. In this research, analytical (statistical-spatial) method is used in data processing. Firstly, indicators affecting the land use in different functions and applications that are the basis for eliminating existing conflicts have been identified functions which are a ground for solving the conflicts were identified and it is prioritized by forming a database and using analytical methods such as information layer overlay and weighing with ARC GIS analytical software.

Study area

Since the case study of this research is Sadeghieh Subway Station, Tehran Subway Line 2 begins at Imam Khomeini Square, and after passing through the middle texture of the city, enters the 5th district in the southwest of Sadeghieh 2nd square. According to the information obtained from the Tehran Urban and Suburban Railway Operation Company, the station is the first subway station in Tehran, which was opened in 1995 as the source and destination of Tehran Subway Line 5 (Sadeghia - Golshahr). Sadeghieh Station along with its facilities covers a wide area and is one of the main subway stations in Tehran. This station is located on the southwest of Sadeghieh Square and is within reach of the area where the most important access networks pass around it. These networks include Mohammad Ali Jenah Highway in the east, Tehran-Karaj Freeway in the south, Sattari Highway in the West, and Ayatollah Kashani in the north. Sadeghieh Station is the source-destination station of the Subway Line 2, as well as the location of replacement of the train to access Karaj and Golshahr via Line Five. This station can be called the virtual terminal of subway lines in the region. In addition, according to the hat mentioned in the second chapter, Sadeghieh subway station can be considered as a terminal station. Sadeghieh Station with a total area of 33,812 m^2 is located on Mohammad Ali Jenah Highway, Water Organization St. The length of the station is 300 m and its distance to the next station is 1,216 m.

Selecting use change model

After reviewing the land use change models, the modeling group was considered as the selected group based on the GIS because of its purpose, scale and number of factors more relevant to the subject matter under study. In order to achieve the desired result, the integrated analysis model in GIS is used, which is an integrated model of decision technique and GIS. Among the decision-making techniques, the AHP technique is chosen due to having binary comparisons to construct the fit matrix as the appropriate decision-making technique for this research. The matrix made by this technique produces a number of binary comparisons as inputs and produces the desired weights as outputs. In addition, since this research has examined the effect of urban rail transport network (subway) on land use change, a model should be selected for analysis of the relationships between the two to consider both aspects of the subject and analyze them.

Description of selected model

Analytical hierarchy process: AHP is a flexible, robust, and simple way to make decisions. This technique is based on paired comparisons and allows managers to examine different scenarios. This method makes it possible to analyze complex problems in a hierarchical way, and it is possible to consider quantitative and qualitative criteria in the problem (Ghodsipour, 2007). The AHP method and its application are based on the following steps:

Establishing a tree and class structure: The transformation of a subject or issue into a hierarchical structure is considered as one of the most important stages in the AHP process. In order to determine the weight of effective factors in locating using AHP, we need to create a class structure for the parameters.

Explaining the CW of criteria and sub-criteria by paired comparison: The CW (weight) of criteria and sub-criteria, with the help of a binary measurement matrix is determined when all the criteria are compared two by two. In the AHP method, the paired comparison between criteria and sub-criteria is done based on a relative weight scale and quantitatively.

To calculate the CW of the criteria, there are four main methods (Zebardast, 2001):

1. Least squares method,
2. Logarithmic least squares method,
3. Eigenvector method,
4. Approximation methods.

From the above methods, eigenvector method is used more, but if the above matrix has larger dimensions, calculating the values and eigenvectors is a long and time consuming task unless software such as Expert Choice is used . It is worth noting that the Marinoni program in GIS also uses an eigenvector method to calculate the coefficient of importance of the criteria.

Establishing consistency in judgments: One of the advantages of the AHP is the ability to check consistency in judgments. In this part, we aim to see how compatible the judgments are. The mechanism used by Saaty for assessing consistency in judgments is the calculation of a coefficient called the consistency Ratio (C.R.) that is derived from the division of the consistency index (C.I.) into a randomness index (R.I.). If this coefficient is less than or equal to 0.1, consistency in judgments is acceptable, otherwise judgments must be revised (Saaty, Vargas, 1991).

$CR=CI/RI$, $CR=\lambda_{max}-n/(n-1)$

Using Marinoni's program in GIS to calculate CW of criteria, consistency ratio (CR), and layer overlapping in many of the modelings and goals that are being done to locate in GIS (Geographic Information Systems), matching or placing layers on each other is considered as one of the main steps in locating. Due to the type of target in overlapping the information layers, it is necessary to pay attention to the amount and importance of each layer in comparison to other layers, so that when the layer is loaded, the CW of each layer is determined. In order to facilitate overlapping layers, taking into account the CW of the layers and calculating the consistency ratio, the AHP can be used in the ARCGIS. Using the application, which was presented by O. Marinoni in 2005 as an extension, there is no need to use Expert Choice. This application calculates the criteria weight (CW) of each of the sub-criteria and, by applying their coefficients, overlaps with other sub-criteria, and finally, produces some maps in the GIS in the form of raster.

AHP analysis in GIS

Conversion of criteria in the form of valued rasterized layers: In order to implement AHP analysis in this system, first we have to create the desired criteria in the form of rasterized and valued layers. Revaluation is done according to the type of target in the location and type of utility. For example, in order to find the best place for construction, it is possible to consider the higher elevation and less slope for regions with more resistant soils.

Implementing the AHP command in ArcGIS: In order to access and implement the AHP analysis by the Marinoni extension, it is necessary to download and install the Ext.AHP from ESRI's website so that the corresponding icon is placed in the ArcGIS toolbar. After running the program, you should select the desired layers that are compared in the binary comparison matrix.

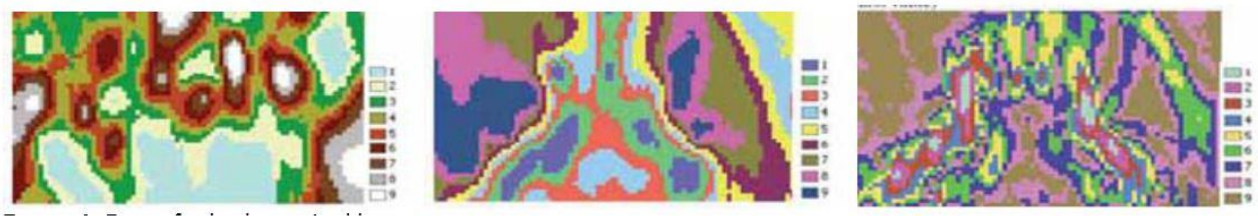

Figure 1. Form of valued rasterized layers.

After choosing the layers, a binary matrix appears that at this stage the criteria must be compared in binary form. Calculating CW of criteria, Inconsistency ratio (IR): After completing the matrix, executing the Calculate command, the application calculates the CW of each criterion and finally displays the CR. If the value of the consistency ratio is less than 0.1, the judgment in the binary measurement is correct, otherwise it should be revised in the evaluation matrix.

Layer overlay by considering the CW of the layers: After implementing the previous steps and, in the case of correctness of the CR (CR ≥ 1.0), the raster layer can be overlaid by applying its CW. After this overlapping, a map in the form of a raster is obtained where higher-rated regions are more desirable for the target.

After a brief overview of the AHP technique, the general description of the GIS is discussed. The geographic information system is: importing, storing, reviewing, communicating, modifying, displaying information as visual-map and eventually providing results that are spatially related to the surface of the planet (Rafieian, 2010). Through the GIS, after collecting data and processing and analyzing them, it leads to obtaining land use tables and maps. The system is highly capable of locating and receiving data and maps (Nazari, 1998).

Finally, in order to evaluate the factors of land use change and obtaining the most effective factor, first, by identifying the effective parameters for land use change and performing the following steps:

- Evaluating the effective layers of information on land use change,
- Creating binary comparison matrix,
- Calculating the CW,
- Estimating agreement ratio,
- Combining information layers,
- Land use change factors have been valued.

Modeling

The AHP model is used to check use changes. For this model, the indices were collected based on the reviewed sources and are scored based on the experts' opinions in this field. Once scored, the effect of each index is specified. Below the model is given along with the AHP method binary comparison (Tables 1-9).

Table 1. Categorization of indices, criteria and sub-criteria.

Index	Criteria	Sub-criteria and categories
Demographic factors	Active to passive population	Comparison through relativization
	Men to women population	Comparison through relativization
Economic factors	Employment rate (employers to whole population)	Comparison through relativization
	Price and rent of land	Comparison through relativization
Land structure	Land slope (interval definition)	Slope 0-4%: 1

state		0-10%: 0.66
		Over 10%: 0.33
	Access (qualitative definition)	Adjacency to the main road grade 1: 1
		Adjacency to the main road grade 2: 0.75
		Adjacency to the by-way: 0.5
		Adjacency to the alley: 0.25
Transportation planning	Access to public vehicles (distance definition)	At the distance of 200 m and less from station: 1
		At the distance of 200 to 500 m from station: 0.66
		At the distance of over 500 m from station: 0.33
	Neighboring station complexes and subway	At the distance of 150 m and less from station: 1
		At the distance of 150 to 350 m from station: 0.75
		At the distance of 350 to 600 m from station: 0.5
		At the distance over 600 m from station: 0.25
Land use planning	Urban development rules and regulations	Presence of special and local plans: presence: 1, non-presence: 0
		Presence of stabilized seven services: presence: 1, non-presence: 0
	State of each use in the status quo (residential, commercial, services)	Compliance with zoning rules:
		Contrary to present use with zoning: 1, relative contrary of present use with zoning: 0.5, no contrary: 0
		Seven services: 0.065
		Residential with high density: 0.126
		Average and low-dense residential: 0.401
		Arid: 0.317
		Commercial and others: 0.091

Table 2. Binary comparison off indexes.

Eigenvector	Land use planning	Transportation planning	Earth structural state	Economic factors	Demographic factors	
0.09	0.25	0.5	0.5	0.5	1	Demographic factors
0.22	0.5	1	3	1	2	Transportation planning
0.12	0.5	0.5	1	0.33	2	Earth structural state
0.19	0.33	1	2	1	2	Economic Planning
0.38	1	3	2	2	4	Land use planning

Table 3. Binary comparison of sub-indices of land use planning.

Eigenvector	Commercial and others	Arid	Medium and low density housing	High density housing	Seven services	
0.07	0.5	0.2	0.25	0.5	1	Seven services
0.13	2	0.25	0.33	1	2	High density housing
0.4	3	3	1	3	4	Medium and low density housing
0.32	5	1	0.33	4	5	Arid
0.09	1	0.2	0.33	0.5	2	Commercial and others

Table 4. Binary comparison of sub-criteria of demographic indexes.

Eigenvector	Male to female population	Active to passive population	
0.8	4	1	Active to passive population
0.2	1	0.25	Male to female population

Table 5. Binary comparison of sub-criteria of economic factors index.

Eigenvector	Price and rent of land	Employment rate (employers to total population)	
0.25	0.33	1	Employment rate (employers to total population)

0.75	1	3	Price and rent of land

Table 6. Binary comparison of sub-criteria of land structural status index.

Eigenvector	Accesses (qualitative definition)	Earth slope (interval definition)	
0.25	0.33	1	Earth slope (interval definition)
0.75	1	3	Accesses (qualitative definition)

Table 7. Binary comparison of sub-criteria of transport planning index.

Eigenvector	Neighboring Subway and Station complexes	Access to public transport vehicles (distance definition)	
0.25	0.33	1	Access to public transport vehicles (distance definition)
0.75	1	3	Neighboring subway and station complexes

Table 8. Binary comparison of sub-criteria of land use program planning.

Eigenvector	The status of every use in the status quo (residential, commercial, service)	City development laws and regulations	
0.25	0.33	1	City development laws and regulations
0.75	1	3	The status of any use in the status quo (residential, commercial, service)

Table 9. Binary comparison of sub-criteria of land use planning.

Eigenvector	Compliance with zoning rules	Presence of seven fixed services	Presence of special and local designs	
0.32	3	0.5	1	Existence of special and local designs
0.56	4	1	2	Presence of seven fixed services
0.12	1	0.25	0.33	Compliance with zoning rules

The model has been implemented in the area use for 1996 and 2016. To implement the model for each of the sub-criteria, a raster map has been developed. Layer data are standardized to raster layers.

Results

Based on the model implemented in 1996, the points with the potential for change are given. By examining the result of the model and the map of use changes, it is determined that there is compliance between changes and the result of the model. The results of the model implementation for the use in 1996 are presented in Table 10.

Table 10. Results of model implementation in 1996.

Number of changed uses	Category
21	Very low potential
46	Low potential
123	Medium Potential
151	High potential
58	Very high potential

Also, for 2016, a potential map is created based on the model that displays points that have high potential for change. These are the points that have the greatest potential for change. Also, in a spatial distribution survey, the use changes in relation to the subway location are shown, with most of the changes being made near the subway, it is presented in Table 11.

Table 11. Spatial distribution of use change in relation to the subway location.

228	Radius 800	21	Radius 150
258	Radius 1000	105	Radius 400
392	Radius 2000	191	Radius 600

Conclusions

How can we prevent the use conflicts in this area by developing rules and changing the urban plans?

In certain urban areas, the regulations should be carefully considered. In this range, the indices that affect the use change should be reviewed and discussed. In the zoning rules, the rules must be defined in smaller ranges to control the intensity and type of changes within the range. Also, services that can work better in these areas can be fixed and prevent changing their use. Similarly, local plans like CDS can be generated for these areas, and consider development perspectives and, provide appropriate plans and actions based on possible changes. In this way, we can have the proper establishment of the population and activities, the improvement of the spatial structure of the area surrounding commercial spaces, the optimal use of urban centers, the optimal distribution of services and facilitating walking, and reducing the volume of urban travel, creating multi-purpose complexes to increase the employment opportunity in the immediate field of public transportation. The following measures can also be considered in the rules:

- Optimal use of lands around the station,
- Increasing density near the station,
- Creating a pedestrian-oriented design,
- Making each station and its surroundings an attractive place for pedestrians,
- Management of parking and transportation of vehicles,
- Land use composition,
- Limiting land uses that are not compatible with the transportation system.
- Designing good quality paths for walking routes,
- Providing comprehensive development structure,
- Creating integrated public systems,
- Considering the weather characteristics of all seasons,
- Building parking in the right places.

How and under which mechanisms do these factors change the pattern of land use in the study area?

Demographic factors: Changes in the demographic and human structure will change the environment. This can be deduced from the formation of human societies throughout history. The more work force, the more work will be done. This may well be seen in ancient Egyptian cities. The population that are dynamic, change their environment in a way. With this argument, it can be said that the active to passive population index can be considered as an appropriate index for the population situation of the complex. So the higher the index is, the more likely it will be to change in the environment. Also, surveys show that the higher the male to female population is, the activity and work will be more. For this case, we can refer to the statistics of various organizations in relation to work. However, in the case study, this criterion will not show itself prominently, which can be attributed to the study area, which is a small part of a city formed a sub-system and the value of this index is in equilibrium. However, due to the involvement in use changes, this index is also considered in the model.

Economic factors: In the study area, factors of employment and land prices are among the economic factors in use change. The presence of passengers and traffic within the scope will strengthen the establishment of service-commercial businesses. Jobs that allow travelers to provide their daily, weekly, and occasionally monthly and yearly supplies. Also, the jobs that provide services to travelers. Within the study area, service and commercial jobs in the field of subway effect included commercial-service applications.

The presence of subway has also increased the demand for buying adjacent properties for easy access to public transportation, which has led to an increase in the price of this area. By increasing the price of buildings, owners changed use to more profitable uses (commercial-services) to increase productivity (increasing density). Ultimately, these factors have caused a change in the use structure.

Land structural state: The structural state of the land leads to a series of limitations and a number of potentialities in the land. Among these factors are the ground slope and the access quality. The land slope more than 5% is less attractive in urban planning, and slopes more than 8% have limitations in this area. For example, the construction of a gas station in the high slopes can cause hazards such as fuel leakage in the area around it in the event of an accident. On another hand, the steep slopes make walking difficult and creates traffic in daily commutes. So, having a proper slope offers the potential for change especially in the sample. Also, the quality of access will be effective in use change. The better the accessibility to a space, the greater the number of trips and the potential for change will be.

Transportation planning: Transportation planning is directly related to land use planning, which should be planned as integrated and in perfect connection. These include access to public transportation and access to station and subway complexes. A certain percentage of daily trips are made using public transportation. Each of these transportation systems has an attractive radius of performance that, getting out of this radius, reduces the attractiveness for the passengers and drives them to use vehicles. For example, the appropriate access radius for bus stations is about 800 meters. If it is more than this, the attractiveness of using a bus for residents and users will be reduced. In residential applications, residents prefer to be closer to public transportation vehicles to be able to start their journeys. Travelers who intend to use certain services and purchases prefer that their shopping venues are close to public transportation so that they can use it following their journey. These arguments lead to an increase in the intensity of land use and also the use change of commercial-service applications. Also, adjacency to station and subway complexes are more attractive than other stations due to their attractiveness. Also, changes in this area have the greatest change due to their high attractiveness.

Land use planning: Land use planning determines how it is used for urban lands. The existing urban planning tools are specific and local plans, zoning rules, and seventh fixed services. Specific and local plans after approval have high executive power, since their budget usually comes from public resources. These plans make changes in the city's body. Also, the zoning rules determine the generality of use in that zone. These criteria are classified in residential, service, industrial, green and mixed areas. Seventh fixed services are services that are within the area and will not be able to change the plan.

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