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Prediction of Urban Spatial Changes Pattern Using Markov Chain

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Abstract

Urban land uses of all kinds are the constituent elements of the urban spatial structure. Because of the influence of economic and social factors, cities in general are characterized by the dynamic state of their elements over time. Urban functions occur in a certain way with different spatial patterns. Hence, urban planners and the relevant urban management teams should understand the future spatial pattern of these changes by resorting to quantitative models in spatial planning. This is to ensure that future predictions are made with a high level of accuracy so that appropriate strategies can be used to address the problems arising from such changes. The Markov chain method is one of the quantitative models used in spatial planning to analyze time series based on current values to predict the series values in the future without relying on the past or historical values of the studied series. The research questions in this study are formulated thus: What are the trends in the patterns of urban land use functions in Al-Najaf, Iraq, between 2005 to 2015? How can the values of the changes be predicted for the year 2025? The hypothesis is based on the increasing spatial functional change of land use patterns in the city during the study period due to various economic and social factors. Making accurate predictions of the size of spatial changes motivates this study as a guide to urban management towards developing possible solutions to address the effects of this change, as well as the need to understand its causes and future upward trends. The contribution of this article is the presented outlook for spatial functions for the next 10 years. The computations using the Markov chain model will enable management to understand future relations and develop appropriate policies to reduce the hazards of unplanned changes in the city. Results show that residential posts, slums, and commercial activities are getting worse, while change values for industrial functions and other things are going down.

Keywords: Functional Change; Land Uses; AL-Najaf; Markov Chain; Spatial Modeling.

1. Introduction

The Markov chain is an operations research method widely used in spatial planning for forecasting purposes [1, 2]. The Markov chain predicts the phenomenon in the future based on the present without the need for historical sequencing of that phenomenon. Understanding the changes of spatial phenomena in cities makes urban management fully aware of the possible solutions and policies to address the negative effects of such changes in the future [3]. To clarify the mathematical mechanism of the model, the logical steps of the mathematical application must be represented as in the following mathematical equations:

$$B(t+1) = Pij \times B(t) \tag{1}$$

where B(t+1) = status of phenomenon at t or t +1; Pij = transition probability matrix of a state which is represented as below:

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$$\begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1n} \\ p_{21} & p_{22} & \cdots & p_{2n} \\ p_{n1} & p_{n2} & \cdots & p_{nn} \end{bmatrix} \quad (2)$$

$$\left(0 < 1\ and \le P_{ij}\ \sum_{j=1}^{N} P_{ij} = 1, (i,j = 1,2, \ldots\ldots, n)\right)$$

Or;

$$\begin{array}{c c} & \begin{array}{cccccccc} 0 & 1 & 2 & 3 & 4 & 5 & . & . \end{array} \\ \begin{array}{c} 0 \\ 1 \\ 2 \\ 3 \\ 4 \\ 5 \\ . \\ . \end{array} & \begin{bmatrix} p_{00} & p_{01} & p_{02} & p_{03} & p_{04} & p_{05} & . & . \\ p_{10} & p_{11} & p_{12} & p_{13} & p_{14} & p_{15} & . & . \\ p_{20} & p_{21} & p_{22} & p_{23} & p_{24} & p_{25} & . & . \\ p_{30} & p_{31} & p_{32} & p_{33} & p_{34} & p_{35} & . & . \\ p_{40} & p_{41} & p_{42} & p_{43} & p_{44} & p_{45} & . & . \\ p_{50} & p_{51} & p_{52} & p_{43} & p_{54} & p_{55} & . & . \\ . & . & . & . & . & . & . & . \\ . & . & . & . & . & . & . & . \end{bmatrix} \end{array}$$

The predictions outcome depends on the current circumstances of the phenomenon, i.e., the current change in the functions of urban land uses in the area of study as in the following mathematical equation:

$$B(t, t+1) = \int (B(t), N) \quad (3)$$

The model adopted by Markov is quantitative in the change's measurements land-used [4, 5].

There is an axiom known to most people interested in probability and statistics, which is that all probabilistic values (their values are between zero and one, i.e., a fraction) [6] when multiplied or multiplied by themselves several times, will lead to stability, or dependence on a certain value. This is a characteristic of probabilistic values. For example, if it is raining today, what is the forecast for the weather two months from now? There must be probabilities that show this according to the fluctuations of the weather during the previous period and the probabilities of determining the values if the weather was rainy or sunny. The expected value, whether the weather is rainy or not after this period (for example, two months), will represent the stability of the weather and indicate the weather trends, i.e., whether it is rainy or sunny.

This is what we call the stability state of Markov chains (because their elements are probability values), or the stability of the probability values of Markov matrices represented by Markov chains [7, 8].

The article will rely on the data issued by the local urban management in Al-Najaf and the satellite visual data after being processed by GIS applications to calculate the areas of spatial functional change for urban land uses in the city. Then, the Markov chain methodology will be applied to make future predictions of the spatial functional changes for the years 2005 to 2015, and then to 2025.

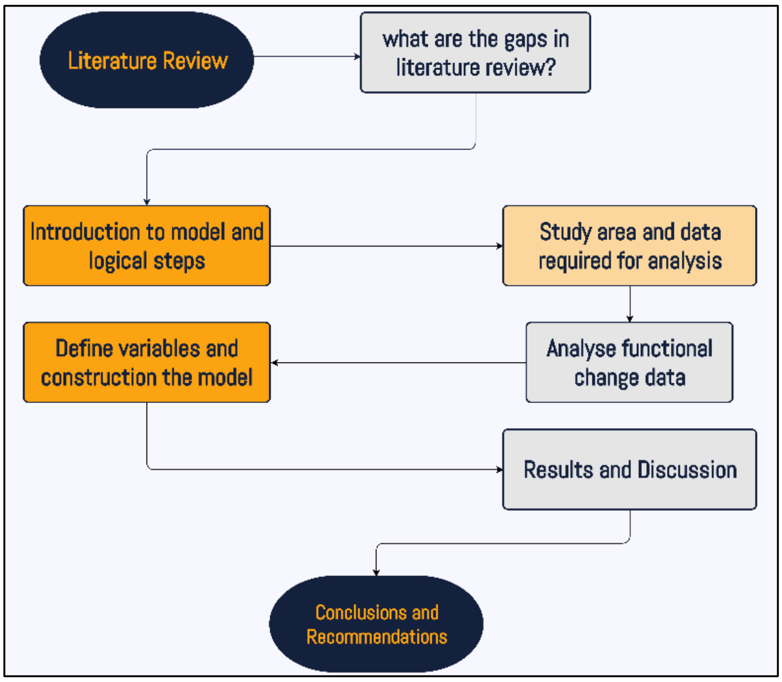

Figure 1. A flowchart of the research methodology

2. Literature Review

Kamran et al. (2022) used the Markov chain to study the changes in land cover (LULC) and land use. Their research analyzed historical as well as current data to prospected LULC changes in one of the Iran regions, which experienced a lot of difficulties in getting the essential wild sources. The present data focused on cellular automata and Markov's role to emulate each LULC. The statistics from 1989 - 2019 LULC maps of Kurdistan Region and West Azarbaijan County, moreover, a prospective study adopted the changes in land till 2049 based on Markov pattern declared that the mountain & pasture LULC class persistent in a decrease in comparison to other classes, furthermore, the amount of precipitation and water resources in the last and coming years are essential to be expanded in a temporal & spatial manner on LULC classes [9].

Muhammad et al. (2021) in this study the Satellite images and random forest algorithm were used to classify LULC in Karachi for every ten years, starting from 1990 to 2020 with the help of Google Earth. The main urban centers, secondary urban cores, dispersed settlements, sub-urban fringes, non-urban areas, and urban open spaces are the six urban classes, were assigned for studying the changes of the urban landscape. A CA–Markov model was used to estimate further LULC sceneries for the year 2030. The findings revealed that the populous region had grown in a highly unanticipated manner. The essential urban core grew larger from the core districts, namely the Central, Southern, and Eastern districts, and a new urban secondary core appeared in Malir in 2020, according to an analysis of urban landscape changes. According to the CA–Markov model, the total urban built-up area could increase from 584.78 km2 in 2020 to 652.59 km^2 in 2030. The integrated method, which incorporates GIS, remote sensing, and an urban sprawl matrix, has proven to be quite useful in analyzing urban sprawl in a rapidly increasing city [10].

Hamide et al. (2019) used CA–Markov to investigate changes in land use, notably in urban areas, in recent years and the likelihood of projecting future changes in the Talesh Region. Satellite imagery from ETM 2000, 2007, and 2014 was used in this study. Categorization of images was observed and monitored by using the maximum likelihood method. After that, the accuracy of the generated land use maps was determined using kappa coefficients. Land use maps in 2000, 2007, and 2014 have kappa coefficients of 0.86, 0.85, and 0.89, respectively, according to the conclusions of the evaluation, total above 90%. The map of land-use changes in the future, i.e., in 2028 was forecasted by using a Model based on the CA–Markov chain. Over the next fourteen years, the findings showed increases in urban land-use area sizes of 29/83 percent and reductions in agricultural land areas, wastelands, and forests of 3/12, 0.59, and 0.48 percent, respectively, in the area under examination. The future of the city's growth could take place mainly and linearly surrounds Hashtpar, particularly on the city's eastern and western outskirts [11].

The purpose of the study by Mohammed et al. (2021) was to predict and combat the removal of trees, i.e., deforestation based on satellite image as environmental statistical analysis. This study used a mathematical cellular automata-Markov model randomly to predict changes in land use in the Tazekka Park, and its borders in TAZA Province in Morocco. The model adopted in this study was mainly used to create thematic forecast maps. The intended approach was used to derive statistics and data covering the period from 2000 - to 2020 for the construction of a predictable map for 2040 by *ArcMap*. The efficiency of the model assessment was verified by estimating the matrix of transitions by Markov in the derivation of the final map. The findings of this study will help to improve the management of forested areas and will serve as a reference for dealing with the direct effects of forests on the environment [12].

A study by Francina et al. (2021) determined land cover changes by using satellite images data, then predicted land cover in the next 10 years. The study also calculated the elements that influence land cover shifts. The Chain has been adopted to explore changes in land use in Paupa Barat, Sorong Regency, Indonesia. The land cover maps were also created using remotely sensed multi-temporal data from Landsat. The data revealed that the decline of wooded lands and the conversion of settlement and shrub areas dominated land cover changes from 2003 to 2017. In Sorong City, a geographical prediction of land cover change from 2017 to 2025 might be made using a Markov Chain and Cellular Automata integration [13, 14].

The following gaps are identified in the literature:

- Understanding the pattern of city spatial changes is critical for preventive planning and long-term sustainability. The importance of the Markov chain in future planning is that it allows to detect and simulate spatial systems and develop a guide for policymakers.
- All the reviewed studies assumed that all the data entered into the Markov model are based on satellite imagery, while in our study, the data is issued by urban managements and from field surveys, city plans, and satellite imagery, as well as through different statistical operations (Plurality and Reliability Data Sources).
- This study was able to create a model for a dynamic transitional matrix that may be used in the (Simulation of Land Use Spatial Pattern) when entering various data to predict spatial systems; the previous studies were only based on digital analysis and the use of algorithms to predict one case for the phenomenon.
- This study has been able to develop a model for a dynamic transitional matrix that can be used in simulations when we enter different data to predict spatial systems. The previous studies relied only on digital analysis and used algorithms to predict one case for the phenomenon.

- There is no similar study using the proposed approach for Al-Najaf or other Iraqi cities.
- The importance of this study, compared to previous studies, is that it focused on functional urban changes analysis, predicting functional changes for the future and not only the land cover, forest area, and green cover.

3. Study Area

Najaf city is one of the important historical Iraqi cities [15]. It is located between longitudes (50` 42° - 44° 44̀) east and two latitudes (50` 29° - 21° 32°) north. It has gone through different historical stages and developments due to many factors. The effects of these factors varied, each according to its importance, i.e., religious and political factors, as well as the other factors. Figure 2 shows the stages of the spatial change of the city from 1925 to 2005.

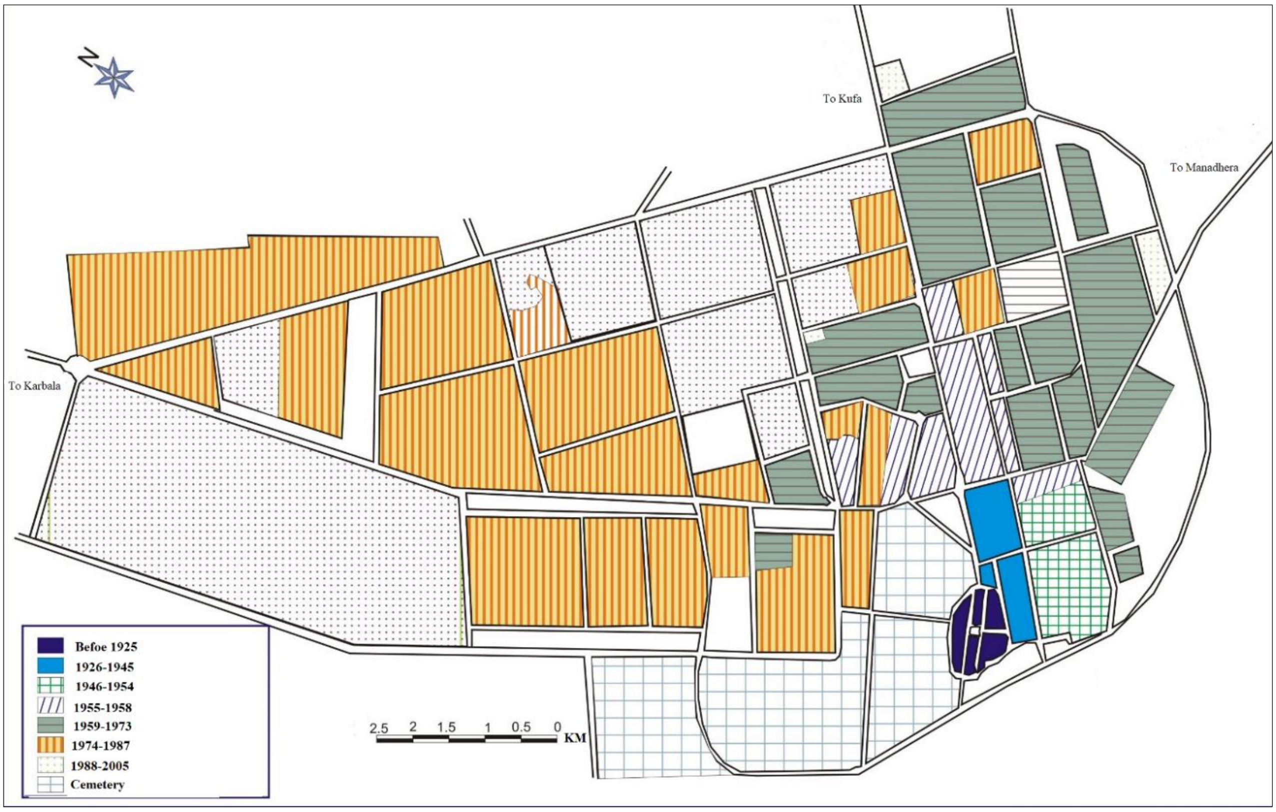

Figure 2. Map of urban spatial change during 80 years from 1925 to 2005

Najaf is on the edge of the Western Desert, which extends to the country's borders with the Kingdom of Saudi Arabia. It overlooks from the north and north-eastern sides, the cemetery of Wadi As-Salam, and from the western side, The Najaf Sea depression. It is about 11 km from Kufa town and rises about 70 meters above sea level. The city consists of 41 residential neighborhoods (see Figure 3).

The city is characterized by the presence of small, medium, and large industries spread within the city limits and its spatial structure. The number was estimated at 985 industries, including construction, food, chemical, textile, engineering, wood, and others. Most of them were concentrated in the urban city center, taking advantage of the economic abundance, employment, the volume of demand, and the availability of appropriate infrastructure. As for the large industries, they are 11 industries in the city.

Tourism has a big impact on the city and has contributed significantly to the development process, whether at the global or local levels. It represents an important source of income for the city and the region by attracting foreign currencies on the one hand, and as one of the main elements of economic activity and cultural exchange, deepening awareness among members of society.

Al-Najaf city is distinguished by its religious characteristics; it is a tourist attraction site that attracts millions of visitors every year from different regions, both local and foreign, all come to visit the Holy Shrines. Students from different parts of the world come to study religious sciences in “Hawza”, the religious institution in Al-Najaf. Another feature is the Wadi As-Salam cemetery, the second largest cemetery in the world. A third one is Al-Najaf International Airport (Figure 4).

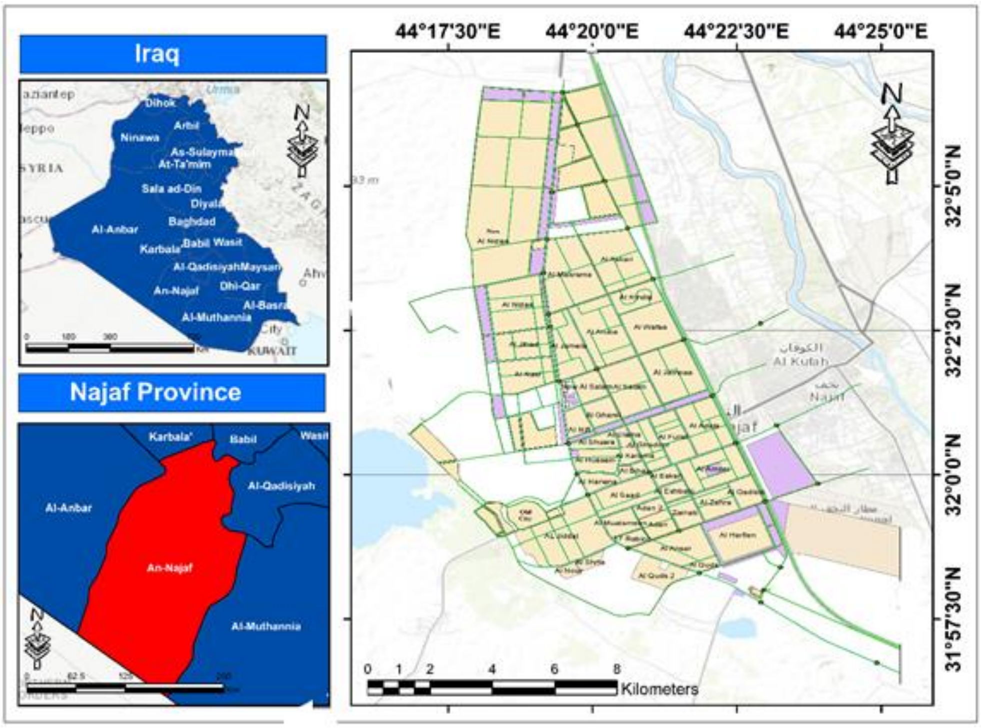

Figure 3. Neighborhoods of Al-Najaf City (41 residential neighborhoods)

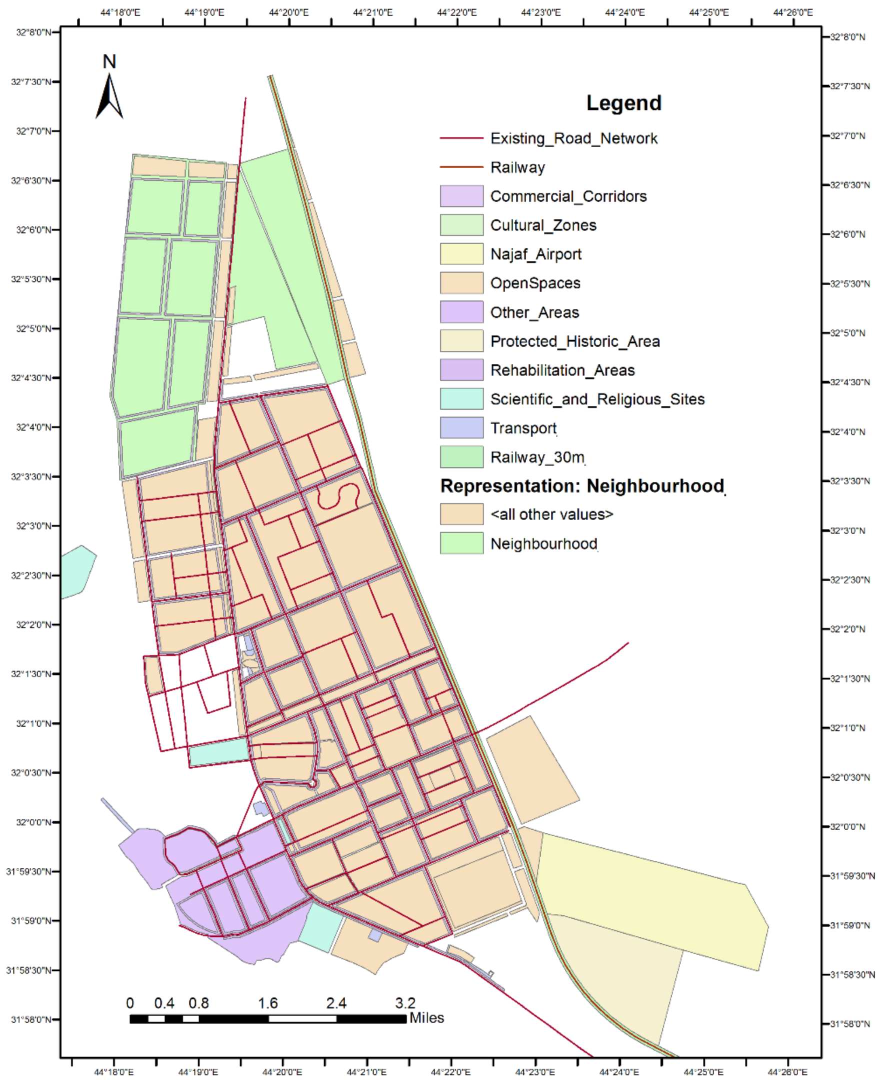

Figure 4. Existing land use of Al-Najaf city

Since the Al-Najaf city is characterized as a result of a rise in the number of visitors, this resulted in the emergence of several services such as transportation, tourist accommodation, food, and entertainment facilities. Tourism marketing is included in this process as one of the important areas in organizing the sale of services and achieving a benefit for tourist facilities and tourists. In other words, the task of tourism marketing is to know and understand the behavior of tourists, which makes the service convenient for them. Al-Najaf contains some elements of tourism marketing, such as the prices of goods, services, and the distinctive location, as well as the location of an international airport in the city, the Najaf International Airport that attracts about three million passengers per year.

Therefore, the author can say that the city is distinguished from the rest of the Iraqi cities in terms of economic activities as it has an Islamic heritage and a historical depth that made it one of the main cities in Iraq. Surely, the existence of the religious factor associated with the Holy Shrine and its impact on the city in terms of economic, social, urban, and political aspects has led to dramatic changes in the urban spatial functions of the city due to the need for expansion and dynamism in the spatial plans to accommodate the multiple effects of the presence of the religious component represented by the Holy Shrine of Imam Ali (Peace be Upon Him) and the other religious shrines and sites.

4. Spatial Change in Al-Najaf City According to Master Plans

The change in the areas and functions of some areas of the city during a specific period is a natural condition in response to the increase in the population, urbanization, complexity of spatial relations, and the economic and social development of the city [16, 17]. Table 1 shows the spatial change according to the three Master plans of the city based on the data from the Department of Physical Planning in Al-Najaf city.

Table 1. Areal change of urban functions based on the three master plans of Al-Najaf

Master plan / Land use	Third		Second		First	
	%	Area H.C	%	Area H.C	%	Area H.C
Residential	44.16	2871.46	54.71	1160	37.5	1500
Commercial	2.75	178.94	1.41	30	6.25	250
Industrial	8.62	560.8	4.1	87	11.25	450
Transportation	18.96	1232.48	27.35	580	25	1000
General Social Services	4.22	274.53	10.84	230	20	800
Open space	13.02	846.61	_	_	_	_
Administrative services	2.5	162.7	1.55	33	_	_
Tourist areas	1.65	107.72	_	_	_	_
Future expansion spaces	4.06	264.4	_	_	_	_
Total	100	6500	100	2120	100	4000

Table 1 shows that the residential use of the first master plan occupies a large area estimated at 1500 hectares, at a rate of 37.5% of the total areas of other uses. Commercial use has taken an area of 250 hectares at a rate of 6.25%. As for the industrial area, it occupies 450 hectares at a rate of 11.25%. This is an indicator that has implications for the advancement of this job category because of its great importance to develop the economy of the city, especially the small handicraft industry that was prevalent at the time. Much attention was paid to the areas allocated for transportation and movement because of their effective impact on the process of linking and interacting between urban functions that constitute the functional structure of the city. Hence, it was allocated 1,000 hectares at a rate of 25%, taking the second rank only to residential use. Its purpose is to ensure easy access within the city centre and facilitate movement for visitors (both locals and foreigners) since the street pattern of the city at the time is still the organic one. The area for public social services took 800 hectares, which is 20% of the total area.

As for the second master plan, the total area is 2120 hectares. It included several uses in the city, which is much less than what was stated in the previous and subsequent master plans. The residential use area occupies 1160 hectares, more than half of the proposed total area, i.e., 54.71% of the total. This confirms that the master plan's priority is to provide housing. Transportation and movement ranked second, with an area of (580 hectares or 27.35% of the total area. The area of industrial use accounted for 87 hectares or (4.10%, which is below the allocated area for it in the other two master plans. As for general social services, the area allocated is 230 hectares or 10.84%. The percentage of commercial use is 1.41%, which is the lowest percentage of the total area.

For the third master plan, the area allocated for residential use was 2871.46 hectares or 44.16% of the total. It is undoubtedly an indication of the dominance of this use over the other uses. The allocation for commercial use is about 178.94 hectares or 2.75% while the land uses for industrial and storage purposes are 560.8 hectares, representing 8.62%). As for the proposed area for transportation and movement purposes, it occupied 1232.48 hectares or 18.96%. It took the second rank after residential use for the three master plans. General social services were allocated a total area of 846.61 hectares, representing 13.02%. As for the administrative, technical and general services, they were allocated 162.7 hectares or 2.5%. The master plan also included the tourist areas of all kinds and levels, as well as empty spaces for future expansion within the city limits, accounting for 107.72 hectares for the first master plan, 264.4 hectares for the second one (or 1.65% and 4.06% of the total for each of them, respectively).

To identify the spatial functional change of land uses in Al-Najaf city from 2005 to 2015, Table 2 and Figure 5 showed the spatial changes and their percentages.

Table 2. The areas and percentages of urban spatial changes in the city from 2005 to 2015

Land use	2005		2015	
	Area. HC	**%**	**Area. HC**	**%**
Residential	3156.822	48.78	3912.5	46.52
Commercial	200.30	3.09	645.7	7.68
Industrial	702.41	10.85	739.52	8.79
Transportation	1109.8	17.15	1403	16.68
General Social Services	500.7	7.74	401.5	4.77
Administrative services	130.67	2.02	193.38	2.30
Open spaces	632.06	9.77	922.27	10.97
Infrastructure	39.45	0.61	191.88	2.28
Total	6472.212	100.00	8409.75	100.00

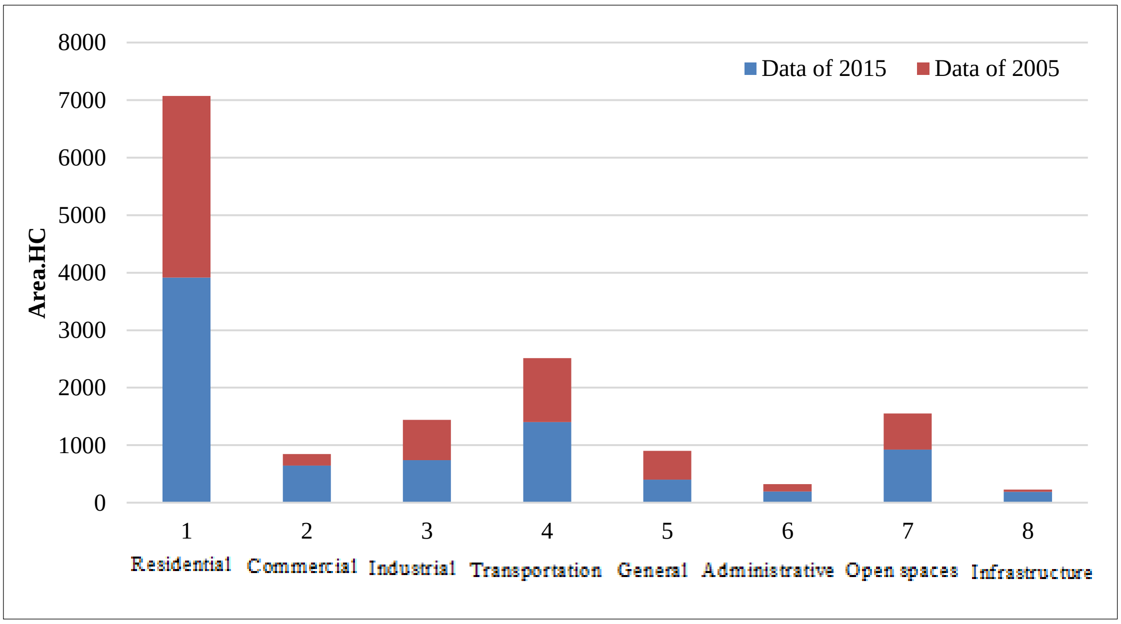

Figure 5. The areas and proportions of the urban spatial changes of the city from 2005 to 2015

These data showed that the urban cadastral changes in Al-Najaf city during the ten years, i.e., from 2005 to 2015 were random, uneven, and without a plan by the local authorities. This affects the nature of the existing spatial relations and also created multiple urban problems. To make a detailed study in the size of spatial functional changes based on the number of buildings and institutions in Al-Najaf, it is necessary to count the number of changing jobs during the period 2005-2015 based on which predictions can be made using the Markov chain.

4.1. Functional Changes in Al-Najaf Land Use

The section will discuss the statistics for the changes in the number of jobs in the city during the period 2005-2015.

4.1.1. The Changes in Residential Spaces into Commercial, Industrial, and Other Functions

Relying on the statistical survey form, GIS, local urban management data in the city, and processed satellite visuals, the author obtained the following data shown in Table 3.

Table 3 and Figure 6 showed that all the city neighborhoods witnessed a functional and spatial change during 2005-2015 and in varying proportions. Most of the areas that have changed in 10 years were commercial services, then industrial, and other jobs due to factors related to spatial competition and the economic ability of business owners to pay money to obtain commercial land areas illegally. This is an infringement on the urban spatial organization of the city because of its effects on spatial relations and the urban structure in general.

Table 3. Urban spatial functional changes in Al-Najaf from 2005 to 2015

Neighborhood	Residential to Commercial		Residential to Industrial		Residential to Others	
	NO	Functional Changes M²	NO	Functional Changes M²	NO	Functional Changes M²
Al Ameer	231	17952	69	1728.2	38	5350
Qadisiya/Hurafeen	122	4103	51	777	2	20
Zahra	220	6100	72	1780	7	250
Zainab	98	2901	33	510	18	811
Ansar	200	4020	74	611	18	1205
Al QUDS first	74	3012	42	523	7	420
Al QUDS Second	73	11865.7	12	67	8	250
Al Nour	31	537	11	230	6	330
Tabuk / Shurtah	23	1929	15	402.25	3	127
Imam Ali	60	1501	18	189	4	245
Al Moalmeen	23	900	13	140.5	10	490
Muthanna and Saad	340	20767	42	1150	21	1121
Al Zohor	111	4035	22	390.5	10	380
Al Eskan	190	4040.5	13	180.5	3	**32**
Al Adala and Alforat	164	7230	32	1001	17	690
Ghadir	176	5045	29	603.5	8	312
Al Siha	132	3672.5	23	300	9	260
Karama& Ulamaa	105	3127.1	29	285	5	120
Al Shuaraa	110	1787.5	26	425	8	167
ELHussein	100	2932	30	289	18	593
Al-Hanana	121	9201	16	195	12	402
Al Gimaa	276	176130	55	3281	11	420
Al Salam	489	25219	201	9120	8	370
Gary&Atibaa	265	8957	74	1874	8	501
Al Jazaer / Al Wafa	265	6021	89	3221	5	254
Orouba	342	15371	198	11000	9	431
Al Jameea/Al Risalah	194	5812.8	152	4400	16	877
Alaskri/Makramah	528	25408	243	12530	15	794
Al Naser/ Jihad	1108	26360	251	8999	5	221
Al Jidedat	809	40042	220	11778	6	256
Old City	388	30902	19	411	21	1200
Total	7368	476881.1	2174	78391.45	336	18899

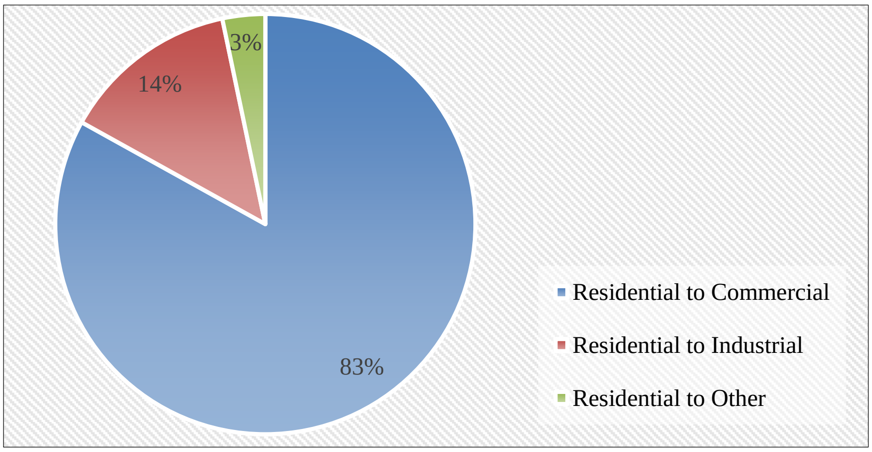

Figure 6. Urban spatio-functional changes in Al-Najaf from 2005-2015

The continuation of this infringement in a rapid way requires urgent intervention by the urban management in the city to develop immediate solutions by limiting the aggravation of the problem. The author also suggests adopting the results of this study that will present future predictions of urban changes and encroachment.

Economic factors play a major role in changing spatial functions as they are directly related to the land and its value. Social factors come in second place in terms of their impact on changing the spatial structure, as indicated by “Chapin F. Stuart” who discovered the effect of ecological and natural factors on changing spatial functions, stressing that these factors influence [3]:

A - Concentration and decentralization.

B- Invasion and succession.

C- Superintendence and segregation which are related to other policies.

4.2. Analysis of the Spatial Change of Slums within Urban Land Uses

Najaf city witnessed a significant increase in the number of slums because of lawlessness, especially after the American invasion in 2003. The result is a deterioration of the elements of the urban environment in general. Table 4 and Figure 7 shows the distribution of slums in the city during the period 2005-2015.

Table 4. Areas of slums according to spatial locations in Al-Najaf from 2005-2015

Neighborhood	Numbers of Slums	Slums H.C
Radhawiah	4107	83.17
Behind Aljidadat	2980	60.2
Al shurtah	1642	32.84
Al Rahma	5275	101.5
Total	14004	277.71

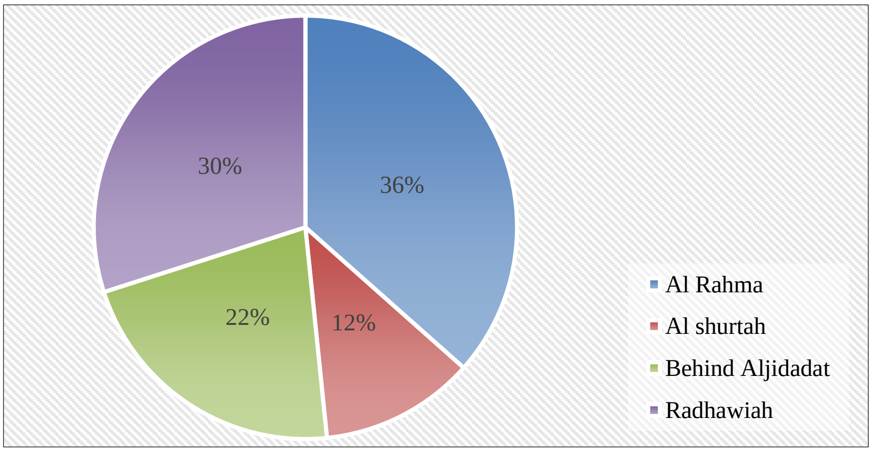

Figure 7. Distribution of slums areas in Al Najaf from 2005-2015

Table 4 and Figure 7 showed the largest change in the Al-Rahma neighborhood, which claimed approximately 36% of the total functional change to slums. Al-Razwiyah neighborhood comes in second place. The reasons for the increase in slums areas in the Al-Rahma neighborhood are: this neighborhood is close to the city’s commercial center, and its location is on an important highway (Najaf-Karbala). Al-Radwiyah neighborhood is characterized by its location to Najaf-Qadisiyah highway, which made it more susceptible to an increase in slums areas during the period of this study (2005-2015).

When the researcher studied the patterns of change in the functions of slums, it was noticed that there are changes in some of the areas allocated for residential, commercial, and service uses to residential slums outside the conditions and laws of the city's master plan. Table 5 and Figure 8 showed the change in spatial functions from and to slums.

Table 5. The spatio-functional change slums in Al-Najaf from 2005 to 2015

	Total	Slums to Residential	Slums to Commercial	Slums to Industrial	Slums to Others
H.C	277.71	124.96	21.3٣	24.37	6.371
NO.	14004	6300	1078	1232	322

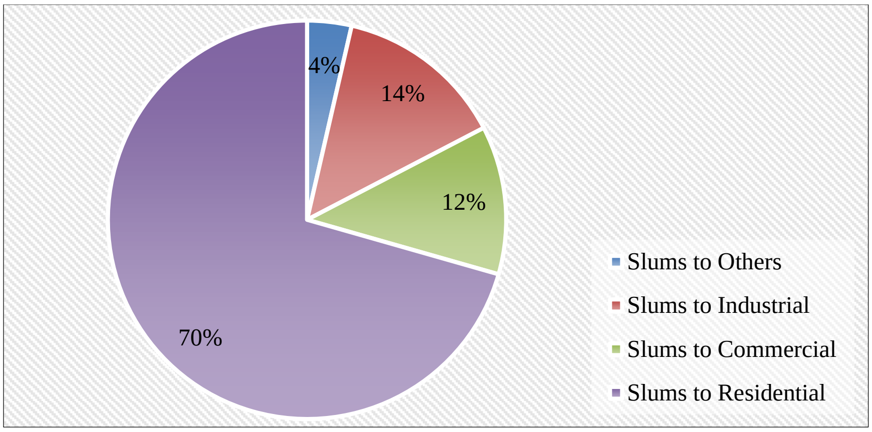

Figure 8. The spatio-functional change of slums for Al Najaf from 2005-to 2015

The residential land use took up a large area of the total quantity of functional change in Al Najaf city from 2005-to 2015. The reason is due to the absence of a housing policy that supports the housing sector to provide housing units for families, as well as the absence of spatial development plans that are concerned to deal with the shortage of housing units in the future. Residents, especially those with low and limited income, were forced to illegally possess the lands of the master plan for housing purposes and other commercial and industrial activities.

5. Results and Discussion

Based on the data obtained from the field study, the field survey, Al-Najaf urban management data, and matching satellite visuals after being processed by GIS from 2005-2015, the predictive analytical results were obtained for the future functional change for Al-Najaf city. A Markov chain is an absorbing chain with at least one absorbing state and a possibility to go from any state to at least one absorbing state in a finite number of steps. Although the coin flips cease after the string is generated, the perspective of the absorbing Markov chain is that the process has transitioned into the absorbing state representing the string and, therefore, cannot leave.

In this part, we shall show a type of Markov chain in which when a certain state is reached, it is impossible to leave that state (final state), called the absorbing states, and a Markov Chain that has at least one such state is called an Absorbing Markov chain. For example, consider the following matrix of transitions.

$$\begin{array}{c} \\ S_1 \\ S_2 \\ S_3 \end{array} \begin{array}{c} \begin{array}{ccc} S_1 & S_2 & S_3 \end{array} \\ \begin{bmatrix} 0.1 & 0.3 & 0.6 \\ 0 & 1 & 0 \\ 0.3 & 0.2 & 0.5 \end{bmatrix} \end{array}$$

The state S_2 is an absorbing state because the probability of moving from state S2 to state S2 is 1; you will remain in state S_2. After applying the model, the results shown in the following states were obtained.

Step One: First State

Based on Table 6, the transitional Markov matrix for the functional change in the city will be as shown in Table 7:

Table 6. Functional change data in Al-Najaf for 2005-2015

Land use H.C	Area H.c	Residential	Slums	Commercial	Industrial	Others
Residential	3913	-	277.71	47.69	7.84	1.89
Slums	278	124.96	-	21.33	24.37	6.371
Commercial	645	12.11	19.46	-	15.6	12.9
Industrial	740	130	34	13.4	-	2
Others	193	2.1	4.2	54	3.33	-

Table 7. Functional change matrix in Al-Najaf city for 2005-2015

Land use H.C	Area H.c	Residential	Slums	Commercial	Industrial	Others
Residential	3913	0.93121135	0.44838129	0.07393798	0.010595	0.009793
Slums	278	0.03193458	0.34420863	0.03306977	0.032932	0.03301
Commercial	645	0.00309481	0.07	0.78849612	0.021081	0.066839
Industrial	740	0.03322259	0.12230216	0.02077519	0.930892	0.010363
Others	193	0.00053667	0.01510791	0.08372093	0.0045	0.879995
		1	1	1	1	1

$$\begin{pmatrix} 0.93121135 & 0.44838129 & 0.07393798 & 0.010595 & 0.009793 \\ 0.03193458 & 0.34420863 & 0.03306977 & 0.032932 & 0.03301 \\ 0.00309481 & 0.07 & 0.78849612 & 0.021081 & 0.066839 \\ 0.03322259 & 0.12230216 & 0.02077519 & 0.930892 & 0.010363 \\ 0.00053667 & 0.01510791 & 0.08372093 & 0.0045 & 0.879995 \end{pmatrix}$$

$$\begin{pmatrix} 0.93121135 & 0.44838129 & 0.07393798 & 0.010595 & 0.009793 \\ 0.03193458 & 0.34420863 & 0.03306977 & 0.032932 & 0.03301 \\ 0.00309481 & 0.07 & 0.78849612 & 0.021081 & 0.066839 \\ 0.03322259 & 0.12230216 & 0.02077519 & 0.930892 & 0.010363 \\ 0.00053667 & 0.01510791 & 0.08372093 & 0.0045 & 0.879995 \end{pmatrix} . \begin{pmatrix} 3913 \\ 278 \\ 645 \\ 740 \\ 193 \end{pmatrix} = \begin{pmatrix} 3825.9 \\ 272.7 \\ 568.6 \\ 868.3 \\ 233.5 \end{pmatrix}$$

Step Two: Second State

Table 8. Functional change matrix for round two

Land use H.C	Area H.c	Residential	Slums	Commercial	Industrial	Others
Residential	3825.9	0.92964531	0.45709571	0.08387267	0.009029	0.008094
Slums	272.7	0.0326616	0.33146315	0.03751319	0.028066	0.027285
Commercial	568.6	0.00316527	0.07136047	0.76007738	0.017966	0.055246
Industrial	868.3	0.03397893	0.12467913	0.02356665	0.941103	0.008565
Others	233.5	0.00054889	0.01540154	0.0949701	0.003835	0.900809
		1	1	1	1	1

$$\begin{pmatrix} 0.92964531 & 0.45709571 & 0.08387267 & 0.009029 & 0.008094 \\ 0.0326616 & 0.33146315 & 0.03751319 & 0.028066 & 0.027285 \\ 0.00316527 & 0.07136047 & 0.76007738 & 0.017966 & 0.055246 \\ 0.03397893 & 0.12467913 & 0.02356665 & 0.941103 & 0.008565 \\ 0.00054889 & 0.01540154 & 0.0949701 & 0.003835 & 0.900809 \end{pmatrix} . \begin{pmatrix} 3825.9 \\ 272.7 \\ 568.6 \\ 868.3 \\ 233.5 \end{pmatrix} = \begin{pmatrix} 3738.8 \\ 267.4 \\ 492.2 \\ 996.6 \\ 274.0 \end{pmatrix}$$

Final Step: Absorbing States

Table 9. Functional change matrix: the final found

Land use H.C	Area H.c	Residential	Slums	Commercial	Industrial	Others
Residential	3738.8	0.92800631	0.46615557	0.09689151	0.007867	0.006898
Slums	267.4	0.03342249	0.31821242	0.04333604	0.024453	0.023252
Commercial	492.2	0.00323901	0.07277487	0.72283625	0.015653	0.04708
Industrial	996.6	0.03477051	0.12715034	0.02722471	0.948686	0.007299
Others	274	0.00056168	0.01570681	0.1097115	0.003341	0.915471
		1	1	1	1	1

$$\begin{pmatrix} 0.92800631 & 0.46615557 & 0.09689151 & 0.007867 & 0.006898 \\ 0.03342249 & 0.31821242 & 0.04333604 & 0.024453 & 0.023252 \\ 0.00323901 & 0.07277487 & 0.72283625 & 0.015653 & 0.04708 \\ 0.03477051 & 0.12715034 & 0.02722471 & 0.948686 & 0.007299 \\ 0.00056168 & 0.01570681 & 0.1097115 & 0.003341 & 0.915471 \end{pmatrix} . \begin{pmatrix} 3738.8 \\ 267.4 \\ 492.2 \\ 996.6 \\ 274 \end{pmatrix} = \begin{pmatrix} 3651.7 \\ 262.1 \\ 415.8 \\ 1124.9 \\ 314.5 \end{pmatrix}$$

The predictive analysis was conducted by the Markov model, which predicted that the rate of change in the next ten years would be rapid. It will change and will not continue in the same pattern and direction. According to the Markov chain, the functional changes of industrial land use will increase rapidly and strongly in the future, as will the case for functional changes of other land use functions in the city.

The future functional change of the city will witness a decrease in the number of residential, slum, and commercial uses. Hence, it is possible to rely on the final Transitional Markov Matrix to make future predictions of the movement of the functional change of the city during the future periods, taking into account the developmental factors and their variables in the reformulation of the final matrix for prediction.

This study assessed the probability of change for each land-use class based on land-use changes. Table 9 displays the outcome. The land use pattern for 2025 was estimated based on the findings and the change for industrial functions of land use in the city of Najaf was protected at 1124.9 hectares during the period of prediction, accounting for 19% of the total land-use area, while 740 hectares was estimated at 13% in the base year. The change for other functions was estimated at 314.5 hectares within ten years (5% of the total land-use area), while in the base year, 193 hectares was estimated, which is 3% of the total change.

Analysis with the predictive Markov model of the study case in Al-Najaf city showed that the pace of change in the future for the next 10 years will change and will not continue in the same pattern and direction. The change of functions to industrial ones will increase rapidly and strongly during the coming period, as will the case for other functions. The future functional change of the city will see a decrease in the number of functions of housing, slums, and commercial uses. Hence, it is possible to rely on the final Transitional Markov Matrix to make future predictions of the movement of the functional change of the city during the future periods, taking into account the developmental factors and their variables in the reformulation of the final matrix for prediction.

6. Conclusion

From 2005 to 2015, Al-Najaf city neighborhoods witnessed major functional changes that included residential, commercial, industrial, and slums throughout the city. This is due to the impact of economic, social, and political conditions, especially after the US occupation in 2003, as well as the weakness of local laws and administration. The changes in Al-Najaf from 2005 to 2015 were random and varied without any planning. This affected the existing spatial relations and also created urban problems. Most of the areas that have changed within 10 years are commercial services, industrial, and other functions due to factors related to spatial competition and the economic ability of business owners to pay more money to get access to illegally and unlawfully areas of land for commercial purposes. The increase in slum areas in Al-Najaf during the study period, especially in Al-Rahma and Al-Razwiyah, is due to the closeness of the city's commercial centre and the Al-Najaf–Karbala highway; this caused an increase in slums during 2005–2015. The absence of a housing policy and spatial developmental plans in the city contributed to the increase in the number of slums. The analysis of the data from this study showed that the pace of changes in the future will change and will not continue in the same pattern. The change of functions in industrial and other functions will increase strongly and exponentially in the future. Residential functions, slum functions, and commercial functions will witness a decrease in the future functional change of the city during the ten years following the forecast period. It is possible to rely on the final transitional Markov matrix to make future predictions of the functional change in the future. The absence of land management policies led to an increased number of slum areas during the current period, as predicted by the prediction model.

The results of this study could serve as the foundation for an urban observatory, which is important to the development of future urban policies that deal with the future changes of spatial functions and control the factors affecting change. The results of this study will guide the formulation of housing policies, future urban plans, regional development plans, urban land management policies, and spatial organization. The advantage of the transition matrix is that it allows for future prediction if different data is entered for a different period. The following suggestions are recommended for future research:

- A Markov model of land-use change dynamics in Al-Najaf new cities;
- The influence of urbanization on agriculture in Iraqi cities' sub-urban areas can study by using the Markov model;
- Production of urban sprawl maps using the Markov model within *GIS*.

7. Declarations

7.1. Author Contributions

Conceptualization, N.A.A. and S.M.A.; methodology, N.A.A.; software, O.J.M.; validation, S.M.A., N.A.A. and O.J.M.; formal analysis, N.A.A.; investigation, S.M.A., O.J.M.; resources, O.J.M.; data curation, N.A.A.; writing—original draft preparation, N.A.A.; writing—review and editing, N.A.A.; visualization, S.M.A.; supervision, S.M.A., N.A.A.; project administration, N.A.A., S.M.A. and O.J.M.; funding acquisition, N.A.A. All authors have read and agreed to the published version of the manuscript.

7.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.

7.3. Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

7.4. Conflicts of Interest

The authors declare no conflict of interest.

8. References

[1] Fathizad, H., Rostami, N., & Faramarzi, M. (2015). Detection and prediction of land cover changes using Markov chain model in semi-arid rangeland in western Iran. Environmental Monitoring and Assessment, 187(10). doi:10.1007/s10661-015-4805-y.

[2] Rahnama, M. R. (2021). Forecasting land-use changes in Mashhad Metropolitan area using Cellular Automata and Markov chain model for 2016-2030. Sustainable Cities and Society, 64. doi:10.1016/j.scs.2020.102548.

[3] Kushwaha, K., Singh, M. M., Singh, S. K., & Patel, A. (2021). Urban growth modeling using earth observation datasets, Cellular Automata-Markov Chain model and urban metrics to measure urban footprints. Remote Sensing Applications: Society and Environment, 22, 100479. doi:10.1016/j.rsase.2021.100479.

[4] Al-Najaf Department of Municipality. (2020). Data of secretarial maps, Department of City Planning, Najaf, Iraq.

[5] Al-Najaf Department of Physical Planning (2020). Al-Najaf city master plans, Najaf, Iraq.

[6] Meghdadi, A. H., & Akbarzadeh-T, M.-R. (2001). Probabilistic fuzzy logic and probabilistic fuzzy systems. 10th IEEE International Conference on Fuzzy Systems. (Cat. No.01CH37297), 1127-1130. doi:10.1109/fuzz.2001.1008853

[7] Ghosh, S., Das Chatterjee, N., & Dinda, S. (2021). Urban ecological security assessment and forecasting using integrated DEMATEL-ANP and CA-Markov models: A case study on Kolkata Metropolitan Area, India. Sustainable Cities and Society, 68, 102773. doi:10.1016/j.scs.2021.102773.

[8] Geyer, C. J. (1992). Practical Markov Chain Monte Carlo. Statistical Science 7(4), 473-483. Statistical Science. doi:10.1214/ss/1177011137.

[9] Jafarpour Ghalehteimouri, K., Shamsoddini, A., Mousavi, M. N., Binti Che Ros, F., & Khedmatzadeh, A. (2022). Predicting spatial and decadal of land use and land cover change using integrated cellular automata Markov chain model based scenarios (2019–2049) Zarriné-Rūd River Basin in Iran. Environmental Challenges, 6, 100399. doi:10.1016/j.envc.2021.100399.

[10] Baqa, M. F., Chen, F., Lu, L., Qureshi, S., Tariq, A., Wang, S., Jing, L., Hamza, S., & Li, Q. (2021). Monitoring and modeling the patterns and trends of urban growth using urban sprawl matrix and CA-Markov model: A case study of Karachi, Pakistan. Land, 10(7). doi:10.3390/land10070700.

[11] Aliani, H., Malmir, M., Sourodi, M., & Kafaky, S. B. (2019). Change detection and prediction of urban land use changes by CA–Markov model (case study: Talesh County). Environmental Earth Sciences, 78(17), 1-12. doi:10.1007/s12665-019-8557-9.

[12] Zouiten, M., Chaaouan, J., & Naoui, I. (2021). Predicting Land Use Changes within the Tazekka Park and Its Borders via a Cellular Automata-Markov Modeling of Satellite Images. Journal of Southwest Jiaotong University, 56(2), 534–541. doi:10.35741/issn.0258-2724.56.2.43.

[13] Kesaulija, F. F., Aipassa, M. I., Sumaryono, M., & Suhardiman, A. (2021). Modeling Land Cover Change Using Markov Chain-Cellular Automata in Sorong, West Papua Province. Proceedings of the Joint Symposium on Tropical Studies (JSTS-19), Advances in Biological Sciences research. doi:10.2991/absr.k.210408.026.

[14] Abbood, A. N., Ahmed, A. R. I., & Ajam, H. K. K. (2021). Evaluation of Parking Demand and Future Requirement in the Urban Area. Civil Engineering Journal, 7(11), 1898–1908. doi:10.28991/cej-2021-03091767

[15] Farhan, S. L., Antón, D., Akef, V. S., Zubaidi, S. L., & Hashim, K. S. (2021). Factors influencing the transformation of Iraqi holy cities: the case of Al-Najaf. Scientific Review Engineering and Environmental Studies (SREES), 30(2), 365–375. doi:10.22630/pniks.2021.30.2.31.

[16] AL-Jawari, S. M. (2020). Regional Development Prospects for Sustainable Urbanization. Case Study – Qalaat Salih in Iraq. Journal of Settlements and Spatial Planning, 11(2), 57–66. doi:10.24193/jssp.2020.2.01.

[17] Al-Jawari, S. M., Al-Mosawy, S. K., Al-Jabari, A. A., & Al-Baghdadi, A. N. (2020). Strategic Analysis of New Cities (Case Study Basmaya City - Republic of Iraq) an Analytical Study of Strength, Weakness, Opportunity, and Threat. IOP Conference Series: Earth and Environmental Science, 459(6), 62108. doi:10.1088/1755-1315/459/6/062108.