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Original article

Analysing formal transformations in sustainable urban structures in Kufa City, Iraq

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ABSTRACT

The research discusses the formal transformation in urban structure, all the cities around the world have undergone a series of formal transformations, resulting in radical transformations to their functions. And to calculate this transformation the descriptive analytical method was applied to this research. First, local urban management data and Landsat-9 visual data were used after processing by GIS. Then, the data were processed mathematically based on their engineering sequences. The aims of this research were as follows: to explore the formal transformations in cities, their dimensions and their consequences and impacts; to identify the underlying causes of their occurrence by deriving realistic results from trends in such degrees of transformation; and to reduce the adverse effects and to establish a sustainable urban structure by taking Kufa City as a model. The research covered the following two time periods: 2002-2012 and 2012-2022, as they represent the time during which Kufa City experienced remarkable formal transformation in urban structure as a result of urbanisation and random growth. Different forms of land use were identified, and formal transformations were analysed. The results showed that the largest transformation occurred when the agricultural land transformed into construction land; which was used in different ways than the original intent. The land uses were visualised digitally at high resolution. The transformation in land use led to formal transformations in the city structure, both planned and randomly implemented. The other objective of this research is to address misuse of the city's infrastructure; however, sustainability was not considered for several reasons. The agricultural land represents the nutritional value of the city as it provides Kufa and nearby cities with agricultural products. It also represents the green barrier as the environmental conduit for the city. This research recommends managing population growth by using basic city schemes of planning and predicting formal transformations. This approach is the basis for transforming city structures by identifying future structural features in sustainable ways.

KEY WORDS: transformations, land use, urban structure, sustainability, ArcMap, Kufa City

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1. Introduction

All cities around the world have undergone a series of transformations and changes in their evolution, resulting in radical transformations to their functions. These transformations are influenced by internal and external forces, and they have likely occurred for different reasons, including the 19th and 20th century changes involving demographic growth in cities. However, the lack of opportunities to preserve cities and their schemes has resulted to formal transformations in urban structure. These transformations must be fully assessed to understand how they can be addressed. On this basis, underlying causes can be determined and interpreted, further allowing the intellectual orientations of city occupants to be recognised.

This research utilised the spatial analytic tools of ArcMap10.6 to provide an accurate and quantitative inventory of the transformations of the city of Kufa through developments, including unprecedented transformations involving the transformation of an original use of a city structure to another use. The aims of this research were to explore the formal transformations in cities, their dimensions and their consequences and impacts; to identify

the underlying causes of their occurrence by deriving realistic results from trends in such degrees of transformation; and to reduce the adverse effects and to establish a sustainable structure, and this research is explain the formal transformations in a city via mathematical analysis, focusing on the histories of formal transformations in the city since the development of schemes. Furthermore, the principles of sustainability were considered in the baseline schemes of the city, effectively avoiding counting transformations according to unsustainable urban structures, and it was also determined to find appropriate solutions and to avoid their occurrence in the future. Furthermore, the research objectives were investigated by clarifying the level to which formal transformations in city structure, types, impacts and outcomes could be achieved and the underlying causes could be revealed, with a view to enhancing and reducing the positive and negative aspects, respectively. Techniques in scientific research were employed by using software tools, methods and mathematical models.

Formal transformations in urban structure were identified by referring to the theory of formal transformation of THOMPSON (1917). The identified forms were interpreted by adopting mathematical foundations, and then they were compared with convergent forms in terms of progression and transformation. The two types of formal transformation, either amplifying or decreasing, are systemic and irregular transformations (SIDDIQ ET AL., 2019). ANTONIADES (1990, p. 55) defines formal transformations as the process of changing shape to reach the final stage by responding to multiple external and internal dynamics. (Formal transformations include the process of handling certain formats without returning to functional requirements; ABBAS & TARIQ, 2005).

Many studies have addressed aspects of the formal transformations, and they have been reviewed here as well. For instance, POLADIAN & AWADIS (1985) adopted the basic plans of Baghdad in its methodology. ZHANG ET AL. (2002) studied land use transformations and their impacts and forecasting trends for future land use transformations and consequently obtained statistical data by linking metadata to spatial data for layer analysis in their programme-based annual projections. SYMEONAKIS ET AL. (2004) studied land use change and land degradation in Greece and Spain by using remote sensing and GIS technology and identified the relationship between land use/land cover (LULC) changes and land degradation of the two Mediterranean sites by using remote sensing data. Their study areas, namely, the northern province of Alicante in south-eastern Spain and the island of Lesbos in the Aegean Sea, Greece, were exposed to changes in LULC, such as abandonment, overgrazing, wildfires and tourism development. Data dating back to the 1970s were used to map the historical land use/cover types, whilst more recent data were used to analyse the latest case. Their results showed that the increased runoff and erosion in those areas were mostly caused by forest fires, urbanisation and/or overgrazing, and measures to mitigate degradation were suggested. Nonetheless, transformations could also be poorly quantified (SYMEONAKIS ET AL., 2004). For instance, ZUREIKAT & ALHUSBAN (2012) studied the transformation in land cover patterns located north of Jordan by using data from 2009, black and white space images from 1978 and colour images from 2009 AD. Three main types of land cover were identified, and the reasons for the changes in each type were determined. However, the ArcMap programme's features and spatial analytical tools were not utilised, and its role was limited to drawing and producing maps.

2. Transformations in urban structures

Urban structures are characterised by continuous transformations over time because of various factors. The following aspects illustrate the dynamic features of urban structures, which might have occurred through a series of transformations (AL-KINANI & MUHAMMAD, 2021):

1) The first aspect is self-transformation, which occurs within the urban architecture system and is governed by the laws of the structure itself.

2) The second aspect is forced transformation, which changes the form of the urban structure by introducing new elements or changing structural relationships for social, economic, or political purposes.

3) The most important propositions for addressing formal transformations in cities can be summarised as follows:

a) UNGERS Theses, 1982: This proposition demonstrates the importance of moving away from functional aspects, not only by using the required technology but also by following prevailing traditions, and attempting to balance different considerations.

This argument highlights the dependence of transformation on structuralism, outlining the distinct relationship between transformation and structure. It also emphasises the notion that structures cannot be conceived without transformations and that all transformations result in new forms of architecture. The propositions also highlight the notion that

patterns of transformation belong to history, as they do not imply the embodiment of a particular thought; rather, they provide an opportunity to utilise the history of planning and architecture when identifying patterns, adopting them in transformation processes as primary sources and references (UNGERS, 1982)

b) LUCHINGER Propositions, 1996: These propositions describe transformations as a solution in which the past can be used to build on these transformations, and transforming them into elements that can fit the needs of the present. LUCHINGER based on Strauss explanation asserted the effectiveness of using the reference system at this stage and returned to the beginning to discover the un-characteristic dimensions, allowing the composition and organisation of everything to be explained. The propositions also emphasised that the production of anything new must be reassessed with respect to what already existed and that the process leading to transformations can reveal attempts to penetrate past systems. Transformations were regarded as a form aimed at adapting to emerging variables based on past data, mainly taking the form of transformation whilst maintaining historical communication, i.e., linking the past, present and future. In this manner, new forms with time–depth meanings and connotations can also be generated, with the transformations taking the form of a process by which old meanings are resurrected to add new meanings. Thereafter, the chronological chain can be maintained whilst connecting with history (LUCHINGER, 1996).

c) CHING Theses, 1996: The concept of formal transformation and how to generate and form shapes based on different shapes, resulting from transformations that had occurred directly or indirectly on the underlying forms, were explored in this study. Transformations at the dimensional level can be classified into two types: dimensional transformations and formal transformations (CHING, 1996), as shown in Fig. 1.

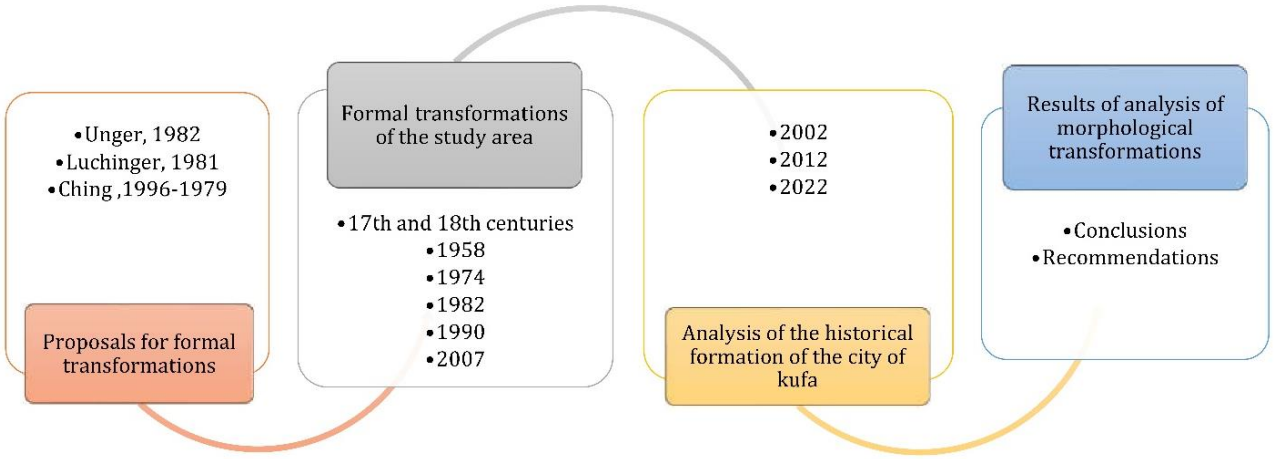


Fig. 1. Flowchart of the research methodology (Source: own study)

3. Reasons for formal transformations in urban structures

Population growth is one of the major factors of urban transformation and expansion in a city, generating increased demand for land for construction. The uses and ratios of urban land must be studied over several periods of time to understand the area and direction of transformation as a function or factor of urban growth. Population growth varies from city to city and neighbourhood to neighbourhood depending on their importance, and the city itself generates varying levels of urban density and land use ratios. A balance must exist between population growth and the area people occupy to provide adequate space for them within the urban structure (HAMIM ET AL., 2020).

As a result of population growth, landscapes and urban structures morph formally over time. For example, residents convert wild areas into farmlands or urban areas. According to the 2021 United Nations report cited by FFAC STAFF (2022), human activity has progressively led to 'extreme transformations' on the equivalent of three quarters of the Earth's surface. Consequently, basic schemes can no longer absorb the large population growth. One of the most important reasons for the failure of most basic plans in Iraq is the inflexibility and limitation to allow the updating of original maps without realistic application on the ground. Other factors include the adoption of engineering standards in determining expansion trends without considering geographical aspects, coupled with poor competence and planning and the relevant scientific expertise

of local staff and limited material support (HASSON, 2017).

3.1. How do formal transformations occur in urban structures?

Spatial transformations, which lead to formal transformations, in certain areas of the city during a given period can be regarded as a natural state of response to population growth, urbanisation, complexity of spatial, economic and social relationships, and city development. Urban land use of all types is a component of urban architecture. Cities generally change over time due to economic and social impacts. Urban structures are dynamic and will change following the use of a given area over a given period, resulting in different spatial patterns. Therefore, urban planners and related urban management teams must understand the spatial patterns and observe transformations as they occur (ALBASRI ET AL., 2022).

Population growth, which accelerates urban growth, causes geographical mobility, in which individual interest supersedes community interest. This phenomenon contrasts with the principles of sustainability. As the number of displaced persons increases, more land in nearby areas of the city is needed. As urbanisation further increases, it will eventually ruin the structure of the city (HAMDAN, 2021). Given the poorly considered result of continuous transformations that could have kept pace with accelerated growth by responding to a multitude of external and internal dynamics, the process of processing the form subsequently occurs without returning to the functional requirements. Governments tend to periodically reclassify peri-urban and rural areas into urban areas because of the change in certain areas that begin to take on urban characteristics (TUAN, 2022).

3.2. What is the impact of formal transformations on the sustainability of the urban structure?

Formal transformations affect the structure and centres of cities in terms of the ability to adapt to these transformations without losing their original structure and identity. Many cities continue to experience urban growth. Urban morphology has dramatically undergone transformation, whilst urban schemes are integrating modern and traditional forms. These transformations in the shape of the city can cause distortions (random transformations), which means that some of these transformations may positively affect the urban structure of cities, whereas others may have a negative impact on the city's sustainability. Overcrowding, pollution, and the loss of landscape aesthetics are some of the negative effects urban transformations can have on cities. These phenomena have been the case in many Middle Eastern cities—new transformations are sometimes incompatible with the current structure, leaving behind neglected spaces that have lost their social identity and appear to be dead spots. Given the importance of formal transformations, scientists around the world have studied them in urban forms over time using a system to quantify the effects of such urban transformations (BASEE & ABDULLA, 2022).

Poorly considered transformations significantly damage urban infrastructure and lead to land waste and pollution of the surrounding environment, further resulting in a lack of consideration for public health and safety and spatial suitability factors. This scenario indicates the non-application of sustainability principles and the non-adherence to laws that would have controlled and improved the distribution of land use, allowing the health and safety of the population to be preserved as population density increases beyond permissible limits, depicting the negative social, security and economic impacts thereof (JABER, 2015).

4. Methodology

4.1. Study area, location and history

Kufa is located near the city of Al-Hirah, on the River Euphrates in the middle of Iraq. It is the second Islamic city built after Basra and founded around 638 AD (ISSA, 2008). Geographically, Kufa is located north of the equator and east of the Greenwich meridian, between latitude 32° 00′–32° 5′ north and longitude 44° 21′–44° 26′ east (KHALIF, 2017).

Kufa is one of the ancient Islamic cities and was known before Islam as Suristan. The city functioned as the crossroads of travellers (JABER, 2015), and its trade and transport flourished and became famous after the spread of Islam, especially after Imam Ali (the most prominent successor to the Muslim prophet and cousin) declared it a government centre and the capital of the Islamic State. This event is of great importance, as it marks a turning point in the history of Kufa City (AMIN, 2001) (Fig. 2).

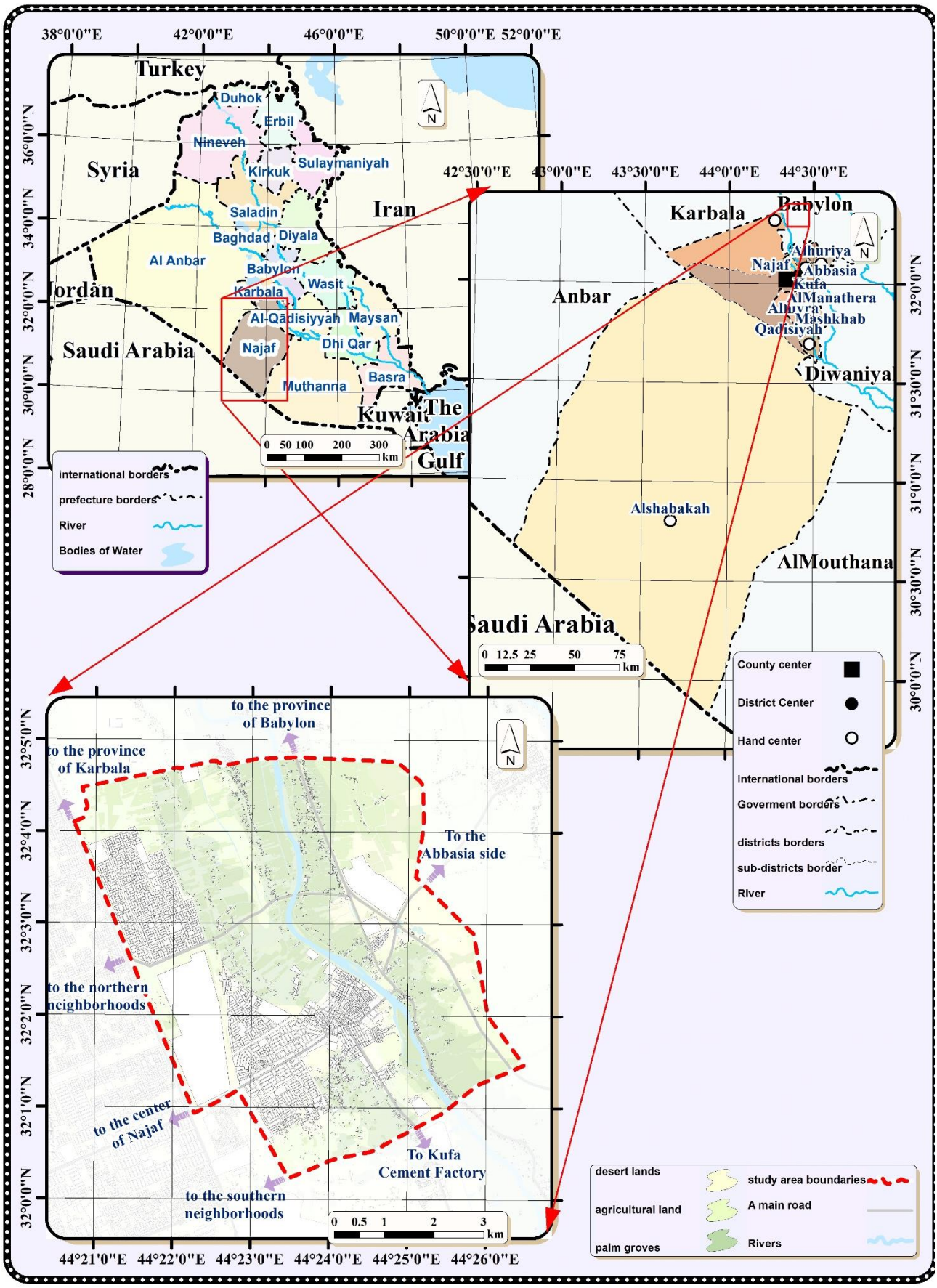


Fig. 2. Study area (Source: own study based on ArcMap software)

Kufa underwent gradual transformations over the years, beginning in the mid-19th century. The urban structure of Kufa is limited by residential and commercial use. The commercial area was located in the middle of the city and included basic industries such as grain milling, blacksmithing and repair workshops. In 1958, the state adopted policies for the distribution of housing plots to employees and state members. As a result of the escalating migration from the countryside to the city, which was primarily sought by people to improve their living conditions and the availability of services in the country, this expansion became indiscriminate despite the organizational plans of the official authorities. Table 1 shows the increase in the population of the city of Kufa in several years. However, the process of excessive and indiscriminate expansion continued until the first base plan was introduced (CITY ORGANISATION DEPARTMENT, 2013); Figure 3 illustrates the area of the basic plan for the city of Kufa during its various stages. The first plan adopted the central district in the middle of the Old City as a commercial area and identified the cultural, archaeological, and religious areas of the city and the industrial zone. Housing was intended to meet the needs of the population, and its location was assigned in the southern and south-eastern parts of the city. The roads linking Kufa to the city of Najaf and its outer sections were also designed. Figure 4 illustrates the formal transformations experienced by the city through its historical stages until the adoption of the basic plan in 2007.

Table 1. The increase in the population of the city of Kufa in several years (Source: own study based on Najaf Census Directorate, Statistical Collection for years 1997, 2002, 2007, 2012,2022, and unpublished data for year 2022

Year	Population / person
1997	97626
2003	110000
2007	183507
2012	202493
2022	268212

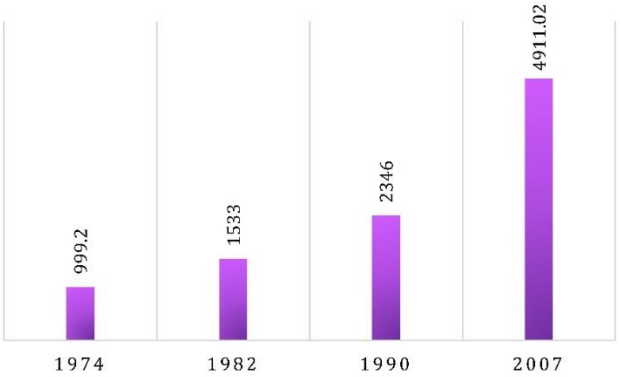


Fig. 3. Area of the basic plan for the city of Kufa during its various stages (Source: own study based on data from the Urban Planning Directorate/Foundation Scheme 1974-1982-1990-2007, and City Organization Department, 2013)

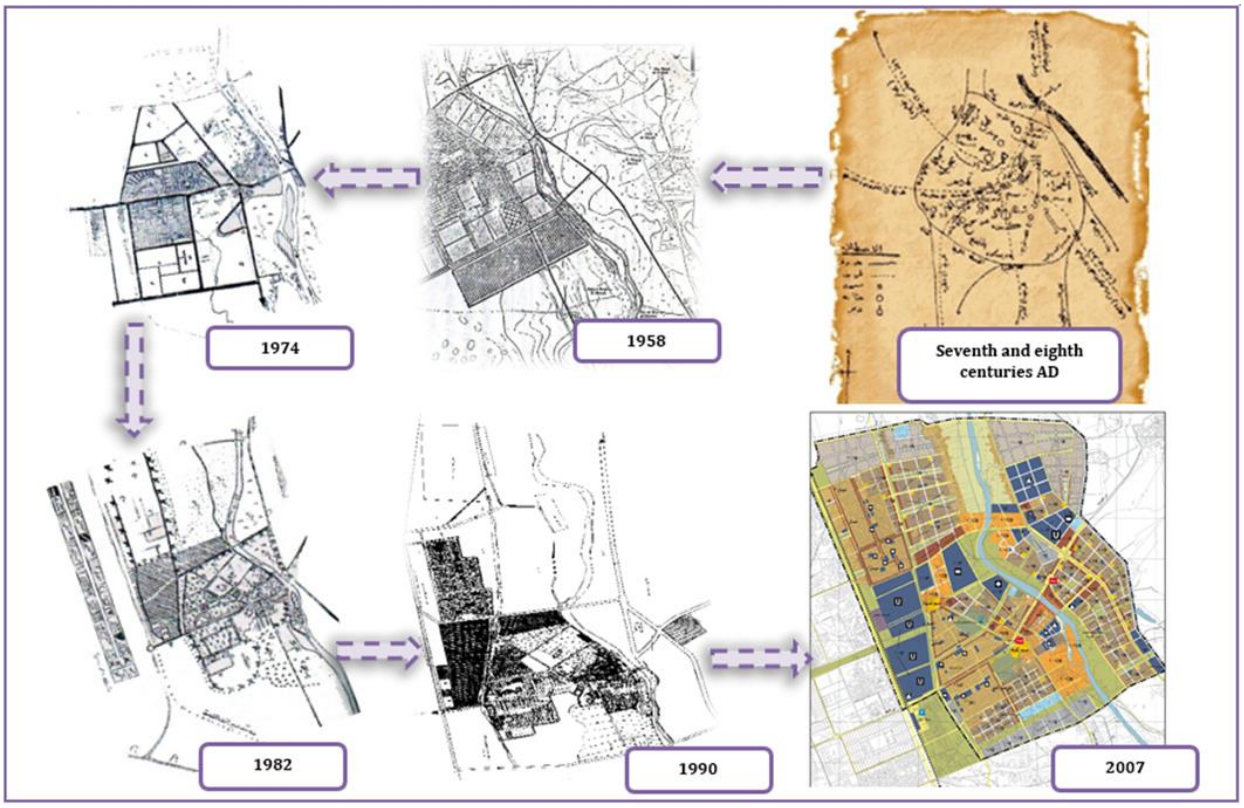


Fig. 4. The formal transformations of the basic plan of the city of Kufa (Source: own study based on Masjed-Alkufa, 2022, and the Directorate of Urban Planning in Najaf Al-Ashraf)

4.2. Formal transformations of Kufa City

Similar to other cities around the world, Kufa underwent many formal transformations. This research focused on the last decades of the city's history for the purpose of analysing and identifying the most important formal transformations and the causes and effects that occurred at that time. The city underwent many political, social and economic transformations between 2002 and 2022. The most necessarily transformations were occurred in the area of construction, which mostly included residential use. Our findings showed that the transformations area increased significantly, and the main expansion was due to the encroachment of agricultural land into residential land in the southern and northern regions of the city. The townspeople were forced to find solutions for themselves by encroachment farmland as a result of the increase in population, further causing natural growth and migration due to the religious and historic status of the city. This phenomenon of agricultural land transform into residential land highlights the importance of economic solutions in the absence of state control or authority and the lack of strictness and firmness in the application of laws. Subsequently, agricultural ownership was transformed to informal housing, given that these lands were less expensive compared with the land known as 'owned land'. This phenomenon had placed pressure on the services provided for the city, although alternative solutions were found, including creating dirt streets as a simple solution for transport. In the region, land was taken over by electricity grids and diesel generators to provide electricity as an alternative to electrical power that provide by the government; in the case of drinking water services, water systems from nearby areas were utilized; Figure 5 shows the reality of Kufa city and a result of the increase in population, where people have been forced to find self-solutions to their problems (JABER, 2015).



Fig. 5. The reality of Kufa city and a result of the increase in population, where people have been forced to find self-solutions to their problems: A – The power lines exceeding the informal dwellings on the regular network of the city during one of the campaigns to lift the excesses (Source: own study based on Al-Faham, 2019; B – A picture of piles of waste and rubble in a street on the outskirts of Kufa city (Source: own study based on Jaber, 2015)

4.3. Practical steps of the research

The ArcMap 10.6 toolbox was used to analyse transformations in the urban structure of Kufa City, specifically the math tool (Minus). This analysis was performed following the establishment of a database in the software and the delineation of the scheme within the total area of the current scheme for 2002, 2012 and 2022. The LULC of the study area can be described as follows:

1) Transportation
2) Different structures, built areas (construction), including commercial and industrial uses and other uses that cannot be observed from the satellite image + municipal sectors
3) Green spaces, such as parks
4) Agricultural land (farmland)
5) Open spaces, or unoccupied land
6) Water bodies

Notably, within the boundaries of the updated baseline, all spaces were drawn without any overlap, with topology order was utilised. Furthermore, the road and street network were represented to achieve the highest possible spatial accuracy by using the erase order in the ArcMap programme.

4.4. Analysing formal transformations by using GIS techniques

The formal transformations of cities, in terms of land use over the years, led to changes in the city structure and shaped the transformations. In this research, GIS techniques, specifically ArcMap applications, were used as follows:

1) For the creation of a layer representing the Earth's surface utilisation over the years (2002, 2012 and 2022) with all kinds of Earth uses, all identified uses were compiled, given appropriate coding, and jointly reviewed. Spatial analytical tools were used to convert the layer into an image for each year after selecting the highest attainable accuracy (Fig. 6A).

2) In terms of the use of spatial analytical tools, each image was reclassified into a geometric numerical sequence. Each type of use was given a value to represent the newly reclassified image. The image processing for 2002 was repeated for 2012 and 2022. The corresponding values of each use are shown in Table 2 and Figure 6B.

Table 2. The corresponding numerical values for each type of use (Source: own study)

Type of use	Numerical value
Transportation	160
Various constructions	80
Agricultural land	40
Green and recreational areas	20
Open spaces	10
Water bodies	5

3) Commercial, industrial, and other unnoticed uses of satellite images were introduced into the construction because commercial use in the city was located in the city centre and along the main streets, such as the city's central street (Najaf-Kufa Street), Bridge Street, Sikka Street and Republic Street, which have increased and expanded in range over time. These transformations are difficult to define at the industry level, especially since the industrial district of the province falls outside the boundaries of the city's base plan. As most factories are also outside their borders with old individual industries, including some crafts, workshops, and others scattered on the edges of the commercial area, they had not been exposed to dramatic transformation; rather, these parts were incorporated into construction (i.e., the research is concerned with land use, as shown in Table 3, that represents the areas of land use in the city of Kufa and the corresponding proportions thereof within the whole city boundaries of Kufa (baseline boundaries). These parts could be observed using the satellite image. The boundaries of the updated base chart were adopted during the drawing to be matched to the satellite image for the years of research, working within the city boundaries of Kufa (not the plan limits adopted in 2002) and according to the reality of the research periods.

4) After converting the maps for the third year into the raster format, the last step was to analyse the formal transformations by using mathematical spatial analytical tools. Then, the resultant uses were mapped using two images. ArcMap 10.6 was utilised to separately extract the variable uses for each instance and depict what this was used for and what it became. These calculations were statistically verified by numerical values using minus order that explained in 4.3. The resultant numerical value could reflect the transformations in a single use and its conversion to another. With the adoption of this descriptive approach and the analytical approach, the results shown in the Table 4 can be depicted. Figure 6 illustrates the relationship between one use and another use. For example, the numerical value of −155 represents the difference between the numerical values, depicting the transformation in the uses of the Earth, particularly the transportation structures of the area in question to water bodies regardless of the mode of transformation and the occurrence of other transformations. Areas corresponding to each use were the same during the research period. Here, output (0) represents the use of the land itself, which also was the same, that did not transform at all years, as shown in Figure 6 and further described in paragraph 16 of Table 4.

Table 3. The areas of land use in the city of Kufa and the corresponding proportions thereof (Source: own study based on Satellite images and using ArcMap10.6

Type of use	Area in 2002 [m²]	Percentage [%]	Area in 2012 [m²]	Percentage [%]	Area in 2022 [m²]	Percentage [%]
Bodies of water	1,471,920	3.00	1,505,245	3.06	1,327,553	2.70
Open spaces	7,759,803	15.80	5,850,922	11.91	8,103,765	16.50
Green areas	70,551	0.14	309,743	0.63	466,313	0.95
Agricultural land	27,129,593	55.24	21,380,468	43.53	13,825,271	28.15
Various constructions	8,173,626	16.64	13,660,675	27.82	17,233,786	35.09
Transport	4,505,636	9.17	6,404,081	13.04	8,154,445	16.60
Total	49,111,129	100	49,111,134	100	49,111,133	100

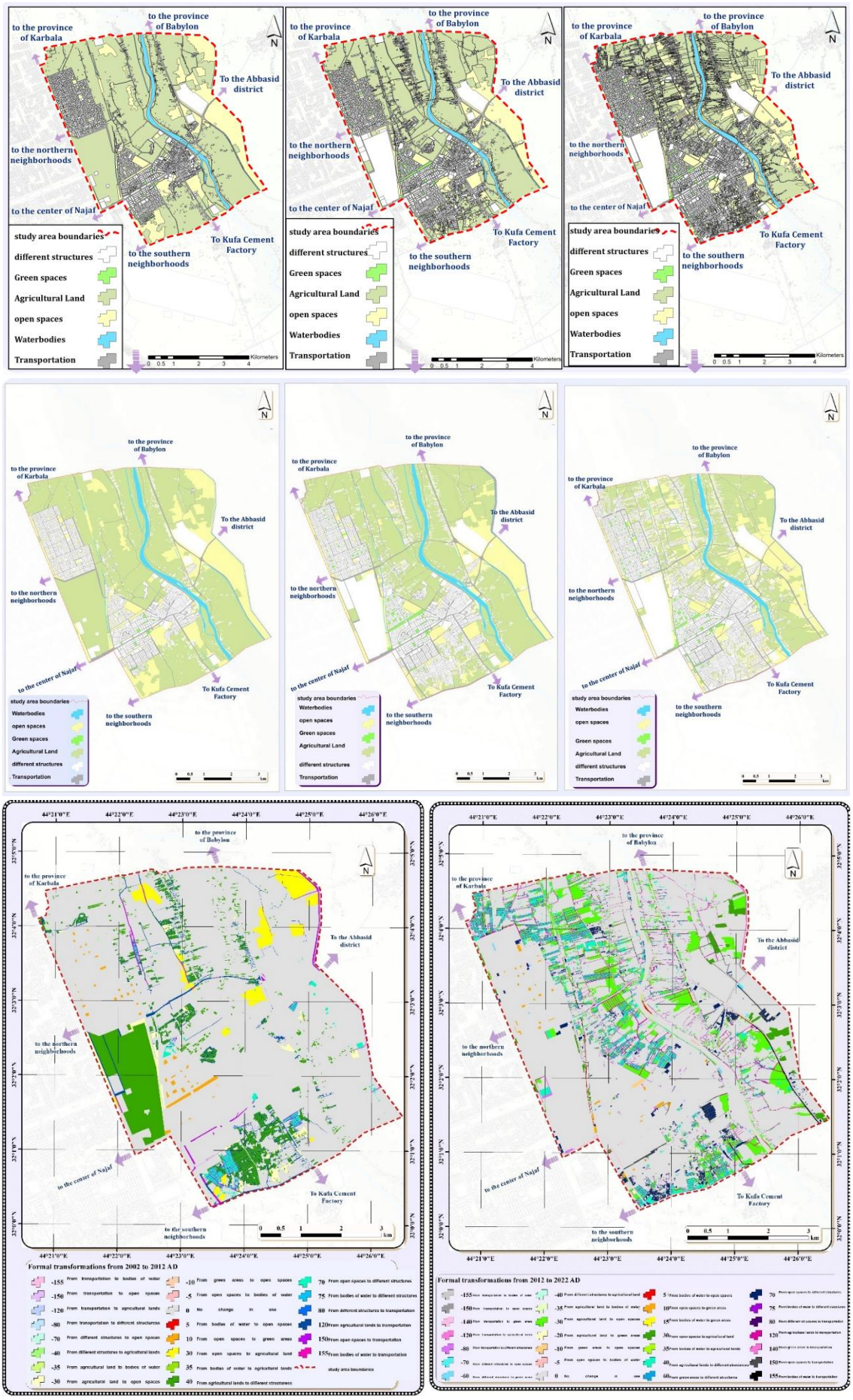


Fig. 6. The maps of the stages (A, B, C) of formal transformations and their results in the city of Kufa during the research period (Source: own study based on Satellite images and using ArcMap10.6)

Table 4. The areas of land use in the city of Kufa and the corresponding proportions thereof (Source: own study based on Satellite images and using ArcMap10.61)

Result	The meaning of transformations	Area transformations between 2002-2012 [m^2]	Area transformations between 2012-2022 [m^2]
-155	From transport to bodies of water	325	4288
-150	From transport to open spaces	15493	374338
-140	From Transportation to Green Areas	---	38310
-120	From transfer to agricultural land	14176	208742
-80	From Transportation to Constructions	26128	228859
-75	From constructs to bodies of water	---	---
-70	From constructs to open spaces	3238	27490
-60	From constructs to green areas		22891
-40	From constructions to agricultural lands	17012	6192
-35	From agricultural land to bodies of water	22612	249
-30	From agricultural land to open spaces	913634	3638708
-20	From agricultural land to green areas	---	9261
-15	From green areas to water bodies	---	---
-10	From green areas to open spaces	4281	33797
-5	From open spaces to bodies of water	13358	9270
0	No transformations in usage	38944780	37697614
5	From bodies of water to open spaces	601	64717
10	From open spaces to green areas	243473	127310
15	From water bodies to green areas	---	1460
20	From green areas to agricultural land	---	---
30	From open spaces to farmland	1454207	543385
35	From bodies of water to agricultural land	638	24094
40	From agricultural land to constructs	4960800	2751685
60	From green areas to constructs	---	6706
70	From open spaces to constructs	521611	679521
75	From bodies of water to constructs	200	7337
80	From constructs to transportation	1440	44426
120	From agricultural land to transfer	1338112	1937708
140	From green areas to transportation	---	2159
150	From open spaces to transportation	613479	526720
155	From bodies of water to transport	1531	93891
		49,111,129	49,111,128

5) Transformations in urban architecture occurred in two directions. The first aspect involved the transformation of farmland into green areas. Here, the value (of –20) represents a natural transformation as a result of time progression; it does not constitute an imbalance in the structure of the city (i.e., approximately 9 km^2), which likely occurred only during the second period of the research. However, the transformation of agricultural land into constructions got a value 40, this approach was the most important type of transformation and change in the city; it is also the widest, occupying large areas (3000 –5000 km^2) and leading to clear formal transformations in the city structure. This finding may be explained by the dynamic urban structure and social, economic, and political reasons that led to certain interruptions, as mentioned above, representing the total transformation without going back to the origin. In other words, each transformation could be explained, by taking into account the planning aspects, from subjective transformation and vice versa. A good example is the transformation in use (agricultural land, open spaces, water bodies and some construction). These transformed spaces represent the ground and the construction of the road leading to the Imam Ali Bridge (Peace be upon him), connecting the new street of Kufa with the Maysan neighbourhood to the city of Najaf and constructing other roads that served residential neighbourhoods. This study also determined which part of the changing agricultural land use could be used as constructions to highlight

the formation of the green and recreational spaces of the University campus, which served the inhabitants and their environmental role. More importantly, the area possessed the necessary legitimacy, was in the interest of the community and promoted aspects of sustainability.

4.5. Reality of the land uses of Kufa City for the years of the research

By using the software, the relevant maps were produced. The distribution of land uses by area and ratio is shown in Table 3. The ratios indicate the varying sizes of water bodies over the years of research, which can be attributed to the transforming dry and rainy seasons and the development of certain water sources and irrigation channels. The ratios started to decline at the time when the River Euphrates receded due to drought and certain irrigation canals north of Kufa. The open space areas varied, decreasing during the first period of research, as large areas of these uses were exploited for housing and other uses. The ratio increased again as a result of the neglect of large parts of agricultural land due to drought and the lack of interest in the agricultural sector, causing workers in this sector to neglect it and seek other jobs.

The increasing green zone sector corresponds to areas within residential neighbourhoods with afforestation (empty squares) and areas in the middle part of residential shops or public squares that were neglected for years. For the agricultural land, the significant decrease can be attributed to the neglect of agricultural land, resulting from the large use for housing purposes as previously explained, in the outskirts of northern and southern Kufa. Maps and quantitative results also showed the increase in construction areas for the same reasons, exceeding the residential function; they can also be explained by the rise in other jobs in agricultural land in the city outskirts. For instance, the construction of the colleges of the University of Kufa (on agricultural land with few buildings under construction) was completely transformed into an educational function (i.e., within the construction sector). The use of transport has also increased, either paving roads for new neighbourhoods or residential areas or untagged (dirt) roads distributed amongst the dwellings and the construction of the Imam Ali Bridge (peace be upon him) and the roads from it to the neighbourhoods of Kufa and Maysan, leading to the neighbourhoods of Najaf. The results of the formal transformations during the research and the trends of those transformations are shown in Table 4 and Figure 6C.

5. Conclusions and recommendations

1) Major formal transformations have taken place in Kufa as a function of time. They can be attributed to human intervention, likely resulting from the inability of the basic planning schemes to keep pace with the rapid urban growth of the city. The study of formal transformations highlights the importance of city structures, which have been depletioned by poorly considered transformations, being depleted without regard for the sustainability of the city. A particular focus is the richness of agricultural land, economically forming the city's food basket, in addition to being an environmental outlet for the city through its green wall.

2) The trends in Tables 3 and 4 indicate the presence of formal transformations in the city over time. Digitally detailing the trends of these transformations was the aim of this research.

3) The formal transformations (Table 4), which were given a certain number to symbolise the type of transformation, occurred because of the transformation of each class from the six to the other five uses[1]. Moreover, one form of transformation might have not occurred during the period of research or in other periods, such as during the transformations (−75, 15, 140, 60, 20, 15 and 60)[2].

5) A reason for the aforementioned changes is the lack of municipal control over urban construction, which led to the emergence Slums. In addition, traditional mean town planners have failed to achieve their objectives due to limited funding and the inability of local administrations to develop and implement plans that consider the specificity of economic and social structures. The state still cannot provide adequate housing for a wide range of populations. These formal transformations, which are a result of the continuous random transformations in land use, have confused the pattern between land use planning, transport planning, and environmental planning.

6) The land uses can be analysed by adopting the ArcMap10.6 programme and using relevant satellite images. Notably, the details of each use cannot be inferred from satellite images only because they show the limits of use; furthermore,

[1]Transportation, construction, green spaces, agricultural land, open spaces and waterbodies

[2]They are uses that did not occur during research periods, and these values symbolize the opposite uses of the same values listed in the Table 4, e.g., -75 is the opposite of 75, i.e., the transformation of construction into waterbodies, etc.

they do not provide information on the type of use. This situation can explain the use of ratios, regardless of whether they conform to, or contravene, the standards adopted at the time. However, the stability of the security situation at the time and the living conditions in the country should be considered. Although the agricultural sector was expanding at the expense of housing and other uses, they were identical to the plan adopted at the time (2002 Before the regime change in Iraq) and did not present any excesses.

6. Research recommendations

1) The ability to absorb population growth in basic city schemes represents the basis for changing city structures. Planning principles (e.g., providing housing, services, etc.) must be applied when developing the master plan to prevent overtaxing the city's infrastructure, and changes in how they are being utilised should be considered.

2) Further research may focus on predicting future transformations in the next decade to determine where they occur and how to manage them whilst developing the features of the future infrastructure in more sustainable ways.

3) Collaboration between citizens and planning departments can be encouraged by holding public information sessions and events aimed at clarifying the importance of city planning. Citizens can be educated and subsequently involved in the preparation of master plans, emphasising that any change in land utilisation must be deliberate and not randomly implemented without impacting future generations. Understanding the viewpoints of citizens is critical, as the main objective of these planning efforts is to achieve well-being, comfort and safety for all citizens by creating sustainable urban structures that are suitable for living within cities.

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