**Chapter**

# Using Multi-Objective Land Allocation Model to Simulate Urban Growth: The Case of Sarakhs Border City in Iran

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## Abstract

This chapter's purpose is to simulate urban growth of Sarakhs, using a Multi-Objective Land Allocation (MOLA) model. To achieve this goal, Landsat 7 and 8 and Sentinel 2A satellite images from 2003 to 2020, and 13 variables affecting the location of land uses with spatial decision model (SDM), multi-criteria evaluation (MCE), and MOLA model were used. Considering the increase in the city's population from 2020 to 2030 and the possibility of turning the city into a Free Economic Industrial Zone (FEIZ), about 322 hectares of land for residential use and 500 hectares for industrial use were estimated until 2030. By using MOLA model, the location of residential and industrial land use with a distance from agricultural lands was simulated in the west of the city. The result of the residential land use simulation is in line with the projected development direction of the City Master Plan to a large extent. But industrial land use is predicted in the vicinity of the Special Economic Zone (SEZ) in the west of the city. Therefore, the research results can be used in simulating of urban growth due to high speed, accuracy, and low-cost compared to traditional methods of preparing Master Plans in the Third World cities.

**Keywords:** border city, Master Plan, multi-criteria evaluation, multi-objective land allocation model, Sarakhs, spatial macro-model

## 1. Introduction

By 2030, 60% of the world's population—nearly 5 billion people—is expected to live in urban areas [1]. This increase in population will lead to urban sprawl and the loss of 1.8–2.5% of arable land, and 80% of this is in Africa and Asia. Given that more than 60% of the world's irrigated fields are located near urban areas, this indicates the potential land competition between agricultural and urban uses. Case studies show that high levels of urban development over the past three decades have led to the loss of agricultural land around cities [2]. In addition, rapid and unplanned urbanization has brought about dramatic changes in the urban-regional landscape [3], and the eradication of significant amounts of major agricultural land, including many environmentally sensitive areas, in suburban areas. To prevent unwanted changes in land use around cities and for the future physical guidance of cities, rapid population growth, and maintaining land use diversity, it is necessary to allocate land use [4]. Generally, Master Plans as a guide for public and private decision-makers are about the future physical development of the city, and the implementation of programs, policies, and projects [5]. These plans play an important role in regulating the future land use of cities [6]. Furthermore, Master Plans are traditional tools used by urban local governments, as planning tools for urban development [7].

Location of Master Plans is prepared more traditionally and semi-automatically through a combination of field studies and aerial photographs, topographic, and geological maps. Recently, GIS and TerrSet software have made it possible to use spatial decision-making and MCE and MOLA techniques with high speed and accuracy. By combining these models with Fuzzy-AHP techniques, not only the amount of land required but also the optimal location according to effective natural, social, and economic factors are provided. The results of Internet surveys have shown that so far, no research has been conducted on the choice of simultaneous location for two purposes (industrial and residential land uses) in the form of a Master Plan for cities. Studies have so far simulated most land use growth changes with different models of cellular automation and Markov chains, multilayer neural networks, etc. [2, 8], and some studies have predicted urban growth with the scenario; for example, in Kathmandu Valley Nepal, by the same models [9]. In addition, Hajehforooshniaa et al. [10] have zoned wildlife in Iran using MOLA model. Also, MCE and GIS models have been used to locate and prioritize landfills, retail centers, and solar energy farms [11].

The purpose of this study is to simulate the urban growth of Sarakhs border city on the border with Turkmenistan, in Northeastern Iran. It is actually the gateway to Central Asia countries with a population of more than 239,796,010 [12], and the gas capital of Iran, considering the possibility of turning Sarakhs into a FEIZ on the one hand and its strategic location on the other hand, urban growth needs to be guided in the form of a comprehensive plan with both residential and industrial goals with innovative methods.

## 2. Study area

The city of Sarakhs with a population of 42,179 (2016) is located at the zero point of the international border between Iran and Turkmenistan (**Figure 1**) [13]. It is located at 36°32′15.36″ N and 61°.09′40.49″ E [14]. The altitude of this city is 277 m above sea level. The Harirod river forms the borderline between the two countries. Similar to the Iranian Sarakhs, on the east side of the Harirod river, is the city of Sarakhs in Turkmenistan with a population of 9505 people (2009) [15]. In the scientific literature, when two cities are separated by an international border, they are referred to as twin cities. It shows their historical continuity. The two cities of Sarakhs were originally one. Until 1884, the Russians occupied the ancient Sarakhs of Iran, along with Marwa and Ashgabat, and annexed them to Russia [14]. The city of Sarakhs is the gateway to the Commonwealth of Independent States, which was formed in 1991 with the collapse of the former Soviet Union with nine members from the former republics [12]. Furthermore, Sarakhs was the gateway to the historic Silk Road to Iran [16].

Due to the strategic and geographical importance of Sarakhs city, in 1996, Sarakhs SEZ was established by Astan Quds Razavi (a non-governmental organization under

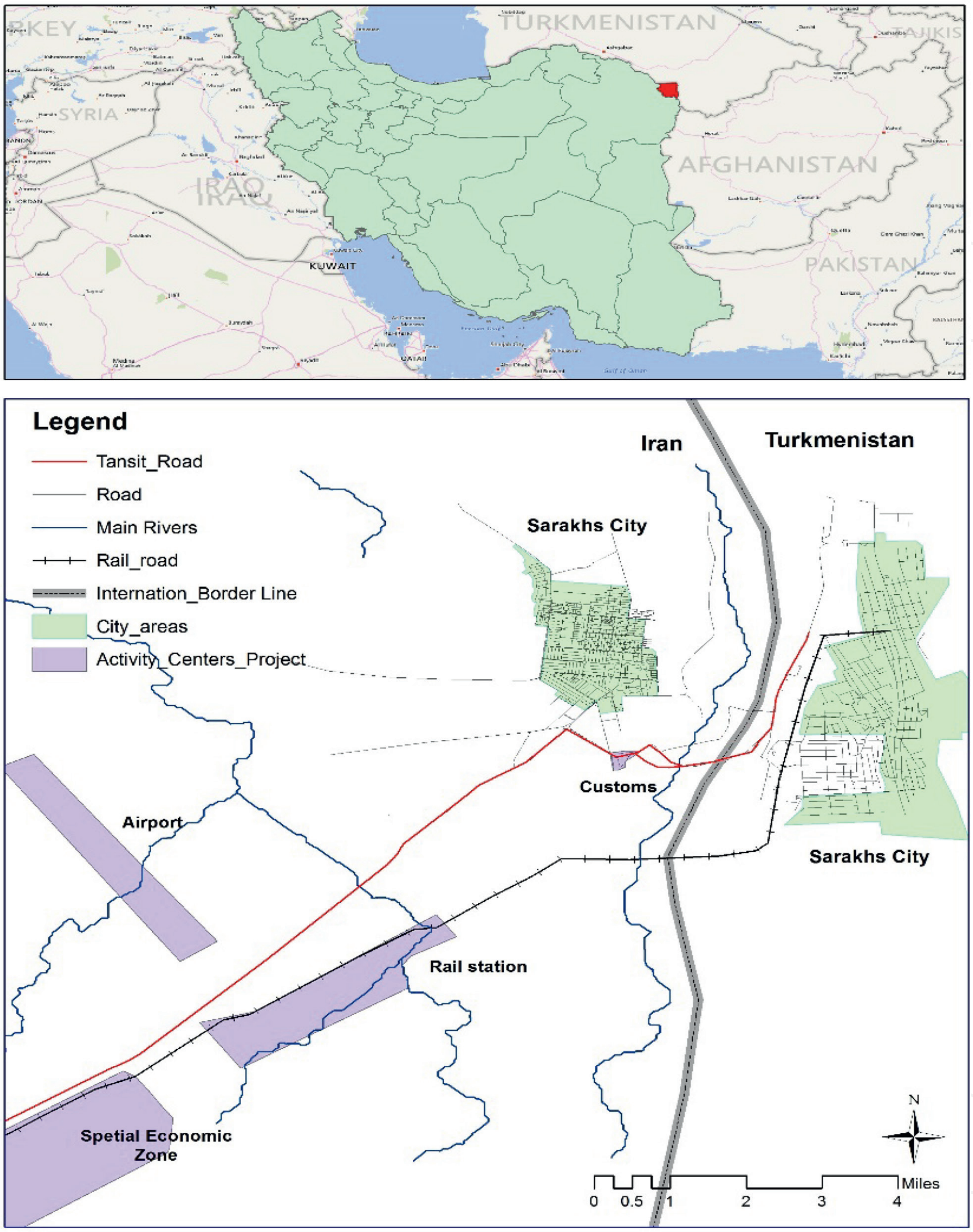


**Figure 1.**
*Study area.*

the supervision of the Iranian government) in an area of 4233 square hectares. Also, Sarakhs Diamond International Airport was put into operation in 1996 during the opening of the Mashhad-Sarakhs-Tajan railway [17]. Rail, customs, and terminals are other infrastructures for the development of the city and region. Sarakhs is also known as the gas capital of Iran because of the huge gas mines in the Khangiran region and the Khangiran refinery which is 40 km away from the city and was opened in 1984 and supplied gas to six provinces of the country [18]. The international and national situation of Sarakhs city caused the strategic and operational plan of Sarakhs city to be prepared by Ferdowsi University of Mashhad in 2016. Its forecast horizon is until 2030. In this plan, it is predicted that the population of Sarakhs city will increase from 2016 to 2030 with an annual growth of 2% from 42,179 people to 62,123 people in 2030. With a per capita land area of 162 square meters, the city is projected to increase from 684 hectares in 2020 to 1006 hectares in 2030 [14]. That means about 322 hectares of the land area is needed for the future development of the city. It is also predicted that if economic activities flourish and the SEZ becomes a FEIZ, about 6786 new jobs will be created. For each new job, about 735 square meters of land is needed for the development of industrial and transportation activities. Therefore, about 500 hectares of the land area is needed for the development of industrial and commercial activities [19]. As a result, the location of the residential and industrial land uses is essential for future development. Due to these features, it is necessary to use an SDM to determine suitable locations for future industrial activities and urban growth.

## 3. Materials and methods

The outline of the research flowchart is shown in **Figure 2**. The research process began with a literature review and proceeded in the following stages: (1) Pre-processing stage, (2) Using the spatial decision model, (3) MCE technique, (4) MOLA problems, and (5) Validation of the results of the simulation with the Master Plan of the Sarakhs and SEZ.

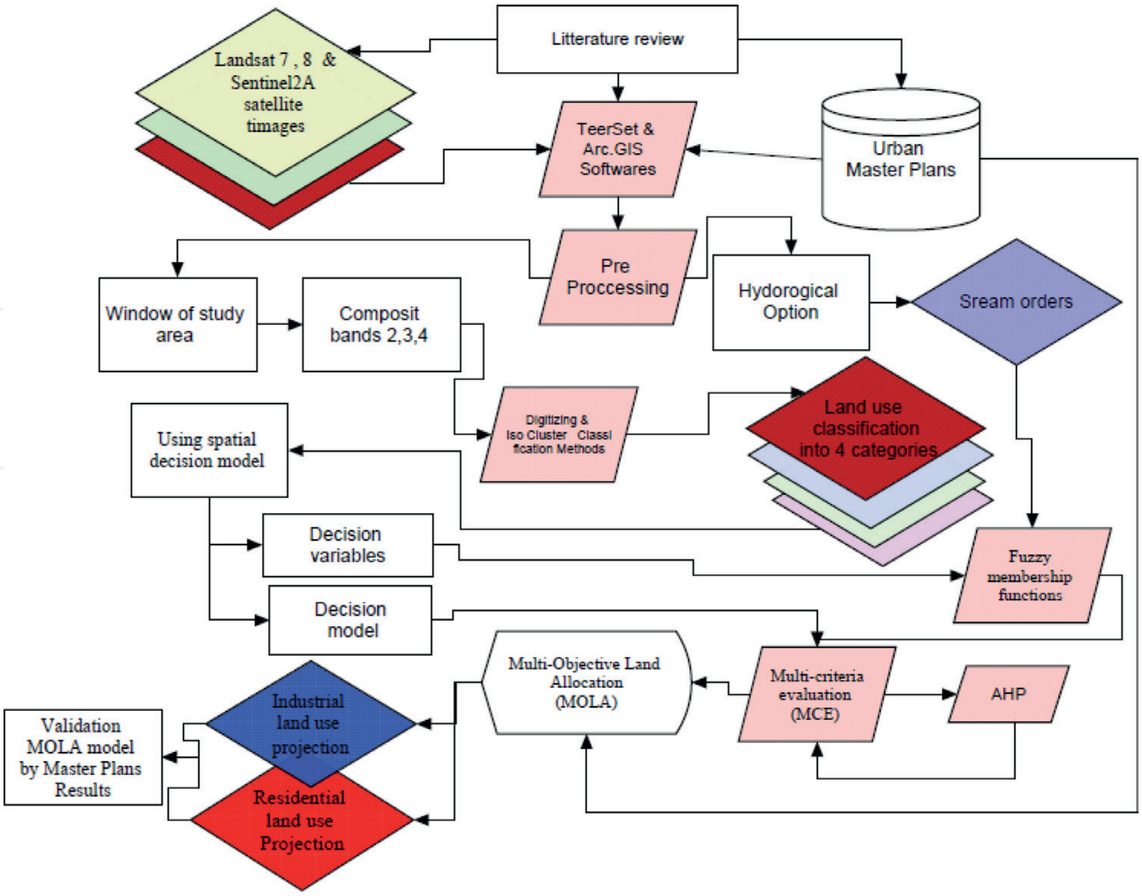


**Figure 2.**
*Research flowchart.*

### 3.1 Pre-processing stage

As can be seen in **Figure 2**, simulating urban growth is a complex and lengthy process. The diagram shows two parallel paths for research. (1) Downloading satellite images, Landsat 7 and 8 images through the USGS database for 2003 and 2020 [20] and Sentinel 2A images (2020) from the European Space Agency database [21]. (2) Studying the Master Plans prepared for the city of Sarakhs. In the end, these two paths are connected. The population forecast results of the Master Plan for the period of 2020–2030 have been used to allocate the land needed for residential and industrial land uses. In addition, the road map of the urban area was downloaded from the BBIKE site [22] and the DEM of the area's study was also downloaded from the USGS database. Also, using the hydrological option in ArcGIS software, river paths were created. The location of major industrial activities, such as train terminals, airports, special economic zone, customs, transit roads, were identified as separate layers. After that, the land uses were classified into four categories using the IsoCluster technique with TerrSet software. Due to the fact that in the SDM, each land use layer should be separated, by using the re-class command, the layer of the studied variables (13 variables) was separated in the form of a Boolean score (0 and 1). Finally, all land use layers that had been converted to raster format were re-evaluated with a distance command in TerrSet software (**Figures 3** and **4**).

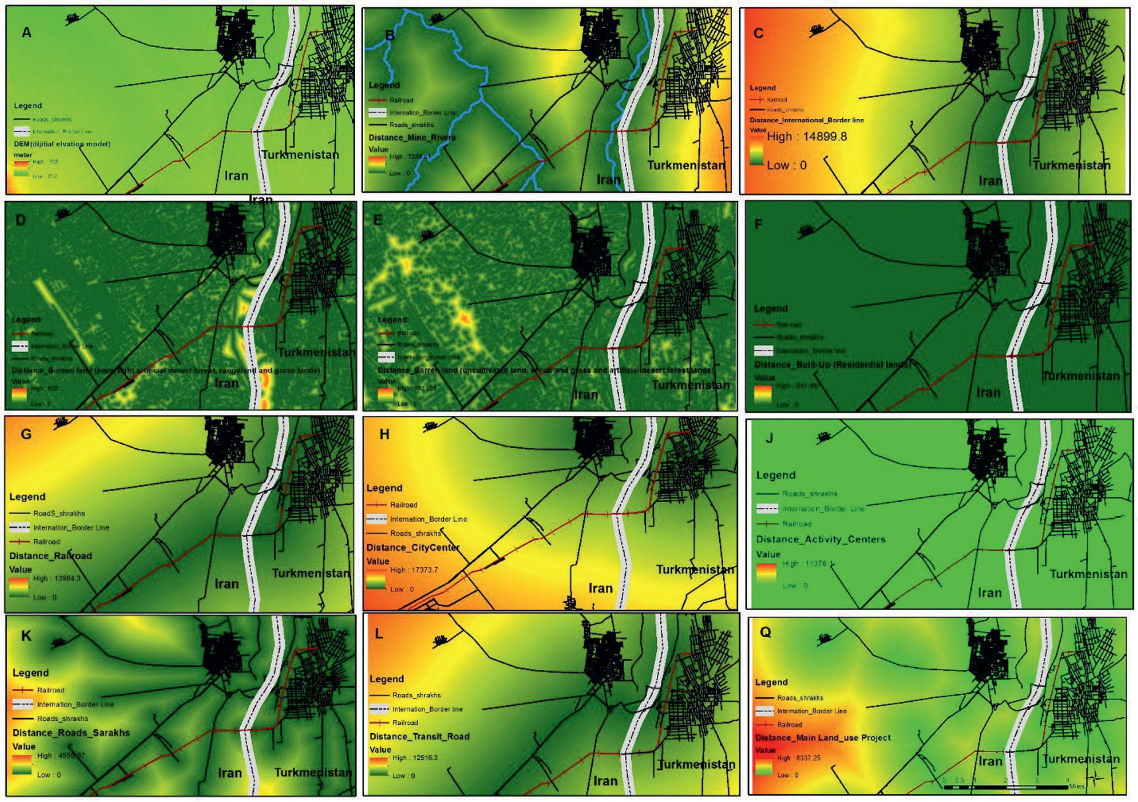


**Figure 3.**
*Special, constraint and common driving variables: A = DEM, B = distance from main rivers, C = distance from international border, D = distance from bare land (bare, light artificial desert forest, rangeland and grass lands), E = distance from barren land (uncultivated land, shrub and grass lands), F = distance from built-up (residential and industrial lands), G = distance from railroad, H = distance from city center, J = distance from activity centers, K = distance from road—Sarakhs, L = distance from transit road, Q = distance from main land use projects.*

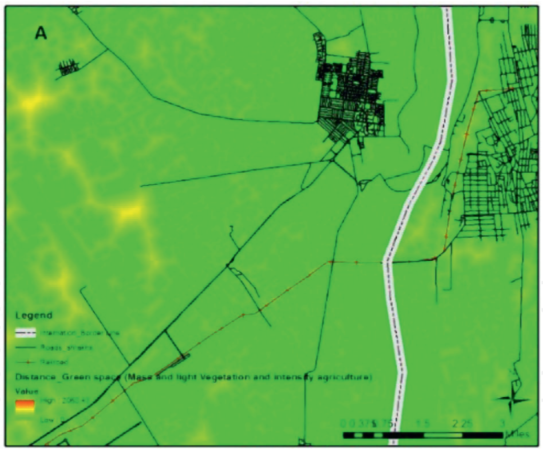


**Figure 4.**
*Constrain variable: Distance_Green space (mass and light vegetation and intensity agriculture).*

### 3.2 Using SDM

SDM is a graphical decision-support environment that can solve complex resource allocation decisions. This model uses the language and logic created around the decision support tools of the TerrSet system, including the development of effective factors and constraints with tools such as Fuzzy and Re-class, a combination of factors to produce appropriate maps with the MCE tool, and its combination by MOLA tool [23]. Due to the fact that this research had two objectives of locating residential and industrial land uses, the SDM was first called in TerrSet software. Then, 13 variables were entered into its environment through the decision variable menu, which included three categories of variables: (1) constraint, (2) common, and (3) special variables (**Figures 3–5**). These variables were selected from the decision operation menu using the fuzzy operation technique to fuzzy the value of the variables. Given that there are three membership functions in the fuzzy technique (monotonically increasing, monotonically decreasing, and symmetric). Based on the characteristics of each of the indicators, the functions appropriate to them were selected. Each of these functions can be calculated in three modes: (1) Sigmoida, (2) J-shape, and (3) Linear. According to the nature of the research variables, proportional functions (three fuzzy membership functions) were selected.

### 3.3 MCE technique

The MCE in spatial decision modeling combines multiple factors into one appropriate objective or map. At MCE, an attempt is made to combine a set of factors to achieve a single composite basis for decision-making according to a specific goal [10]. To use MCE operations in a spatial decision model, variables, factors, or goals and constraints must be connected to the MCE operator. One of the MCE parameters is the Tradeoff option. The weighting style or the resulting balance between the two desirable but incompatible characteristics is the degree to which one variable can compensate for the other. For example, with a full swap, a variable location with a high value can compensate for other low-value variables.

Another feature of MCE is the use of the AHP technique. AHP developed by Saati in the late 1970s is one of the multi-criteria decision-making methods. AHP breaks down a complex decision issue at different hierarchical levels. The weight of each criterion and

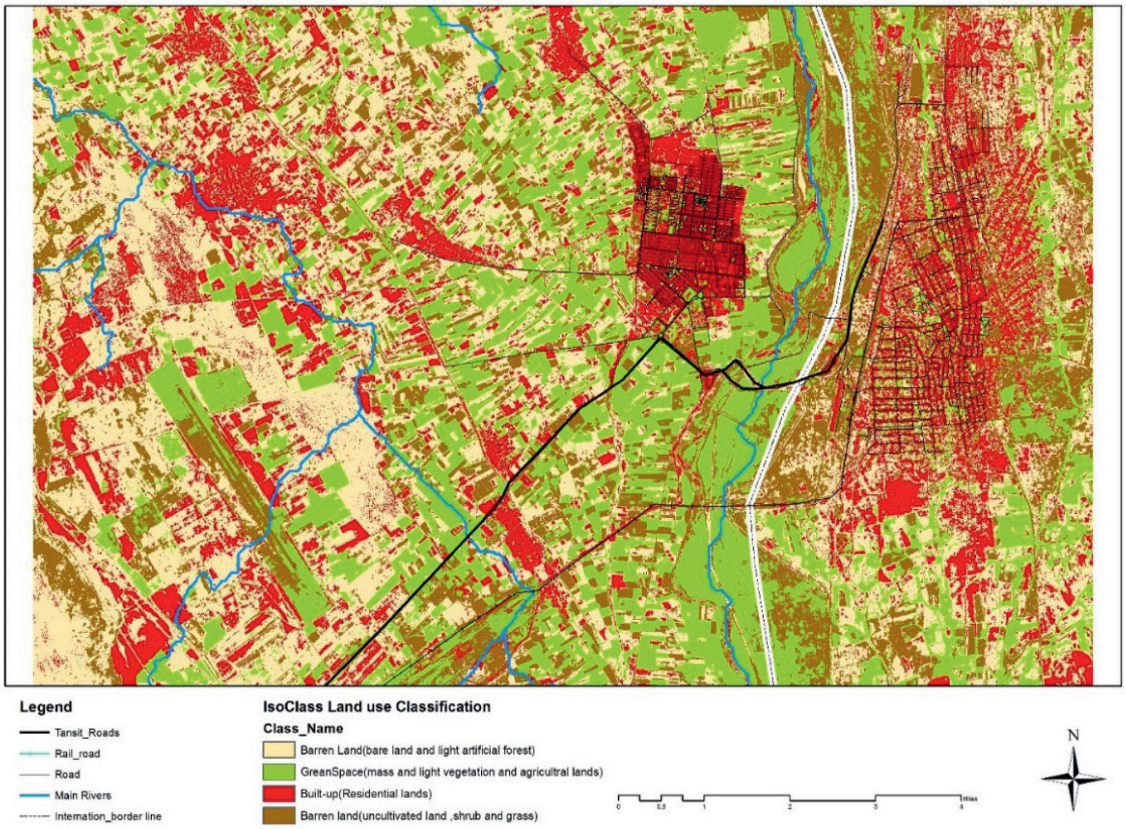


**Figure 5.**
*Distribution of land uses in the study area in 2020.*

its alternative is judged in pairwise comparisons and priorities are calculated by them [24]. In this study, after fuzzy (standardization), with the AHP technique, the variables were weighed in pairs (relative weight range from 1 to 9), based on the Saati table, and ultimately, the relative weight of the variables was determined. Furthermore, the indicators were combined by a multi-criteria evaluator. Then, the medium decision risk/no tradeoff option was calculated. Finally, the weighted variables were combined [10].

### 3.4 MOLA problems

This model provides a way to solve multi-objective land allocation problems for cases with conflicting goals. It determines a compromise solution that seeks to maximize the suitability of land for each purpose according to the weight allocated to them [10]. The user can specify either the required area or the maximum budget required to solve the allocation problem. There are options for forcing cohesion and compression [25]. In this research, the required area of residential and industrial land uses is 322 and 500 hectares, respectively. The option of continuity and compactness has been used due to being multi-purpose to locate the future development of Sarakhs city in the future horizon of 2030.

### 3.5 Validation of the results of the simulation with the Master Plan of the Sarakhs and SEZ

At this stage, the results of the MOLA model were compared with the proposed location of the Sarakhs and SEZ Master Plan through coverage alignment in TerrSet and GIS software. The ability and accuracy of the model were measured in determining the direction of development and guiding and managing the planned growth of the city. The research process can be seen in **Figure 2**.

### 3.6 Driving factors affecting the location of the future development of Sarakhs City

Identifying and selecting variables affecting the location of residential and industrial land uses in Sarakhs includes a wide range of different variables and hypotheses. These variables should have the following characteristics, in order to achieve sustainable environmental development: (1) Agricultural lands and vegetation should be preserved. (2) The proposed residential land use should not be far from the built-up area of the main city and should be connected to it. (3) Residential and industrial locations should not be on agricultural lands along the riverbed. (4) This land uses should not be at risk of river flooding. (5) They should be located on wastelands and near roads. These hypotheses are the most important features that distinguish this research from other research. In this study, according to the above hypotheses, 13 variables were selected, which were divided into three categories: (1) constraint variables, (2) common, and (3) special variables (**Figures 3**–**5**). First, the variables were re-evaluated by the distance command in TerrSet software. The status of these variables was determined in **Figures 3** and **4**. As can be seen in **Figures 3** and **4**, the value of the cells in raster maps increases with the distance from the variables.

## 4. Research findings

### 4.1 Land use classification of the study area

To predict a proper place for the future development of the city, both residential and industrial, it is necessary to study an area larger than the current state of the city (the current state of the city was 684 hectares in 2020). For this purpose, satellite images of Sentinel 2A were used [21]. Then, the land uses were classified into four classes using the IsoCluster technique with TerrSet software. The result is depicted in **Table 1**. The study area was 32234.29 hectares. **Figure 4** also shows the distribution of land uses in the study area. As the figure shows, most of the barren land is located to the south and north of the city. Agricultural lands are scattered around the city, especially in the eastern, western, and northern parts of the city. An important

| Legend | Hectares | Percent |
|---|---|---|
| Barren Land(bare land and light artificial forest) | 11366.73 | 35.26 |
| Green Space(mass and light vegetation and agricultural lands) | 7999.18 | 24.82 |
| Built-up(residential lands) | 5750.16 | 17.84 |
| Barren land(uncultivated land, shrub and grass) | 7118.22 | 22.08 |
| Total | 32234.29 | 100.00 |

*Source: Research Findings.*

**Table 1.**
*Classification of land uses in study area of Sarakhs in 2020.*

point in the land use classification of 2020 is the lack of proper separation of colors by the IsoCluster classification model, which could not separate the land uses well. In particular, the western and eastern parts of the city, which are barren, are classified as residential.

### 4.2 Trend of spatial expansion of the city

Managing and guiding the future growth of the city require studying the physical expansion of the city in the past and present. Therefore, using Landsat 7 and 8 satellite images in 2003 and 2020, the city limits and the process of its physical expansion were determined through the Digitize command in TerrSet software (**Figure 6**). As can be seen from the figure, the built-up area of Sarakhs for 2003 and 2020 was 439 and 684 hectares, respectively (55.80% growth). In addition, the spatial development of the city has been in different directions. The important point is that the urban growth of the city, in the Master Plan, was projected on the barren lands in the north and south of the city in 2016. The expansion of the city has to some extent been in line with the proposal of the Master Plan until 2020, but most of the spatial expansion of the city has been on agricultural lands and around the roads to the west and east of the city.

### 4.3 Urban growth in the Master Plan

As mentioned in the earlier sections, cities are gradually growing. To guide the city's spatial expansion, the city administration determines the Master Plan which delineates the future development direction of the city according to the population growth trend in a new coming 15-year period. The comprehensive plan tries to expand the spatial future of the city low-value of agricultural production and barren land. In the Sarakhs Master Plan 2016–2030, according to the calculation of 2%

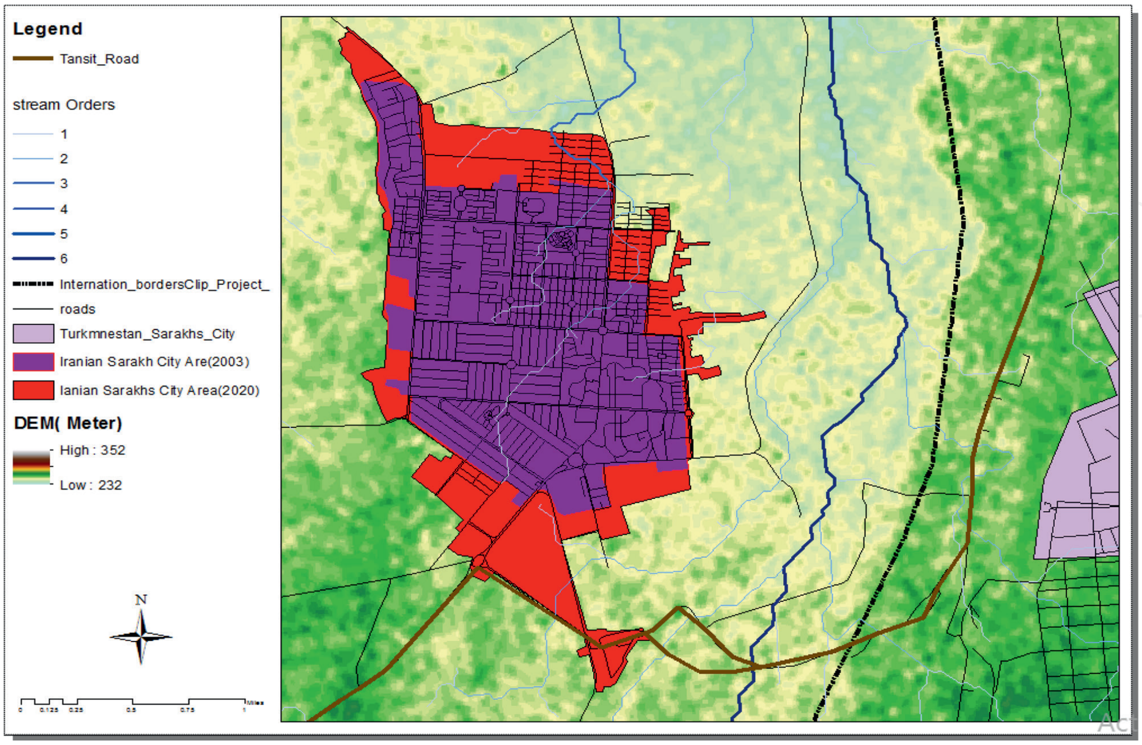


**Figure 6.**
*The trend of spatial expansion of Sarakhs city during the period 2003–2020.*

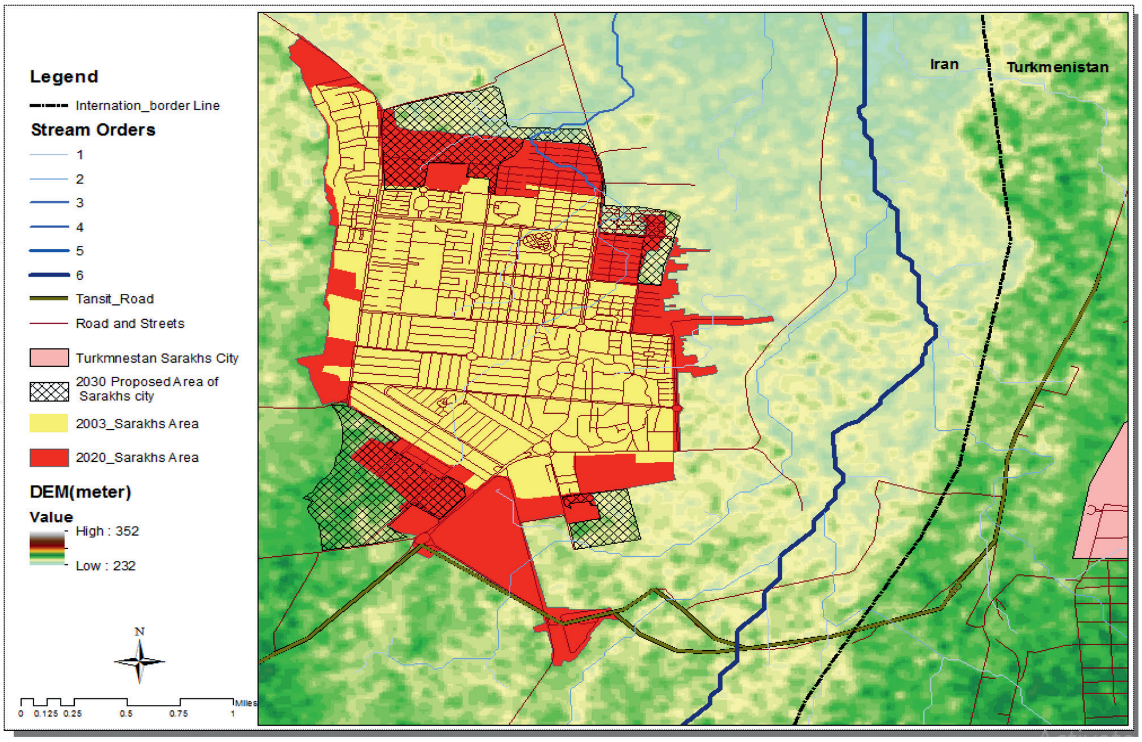


**Figure 7.**
*Spatial development of Sarakhs's Master Plan 2016–2030.*

annual population growth, 322 hectares of required land use have been proposed on vacant and barren lands in and around the city. The lattice area in **Figure 7** shows the proposed land use of the Master Plan until 2030 [19].

### 4.4 Result of designing a spatial decision model for projecting of urban growth

The purpose of this study has two objectives for locating the future residential and industrial development of the city with a MOLA model. A total of 13 variables affects the site selection of residential and industrial land uses. These variables include three categories: (1) constraint variable, (2) common variables, and (3) special variables (**Figure 8**). In general, nine variables were used for selecting an industrial site and eight variables for residential location. Among these, one variable is as a constraint (agricultural land use) and five are common variables between two objects (residential and industrial land uses). A number of specific variables for each object were identified separately (four land uses for industrial and three for a residential objects). These variables play a decisive role in site selection. This situation is shown in **Figure 8**. Therefore, according to the objectives of preparing comprehensive urban plans in Iran in the next 15 years, the SDM was designed in the form of **Figure 8**. In this model, research variables, Fuzzy membership functions, and results are identified along with an MCE and MOLA models.

Given the number of populations that will be added to the city's population by 2030 (20,000 people) and the land required for this population (322 hectares of residential and 500 hectares for industrial activities), the main issue was the location of this land uses. Where should these areas be located? To find the best location for residential and industrial land uses of the city in the SDM according to the research objectives, it should be in line with sustainable environmental development. Initially, several assumptions were made. These hypotheses were determined according to

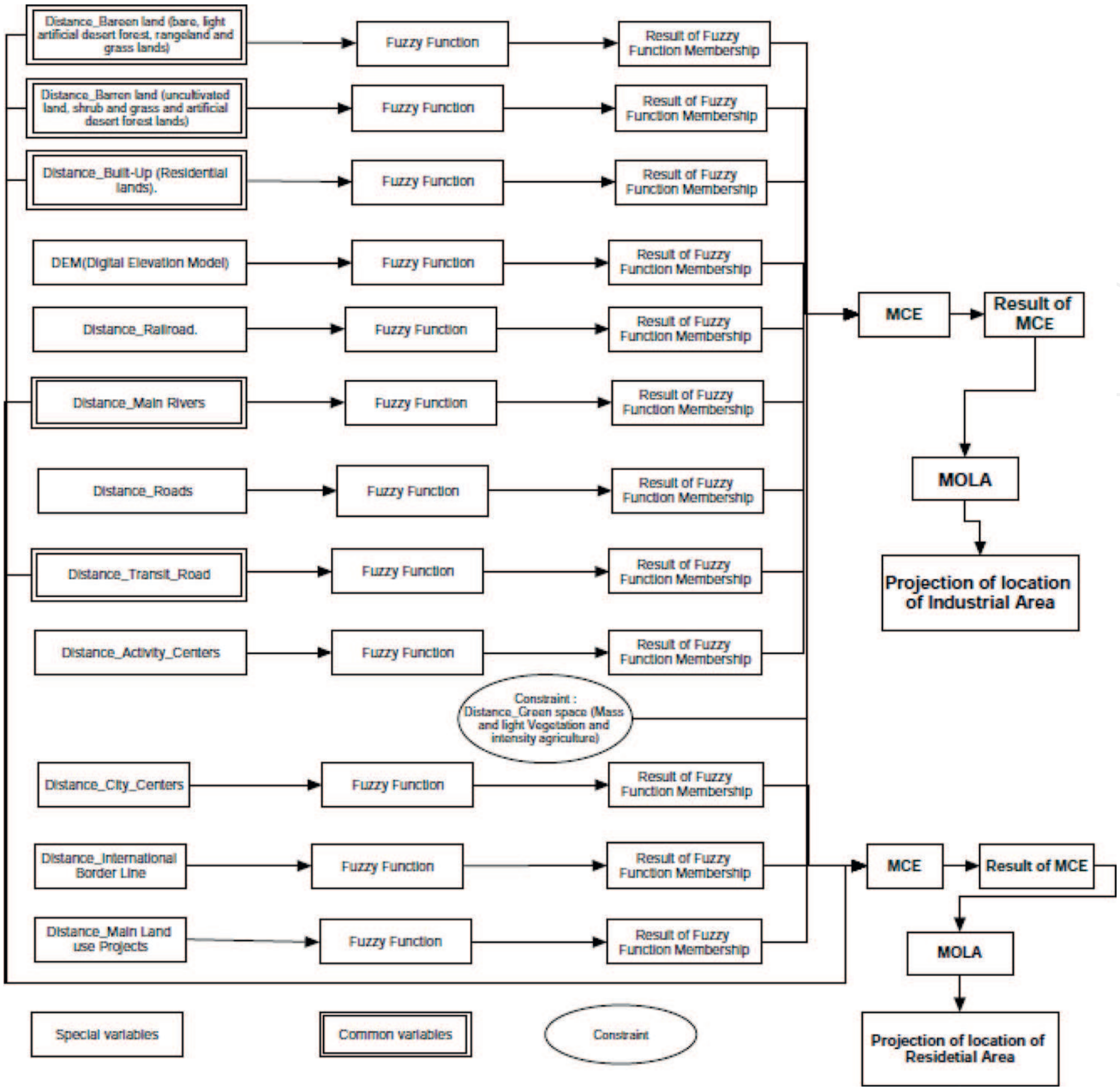
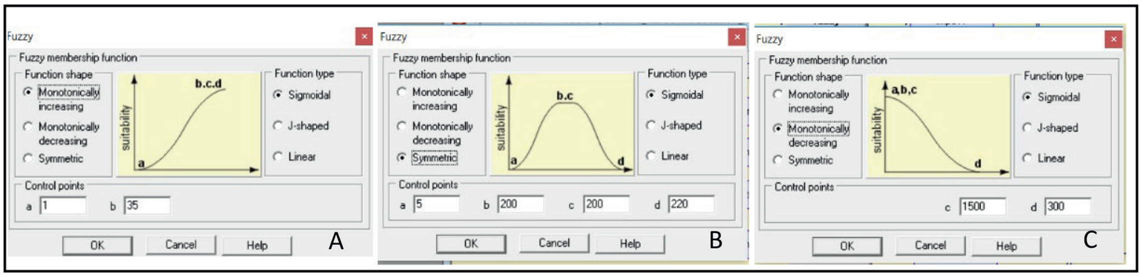


**Figure 8.**
*Structured framework of spatial decision model.*

the research objectives, a number of driving factors, the trend of physical expansion of the city from 2003 to 2020, analyzing the land use map in 2020, and studying the results of locating the city development in the Master Plan. These indicators are the main background for the formation of hypotheses and research models. These hypotheses are as follows:


A
Fuzzy
Fuzzy membership function
Function shape: ● Monotonically increasing ○ Monotonically decreasing ○ Symmetric
Function type: ● Sigmoidal ○ J-shaped ○ Linear
Control points: a 1 b 35

B
Fuzzy
Fuzzy membership function
Function shape: ○ Monotonically increasing ○ Monotonically decreasing ● Symmetric
Function type: ● Sigmoidal ○ J-shaped ○ Linear
Control points: a 5 b 200 c 200 d 220

C
Fuzzy
Fuzzy membership function
Function shape: ○ Monotonically increasing ● Monotonically decreasing ○ Symmetric
Function type: ● Sigmoidal ○ J-shaped ○ Linear
Control points: c 1500 d 300

**Figure 9.**
*Sigmoid fuzzy function scheme for increasing, decreasing and symmetry conditions: A = monotonically increasing sigmoidal, B = symmetric sigmoidal, C = monotonically decreasing sigmoidal.*

1. The future residential land use of the city should be available next to the residential use. Therefore, to fuzzy it, the symmetric sigmoid equation was used with respect to the values obtained using the Distance method (**Figures 8** and **9A**).

2. With the distance from the city center, the value of land should gradually decrease, until urban growth is directed toward the compact city model. According to the values obtained from the application of the Distance equation, the sigmoid symmetric fuzzy method was used (**Figures 8** and **9B3**).

3. With the distance from the roads, the value of lands for industrial and residential uses should gradually decrease. According to the values obtained from the application of the Distance equation, the Symmetric Sigmoid fuzzy technique was used (**Figures 8** and **9A**).

4. With the distance from agricultural lands, the value of lands should increase. In fact, residential and industrial lands should not be located on agricultural land. Agricultural land entered the equation as protection and constraint (**Figure 8**).

5. Considering that the city of Sarakhs is located in the low slope of Sarakhs plain and the difference in altitude is 232 and 380 m above sea level, respectively. According to the values obtained from the application of the Distance equation, the sigmoid symmetric fuzzy method has been used (**Figures 8** and **9A**).

6. With the distance from barren lands, the value of lands should increase. In fact, residential and industrial land uses should be located on barren lands. According to the values obtained from the application of the Distance equation, the Monotonically increasing Sigmoid fuzzy technique was used (**Figures 8** and **9B**).

7. With the distance from the international transit road, the value of lands for industrial and residential uses will gradually increase. According to the values obtained from the application of the Distance equation, the Symmetric Sigmoid fuzzy technique was used (**Figures 8** and **9A**).

8. Due to the possibility of flooding of major rivers and the destruction of residential and industrial areas and the preservation of agricultural lands around rivers, these land uses should be away from the river. Therefore, according to the values obtained from the application of the Distance equation, the Symmetric Sigmoid fuzzy method has been used (**Figures 8** and **9A**).

Therefore, due to numerous fuzzy membership functions on the one hand and the number of variables and their importance in the site selection (residential and industrial land), on the other hand, three fuzzy membership functions were used. The results of the above hypotheses are shown in **Figure 9**. Points a, b, c, and d are control points [26]. Perhaps the most important feature of the model is the design of fuzzy equations for variables based on the above assumptions, which distinguishes this research from other research.

### 4.5 Result of application of MCE technique

In MCE, different factors are combined in a suitable plan or goal. First, the weight of each variable (13 variables except agricultural land variable) was calculated using the AHP option, based on the Saati table (weights 1–9). The weight of each variable for the purposes of residential and industrial sites was determined in **Tables 2** and **3**. As shown in **Table 2** for residential land use, the three factors of distance from agricultural land (0.5034), distance from residential lands (0.2688), and distance from roads (0.1505) have more weight than other variables. The stability coefficient obtained from the calculation of real judgments of the random matrix index is 0.07, which is reliable [27]. Furthermore, in **Table 3**, distance from major centers of activity (0.2898), distance from transit road (0.1695), and distance from railway (0.1501) have more weight than other variables of industrial land use. The calculation of real judgments for the random matrix index is 0.08, which is reliable.

In general, in MCE, an attempt is made to combine a set of factors to achieve a single composite basis for decision-making according to a specific goal, which is done here.

| Factor (variable) | Factor (variable) weight |
|---|---|
| Distance_Built-Up (Residential lands) | 0.1526 |
| Distance_Main Rivers | 0.0409 |
| Distance_International Line Border | 0.0770 |
| Distance_Barren land (bare, light artificial desert forest, rangeland, and grass lands) | 0.1465 |
| Distance_Barren land (uncultivated land, shrub, and grass and artificial desert forest lands) | 0.0343 |
| Distance_Main land use projects | 0.2344 |
| Distance_Transit Road | 0.0246 |
| Distance_City Center | 0.2898 |
| *Consistency ratio = 0.07, Consistency is acceptable.* | |

**Table 2.**
*The eigenvector of residential weights.*

| Factor (variable) | Factor (variable) weight |
|---|---|
| Distance_Built-Up (Residential lands) | 0.0981 |
| Distance_Main Rivers | 0.0465 |
| Distance_Barren land (bare, light artificial desert forest, rangeland, and grass lands) | 0.0908 |
| DEM(Digital Elevation Model) | 0.0458 |
| Distance_Barren land (uncultivated land, shrub and grass, and artificial desert forest lands) | 0.0782 |
| Distance_Transit_Road | 0.1659 |
| Distance Railroad | 0.1501 |
| Distance Roads Sarakhs | 0.1167 |
| Distance Activity Centers | 0.2079 |
| *Consistency ratio = 0.08, Consistency is acceptable.* | |

**Table 3.**
*The eigenvector of industrial weights.*

### 4.6 Simulation of location of future residential and industrial land uses by MOLA model

The main purpose of this research was to locate residential and industrial land uses. So to locate the future development of residential (332 hectares) and industrial land uses (500 hectares) with SDM and MOLA problems, the two above-mentioned targets must first be routinely created from the MCE (**Figure 8**). As the name implies, this option allows you to select multiple targets at the same time, such as locating residential, industrial, and so on. The MOLA operator in the spatial decision model is a way to solve the land allocation problem. Based on the information of several suitable unit goals or maps, MOLA determines the best solution according to the specified limitations. According to the required amount of residential (322 hectares) and industrial (500 hectares) land, and a map raster format marked with a cell with a resolution of 10 m, about 32,200 cells for residential use and 50,000 cells for industrial land uses entered the equation. As a result, the residential and industrial land uses of Sarakhs in 2030 were identified in **Figure 10**. Residential land use was located discretely and continuously on barren lands around the city of Sarakhs. Industrial land use has been determined in the southwest with the distance from the city on barren lands and next to the transit road, railways, and major centers of economic activities such as the airport, railway terminal, and SEZ. These results indicate the model's ability to locate the proposed land uses.

### 4.7 Validation of simulation results of MOLA model with Sarakhs Master Plan

As mentioned earlier, the Master Plan plans are prepared using the traditional field survey approach and its combination with natural maps. More recently, these plans have been prepared by overlaying different layers and field observations using

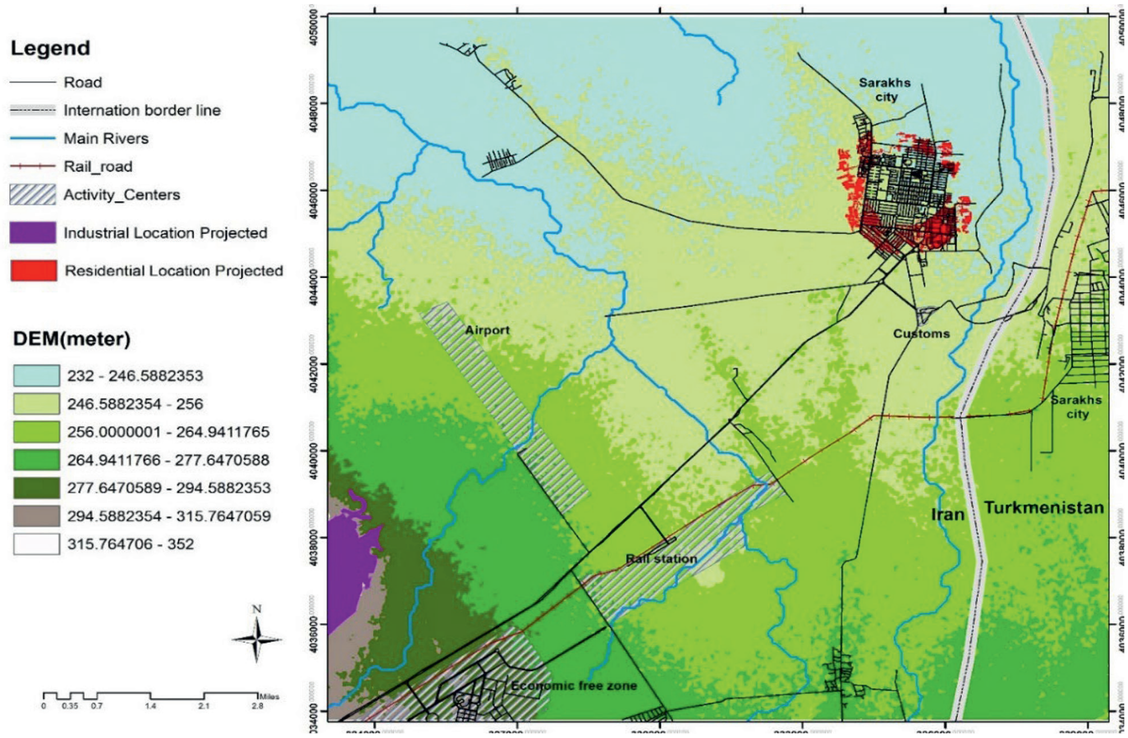


**Figure 10.**
*Simulation of the location of future residential and industrial land uses of Sarakhs city based on MOLA model.*

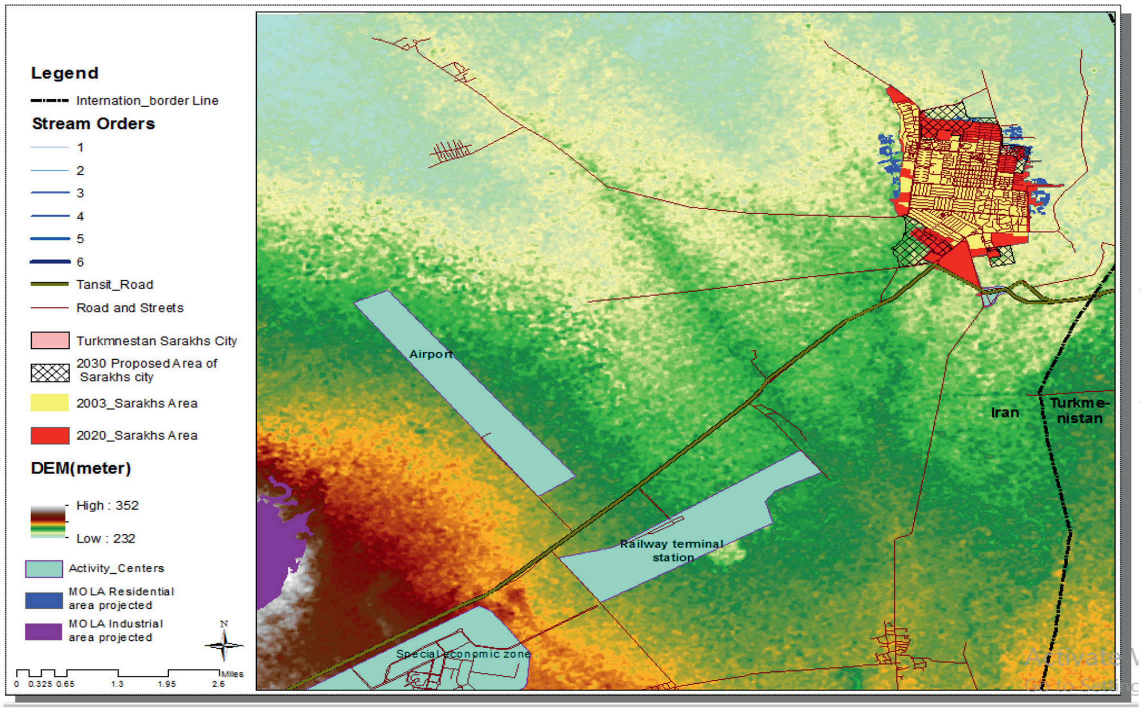


**Figure 11.**
*Validation of the proposed development side of the Master Plan and MOLA model of Sarakhs city.*

GIS tools. An example of such a plan is the comprehensive plan of the city of Sarakhs, which is projected as a discrete black checkered grid in the south and north of the city on barren lands. In addition, a special economic zone has been designed on the western side of the city with a 15 km distance (**Figure 11**). The results of using the MOLA model according to 13 variables, research hypotheses, and Fuzzy and AHP techniques show the compliance of residential land use with the proposed results of the city Master Plan on barren lands (**Figure 11**). Meanwhile, industrial land use was proposed in the southwest of the city on barren lands and in the north of the SEZ, next to the transit road, railway terminal, and airport. This relative overlap of the residential land use of the MOLA model and the comprehensive plan on the one hand and the proximity of the industrial land use with the major centers of economic and industrial activities, on the other hand, show the ability of the model to find different objects with high speed, reasonable accuracy, and low cost. This is a feature of the application of spatial allocation models in optimizing the goal and minimizing the cost and can support the urban management decision-making system. However, until now, this procedure has not been used in site selection and urban growth simulation. Internet reviews also confirm this. Although the simulation of urban growth has been done with cellular automation and neural network models, single-purpose and multipurpose land allocations are one of the things that can be used in urban planning to replace the traditional process of preparing Master Plans (**Figure 11**). The proposed development side of the comprehensive plan and MOLA model of Sarakhs city is validated.

## 5. Discussion

The change in the use of agricultural land, especially around cities (1.8–2.5% of arable land) as a result of the rapid growth of urbanization in Asia (1.7%) and Africa (2.3%) [28], makes it necessary to control urban growth with new tools.

Urban Master Plans have been a tool to control urban growth traditionally since 1947 in developed countries [29], and since 1967 in Third World countries [29, 30]. Until now, the method of preparing these plans has been manual and with traditional tools, which was time consuming, imprecise, and costly. The combination of GIS and spatial decision-making models can help to solve these problems.

In this research, the urban growth of Sarakhs city with the MOLA model in the form of two goals of residential and industrial land use from 2020 to 2030 has been estimated, and these results are compared with the proposal of the traditional Sarakhs Master Plan. The urban growth of the city is simulated on the barren lands around the city using remote sensing data and TerrSet and ArcGIS software. Spatial decision-making model, Fuzzy-AHP technique, MCE, and MOLA techniques were used for the vision of the city by 2030. The MOLA model makes this possible, to select one or more different objects at the same time, such as residential and industrial land uses. The results of the study showed that the built-up area of Sarakhs increased from 439 to 684 hectares from 2003 to 2020. In addition, the results of using 13 variables affecting the location of residential and industrial land uses with the combined fuzzy-HP technique and the MCEA model showed that the factors influencing the location of land uses have different weights. For residential land use location simulation, the three factors of distance from agricultural land (0.5034), distance from residential land (0.2688), and distance from roads (0.1505) have more weight than other variables. The stability coefficient obtained from the calculation of real judgments for the stochastic matrix index was 0.07, which was reliable [27]. Also, for industrial sites, the factors of distance from major centers of activity (0.2898), distance from transit road (0.1695), and distance from the railway (0.1501) have more weight than other variables. The stability coefficient obtained from the calculation of real judgments for the stochastic matrix index was equal to 0.08, which was reliable. Finally, using the MOLA model, considering the area of residential and industrial land use for 2030, which is equal to 322 and 500 hectares, respectively. Residential land uses were sporadically located along barren lands around the city to the north, west, east, and south of the city (**Figure 10**). Meanwhile, the proposed development of industrial land on barren lands was located at a distance from agricultural lands and adjacent to major roads, centers of activity, and transit roads in the south-west of Sarakhs city. These simulations are relatively consistent with the proposed Master Plan of the city. The use of this method to locate the development side of cities has not been observed in online surveys. But Bahadur Thapaa and Murayamab [9] proposed urban growth until 2050 under three scenarios, using artificial neural network for Nepal Kathmandu Valley: To some extent, the results of urban growth simulation of Sarakhs are compatible with the environmental protection scenario of Nepal Kathmandu Valley. The only case identified on the Internet is the application of the MOLA model of the zoning of Iran's Qomishloo Wildlife Sanctuary, allocating suitable land for four purposes of protection, improvement, tourism, and heritage history [10]. The most important difference between this research and other research was summarized in the fact that they first find several options and then prioritize between them, such as prioritizing the selection of municipal landfills with the AHP model [31], combining GIS and allocating space to give optimal health services and locating health centers [23, 32], and prioritizing several sites to select the best place for Solar energy farms [11]. In these examples, several predefined sites are first prioritized as a result of using the model. But in MOLA model, one or more sites are selected from the infinite number of options in the optimal mode. These options are not known in advance. Therefore, the MOLA model is the optimization of the goals according to the status of the factors affecting it. Speed of operation and more accuracy and less cost are the features of using the MOLA model for location-allocation problems for the Third World countries such as Iran with rapid urbanization, especially small-scale cities such as Sarakhs. Due to the weakness of the scientific literature on the use of the MOLA model in allocating space in the preparation of Master Plans, the published scientific experience can no longer be found in the TerrSet software directory. Internet searches on reputable scientific databases also confirm this shortcoming. Further studies on the application of the model in different cities and regions and the selection of effective variables, especially social, economic, and environmental variables, are needed for better result.

## 6. Conclusions

The presence of more than 50% of the world's population in cities in 2018 and the forecast of its share up to 68% by 2050, raising the need to guide and manage urban growth, especially in Third World countries in the form of preparing Master Plans. These plans, despite being abandoned in developed countries, are major tools for guiding and managing urban growth in Third World cities [33]. Numerous reasons have been cited for the failure of these plans in practice, the long process of traditional methodological preparation of plans, especially site selection of the cities has been one of their major problems. In this study, we tried to simulate the urban growth of Sarakhs as a small border town with a population of fewer than 100,000 people, according to the two purposes of residential and industrial land use with the MOLA model in TerrSet software, and Landsat 7 and 8 satellite images and Sentinel 2A by 2030. The results of applying the MOLA model in the site selection of Sarakhs city with both residential and industrial purposes showed that the model has the ability to simulate such urban growth in such cities. And this simulation is in relative compliance with the prediction results of the traditional city Master Plan. Due to its high speed of operation, high accuracy, time, and cost savings, this model can help guide urban growth to improve the quality of comprehensive plans, which are the dominant model of development in Third World countries. In order to improve the quality of the model, other social, economic, and environmental aspects need to be studied.

## Data availability statement

Some or all data, models, or code that support the findings of this study are available from the corresponding author upon reasonable request.

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