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The Role of Urban Structure in Enhancing the Sustainability of Cities: A Comparative Study

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Abstract

The topic of sustainable urban structure is a crucial area in urban planning, given its direct connection to land use patterns, their distribution and density, as well as their relationship with transportation network patterns. These factors play a vital role in achieving sustainability. The theoretical aspect of the research focused on modern literature and global experiences addressing sustainable urban structures, aiming to provide a clear definition and to identify critical indicators that influence the achievement of urban sustainability. The study identified seven key indicators: density, average distance to the center, hierarchical structure, spread index, land price, the location of the center relative to the city, and the street network pattern. These indicators are applicable and measurable for any city worldwide to assess the sustainability of its urban structure. The research conducted a comparative case study between the cities of Kut and Hillah. The urban structure of Kut is characterized by separation due to the presence of a river, whereas Hillah features a more connected structure, in addition to differences in density distribution, land use, and transportation network patterns. The indicators for both cities were measured using mathematical models, geographic information systems (GIS), and three-dimensional spatial representations. The study concluded that while the indicator results varied between the two cities, Kut achieved better outcomes than Hillah in four of the seven indicators.

Keywords: Urban Spatial Structure; Al-Kut City; Al-Hillah City; Spread Index; Land Price.

1. Introduction

Understanding the complexity of urban spatial structure is crucial as it encompasses the intricate relationships between various urban activities (housing, trade, industry, services) and the factors that influence their emergence (land market, building regulations, community behavior). This overlapping nature makes analysis challenging. Shan et al. (2025) sought to identify the urban factors affecting urban expansion and relied on an analysis of three American cities (Washington, Chicago, and New York) with an urban structure characterized by urban expansion characteristics. The study conducted a comprehensive analysis of the urban structure and the social and economic factors affecting these

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cities. The study identified the factors affecting the spatial structure and their reflection in achieving different patterns of cities represented in income distribution and workplaces. In addition to built environment factors such as road networks and land uses. The study concluded that improving urban formation limits urban expansion and thus enhances urban sustainability [1].

Du et al. (2024) used data from Chinese cities to study the level of urban sustainability. Using three methods to measure urban structure: center density, Gini coefficient, and spatial measurement model, to explore the spatial effects and factors influencing the sustainable development of cities and urban agglomerations. The study found that urban structure varies as a result of the different temporal and spatial changes of agglomerations within urban areas, which affects the shape of the city. The study demonstrated the role of educational and advisory awareness in reducing resource consumption and promoting sustainable urban development. It also demonstrated the impact of built-up urban structure factors on the shape of urban agglomerations. The study attempted to provide recommendations for policymakers and stakeholders to promote balanced and effective sustainable urban development [2].

Jadi & Al-Jawari (2023) addressed the formal transformation of the urban structure of Kufa city. The study aimed to identify the causes and repercussions of formal changes in cities and to identify their dimensions and effects to understand how to achieve a sustainable urban structure. The study concluded that urbanization and random growth have a significant impact on the formation of cities and directing their development due to the consumption of agricultural lands and the transformation of urban uses and their reflection in functions and ease of access to them. The study showed that these transformations have a significant impact on cities in terms of infrastructure supplies and food security because the lands that have been transformed into different uses for functions and human activities are agricultural lands that supply cities with food products; they also represent the green lung of the city and its only outlet. The study recommended setting expectations to determine population growth and land consumption to direct the city toward sustainable urbanization [3].

Wang et al. (2025) discussed the role of urban industrial infrastructure and its impact on the establishment of smart cities by enhancing green productivity and technology. Environmentally friendly industrial infrastructure is a link in the production of sustainable smart cities. The study identified a set of factors that directly affect the achievement of sustainability by contributing to the enhancement of smart cities. These factors were represented by the provision of information technology, digitalization, smart governance, social trust, reducing travel distances, and the continuity of financing. These factors were found to work together to enhance the quality of life in cities [4].

The study of Al-Abayechi & Al-Khafaji (2023) focused on the characteristics of the spatial structure of cities that contribute to reducing energy consumption and pollution rates and making them more sustainable. The study adopted the statistical approach that studies the interconnectedness of relationships and the strength of the association between the indicators affecting the achievement of sustainability. It also showed that most studies focused on the descriptive aspect of studying sustainability indicators, in addition to discussing the possibility of achieving them in cities. This prompted this study to develop a method based on linking the spatial characteristics of the urban structure to mathematical models and using the geographic information systems program [5].

Through what has been presented in the previous literature, we note that the first study focused largely on studying urban factors represented by factors of distribution of urban activities and employment places related to economic and social factors that directly affect the urban structure. The second study focused on finding three methods to measure the urban structure, which are density of centers, Gini coefficient, and spatial measurement model, as its main goal was to explore the spatial effects and factors affecting the sustainable development of cities and urban agglomerations.

The third study focused on studying the causes of urban expansion, random growth, and its direct impact on achieving urban sustainability, especially infrastructure supplies and measuring land consumption indicators. The fourth study focused on the role of green industrial infrastructure and how it contributes to achieving sustainable urban infrastructure through the advantages provided by smart city policies.

The fifth study focused on the characteristics of urban structure that contribute to reducing energy consumption and pollution rates as the main focus of sustainability issues. Therefore, it relied on finding a statistical model that explains the relationship and effects between indicators and levels of achieving sustainability in cities.

Thus, our study differs from previous literature in that it is not limited to a specific aspect in the study of urban structure, but rather it has developed an integrated set of measurable indicators through which the urban structure of any city in the world can be measured. These indicators enable us to know the extent to which sustainability is achieved in cities. In addition, these indicators can be represented graphically and spatially using geographic information systems, and then a three-dimensional representation can be made that shows how cluster patterns spread and are distributed spatially. All of this greatly helps researchers and decision-makers in understanding how urban structure works and knowing its relationship to achieving sustainability for cities.

2. Theoretical Approach

In the following paragraph of the research, the indicators of urban structure that greatly affect the achievement of urban sustainability will be shown by reducing travel distances and reducing the consumption of land resources, in addition to reducing social costs and construction costs of buildings.

2.1. Sustainable Urban Structure

The structure is a property of all systems in the external world: the elements or parts connected with fixed relationships and an internal arrangement [6, 7]. The structure of the system consists of a set of relationships. Each system, whether primary or secondary, has structures that represent that system's essence and its various relationships. The structure represents the internal entity of the system and is responsible for its survival and perpetuation of its existence and is responsible for its appearance and disappearance and change and alteration. It can be said that the true nature of things does not lie in the elements only but rather in the relationships that they form and that then we perceive between things [8, 9]. Urban spatial structure is the distribution of producers of goods and services and consumers in cities. The urban spatial structure combines form and function in a specific system. The form refers to interconnected parts of the road network, housing, warehouses, parks, and others. Function refers to the interrelationships between them [7, 10]. It is widely believed that the urban spatial structure is complex, resulting from the relationship of urban form with the overlay of behavior patterns and interaction between sub-systems with a set of organizational rules that link these sub-systems together in the city system [11].

Recent studies focus on the relationship between urban form and travel patterns, two main factors in the urban structure industry, as urban traffic depends on the locations of activities that supply services. The change in the urban form is the most important indicator of the demand for urban transport, which in turn leads to a reduction in fuel consumption and an improvement in environmental quality. Recent studies have focused on reducing the number of trips by encouraging efficient land use patterns and a well-designed and better-managed transportation system [12].

Sustainable urban structure is defined as the structure that contributes to achieving the sustainability characteristics of cities through its indicators that support the quality of life and achieve environmental, social, and economic benefits. Urban structure results from different uses of land that are places for activities and functions (residential, commercial, recreational, industrial, religious, educational, and health). These functions are interconnected in relationships of attraction reflected in road networks, movement, and daily trips [13]. Therefore, the literature in the field of urban planning focused on deconstructing the relationships between different uses to identify the benefits and harms resulting from that [14].

A study by the US Environmental Protection Agency found that urban agglomerations can achieve high densities that greatly enhance the mix of land uses, thereby reducing travel distances and achieving accessibility. This will also significantly reduce pollution and harmful emissions to the environment [15]. Technological improvements can also greatly contribute to the smartness of cities, as they dissolve the concept of physical distance and replace it with the time required to communicate to complete shopping, social interaction, education, or medical consultation. This makes the physical distance traveled equal to zero. This can be done directly from home without the need for a trip by using a car or walking [16].

This makes us think of the beginning of a new era that gives a different understanding of the traditional place and the prevailing urban structure, as it previously depended on physical spatial dimensions, but now it depends on virtual space and information communication. Indeed, studies have begun to examine the impact of information and communication technology on the urban spatial structure through a comprehensive review of the literature. It was based on the analysis of 130 research papers that studied the major impacts of information and communication technology on aspects of the urban structure and its spatial distribution. Human aspects, mobility and flows, and activities within cities were studied. Information and communication technology factors were identified as important catalysts for transforming urban spatial structures in the future [17].

Indicators relating to housing and its relationship to physical proximity, especially about activities and jobs, are usually reflected in land prices. City centers tend to have higher land prices and lower energy consumption rates than outlying areas [18]. This explains the increased concentration of spatial structure density in city centers, as density increases as we move toward the center. It is worth noting that at a certain level of density, the benefits are acceptable, but increasing density requires strengthening the supporting infrastructure to ensure the quality of life in city centers [19].

This explains in some cases the reverse migration of population concentration to the outskirts of cities, escaping from poor services and social problems, as well as the additional material costs resulting from the increasing agglomeration. Therefore, groups of urban structure agglomerations may appear, with multiple nuclei. The changes that occur in the development stages to obtain an optimal size for cities may impose restrictions to control urbanization rates and density in an attempt to mitigate the negative impact of the monocentric structure and manage it effectively [20].

Hence, questions arose among specialists about the best urban structure: is it the one with a single center, which is usually high in density, or the one with multiple centers, which is usually characterized by moderate densities compared to the single center [21].

To accurately answer the question, the above variables must be studied in detail using mathematical models as well as the geographic information systems environment, which helps in representing data in the form of two- and three-dimensional charts to explain the variation in variables more clearly [22].

2.2. Global Experiences in Sustainable Urban Structure

In this section, we will discuss two leading cities in the field of urban sustainability: Melbourne and Copenhagen. These two cities differ in their urban form, expansion options, population density, etc., but they are similar in that they are sustainable as a result of investing in urban structure elements to support the city's transition towards sustainability.

2.2.1. Melbourne City

Melbourne is one of the leading urban models in the field of urban sustainability. This city has been able to achieve its sustainability by relying on some changes and developments in its spatial structure. Melbourne recorded a high population density, as it ranked first according to the 2023 statistics, with 521 people per square kilometer, which is a high-density rate compared to other Australian cities [23].

Melbourne has a gradual spatial structure that starts from the outskirts and moves towards the center in an attempt to relieve pressure on the city center, as approved by the city development plan. Melbourne's city center has suffered from very high density and concentration, so development has been spread over parts of the city using a compaction policy. Melbourne has begun to increase urban density in different areas of the city following the Melbourne 2030 Plan, which has already started to be implemented. The policy of densification and compact city has been adopted by creating new activity centers as development hubs where the quality of living and working combine. A large proportion of new housing has also been allocated to be close to activity centers, thus providing easy access to transport and services, which achieves ease of access. These developments mean that people are increasingly willing to live and work in these areas, which reflects an increase in population density, as they are among the most densely populated areas in Australia. [24].

Melbourne had been following a sprawling pattern in its expansion, but city planners adopted a plan to develop the city using a compact pattern. According to the available data on land prices in Melbourne until 2023, they are generally on the rise in many of its suburbs, which indicates an increase in demand and desire for housing [25].

Melbourne city center is located in the city center, providing easy access to and from the city by various means of transport. Melbourne has a good transport system that provides easy access for people to jobs and activities and also facilitates the movement of goods and their access to markets. The transport network pattern in Melbourne is a grid-based division (see Figures 1 and 2) [26, 27].

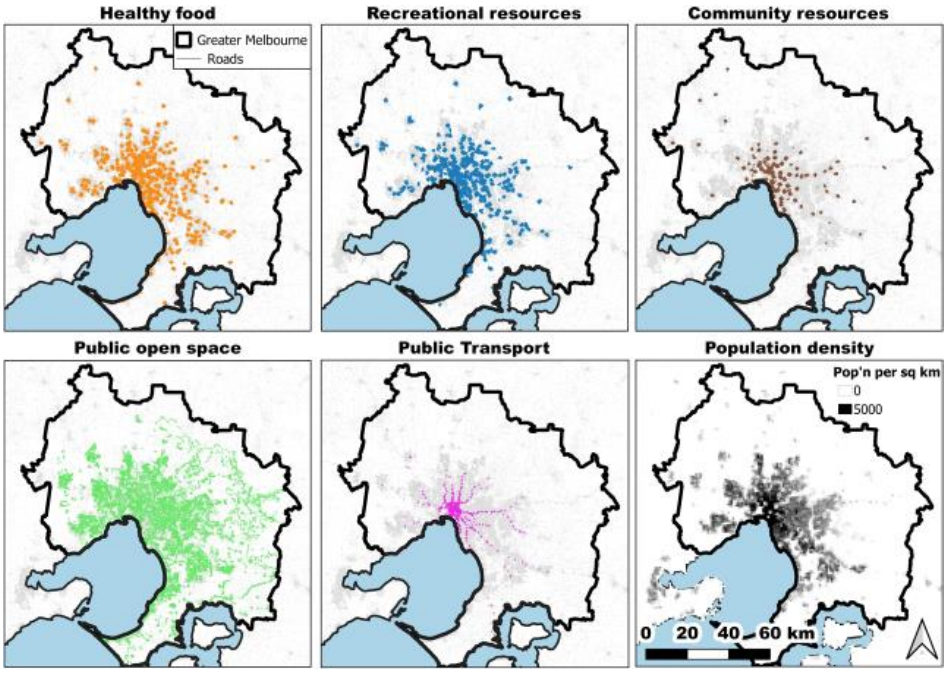


Figure 1. Spatial distribution of land use, density and transport network in Melbourne

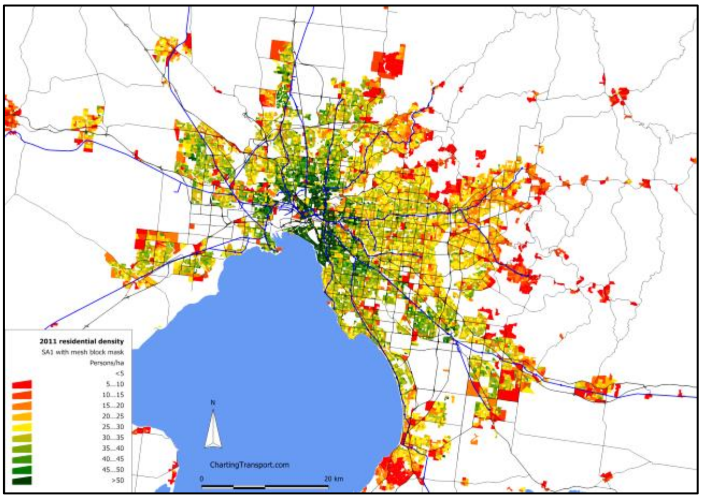


Figure 2. Density variation in Melbourne

2.2.2. Copenhagen

Copenhagen is characterized by its distinctive urban structure, as it was built according to the five-finger plan, which allowed for controlling the expansion of the city while leaving adequate space for recreational activities and agricultural land. What distinguishes the urban structure of this city is that it reflects the balance between the built environment and natural areas. According to the 2024 statistics, the population density in the city is about 90 people/hectare, and this density rate is a good indicator of development processes [28].

The Copenhagen city plan reflects the urban structure of the city gradually from the center to the periphery. The form of Copenhagen is characterized by a polycentric development pattern, with a concentration of services and uses in the foreground part, followed by a finger-like development interspersed with open spaces. These spaces contain agricultural land, wildlife, sports and recreation activities, and temporary low-density activities. This plan has enabled the production of an organized urban growth plan in good shape, with environmental corridors available to people [29].

Land and housing prices in Copenhagen are rising significantly and strongly, especially in the city center. Available data indicate that land prices, especially housing prices, have increased by about 50% since 2013. The main reasons for the rise in land prices are the increased demand for housing due to the increase in the number of families, as well as major economic and urban developments in all areas. In addition, the decrease in interest rates on housing in urban areas has had an impact on housing, leading to an increase in its prices [30].

Copenhagen's city center is located at the edge of the city, and development axes start from it in different directions, and the center is connected to the outskirts by transport lines. The city is characterized by an advanced public transport system, and walking and cycling are the main means of transport, and the city provides easy movement between all its parts, especially the unique ones, including the city center. The five-finger plan facilitated the extension of railway lines and highways, which facilitated the connection of the city center with other parts. The city's transport network is characterized by a grid plan with ribbon axes along the fingers (see Figures 3 and 4) [31].

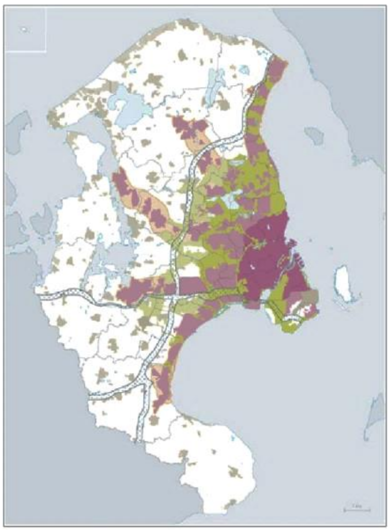


Figure 3. Spatial distribution of land use in Copenhagen

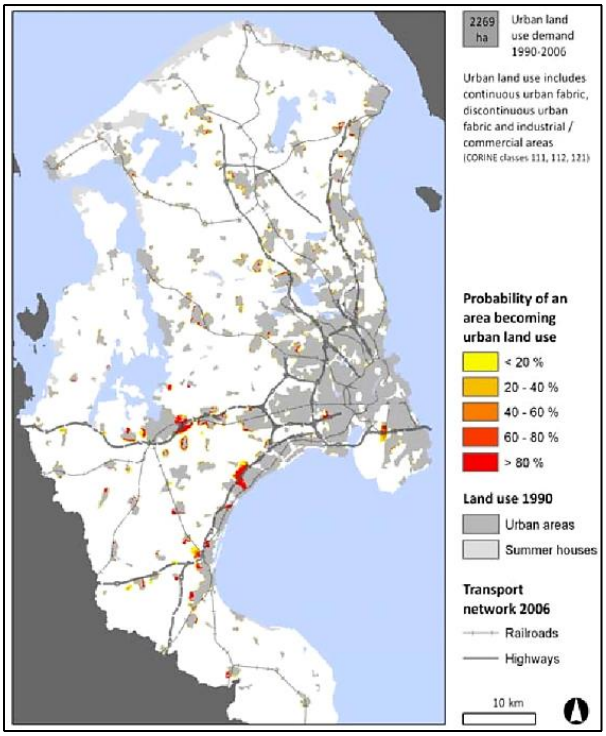


Figure 4. The spread of urban development in Copenhagen

By presenting the two pioneering experiences in the field of urban sustainability, it was possible to distinguish several important indicators of the urban structure that support achieving sustainability. Although both cities are sustainable, there is something that distinguishes one from the other in some indicators. The population density in these two cities reflected the quality of life and people's desire to settle in them, in addition to the development plans that support increasing density and distributing it correctly. The density in Melbourne was the highest in Australian cities; it was concentrated in some areas more than others, so it was redistributed through the use of the compact city policy. As for Copenhagen, the density was in line with the general standard for population density, which ranges from 80 to 140 people/hectare.

Through the planning plan set by the city of Melbourne to relieve pressure on the city center, it was adopted for the integrated city center for urban development in the major city as a part. It was decided to propose construction by adopting the gradual adoption of the important edges, while the city of Copenhagen has graduated its structure from the city center to the edges by adopting the fingers plan. By following the plans of Melbourne City, it becomes clear that it relied on the policy of urban sprawl in its expansion, and to address this issue, the compaction policy was adopted. As for Copenhagen city, it relied on the multi-centered model in its expansion by implementing the fingers plan. This distinguishes Copenhagen City, as the multi-centered model is the best in achieving sustainability, as it achieves many economic, social, and environmental goals.

People’s behavior and desire to live in certain places rather than others or invest in them can often lead to an increase in the prices of these lands, which was reflected in the city of Copenhagen more than in the city of Melbourne, as land prices, according to available data, indicate a significant increase. This increase in prices has implications that support sustainability by achieving many economic goals and benefits, in addition to achieving quality of life. The location of the city center relative to the city is one of the indicators that give the city its urban form and structure. The central location of the city center achieves many benefits and goals for urban sustainability, and this is what distinguished the city of Melbourne, as the location of its central center provided easy access to and from the center and helped in the hierarchical gradation of streets, which enhanced the use of multiple means of transportation that are compatible with the street level. As for the city of Copenhagen, despite being a sustainable city with environmentally friendly means of transportation and a good road network, the peripheral location of its center and the distance difference between the center and the outskirts are negative matters, because it did not achieve social justice in the ease of access to the center, and the center was linked to the outskirts by railways and highways.

Based on the above, we note that the average distance between the center and the outskirts in Melbourne is equal or close due to the location of the city center, but in Copenhagen, it is not equal because its center is peripheral, and the extension of the development axes is not the same distance. The street network is one of the important elements of the urban structure, as the coherence and clarity of the urban structure are formed through the coherence and clarity of its streets. The grid division of streets allows high connectivity; it also provides the possibility of dividing streets according to the means of transportation, with the identification of special paths for pedestrians. Both Copenhagen and Melbourne are characterized by a network-style transportation network, with multiple means of transportation, and giving priority to pedestrian movement.

Based on the above, the elements of the urban structure that support sustainability can be identified as follows: Population density rate of development Hierarchy of city structure, Average distance to the city center, Spread index, The location of the center in relation to the city Street grid pattern.

2.3. Indicators of Sustainable Urban Structure

After deriving the indicators within the theoretical framework based on the proposals of theorists in the field of urban structure and further clarifying them through a review of global experiences from the cities of Melbourne and Copenhagen, this section provides an explanation and definition of the spatial structure indicators and the methods for measuring them. These indicators are designed to be applicable for evaluating the urban structure of any city, as they are comprehensive and not limited to the specific context of this study. This highlights the importance of specialization in this field, as these indicators serve as valuable tools for testing and improving different models of urban structure. The indicators include the following:

2.3.1. Population Density Rate of Development

This indicator is one of the key indicators in the field of urban structure sustainability. It is directly linked to achieving city sustainability, as it reflects the relationship between land consumption rates and occupancy efficiency. Low-density rates are typically associated with higher land consumption required for urban expansion to accommodate population growth. Conversely, high density and vertical housing development help achieve lower land consumption with a reduced need for infrastructure services. However, these services must be highly efficient due to the large number of people concentrated within a unit area [32].

Population density rates are generally calculated by dividing the number of inhabitants by the unit area. This can be classified as net density, by considering only the area allocated for residential purposes; gross density, by including both residential and related service areas; or general density, by dividing by the total area of the city. All these definitions are appropriate for developing a scale that reflects the level of population density relevant to urban development. In this research, the general density of the city will be adopted, as it provides a realistic measure that captures the tendency of the population to concentrate within specific locations. This tendency explains the prevalence of vertical construction and higher population densities in central areas compared to peripheral zones [33]. Figure 5 illustrates a three-dimensional representation of population density in built-up areas.

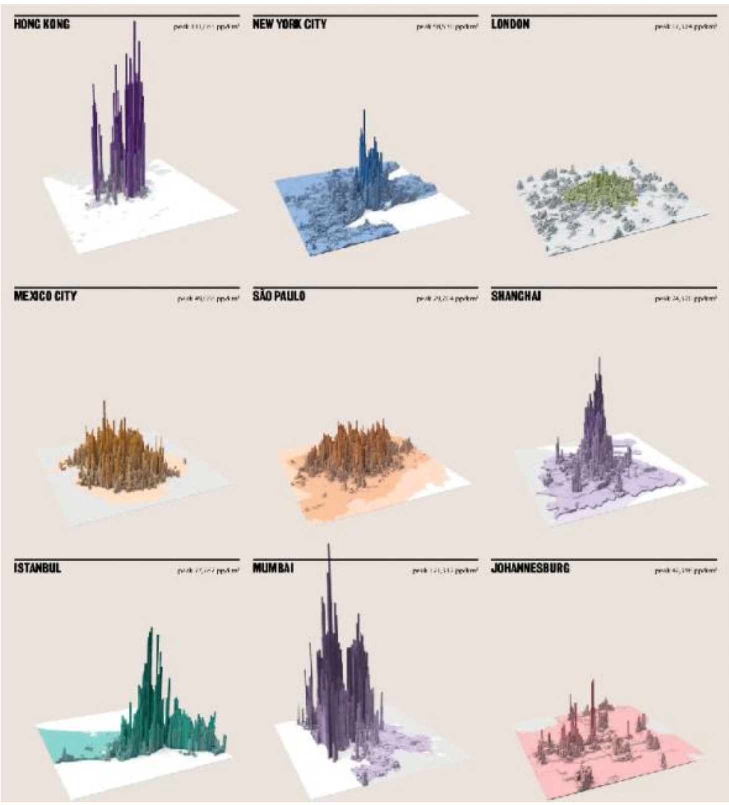


Figure 5. Dimensional representation of population densities in built-up areas

2.3.2. Hierarchy of City Structure

This indicator is important because it expresses the relationship between the density index and the distance traveled index. It can be calculated by the average density of a certain area and the average distance traveled from that area to the city center [34]. This reveals the extent of variation in the concentration of densities between the different areas of the city. Through this indicator, we can know the concentration or spread of the urban structure of the city, as well as the rate of trips traveled to obtain services and goods that are usually concentrated in city centers. We find the distribution of services within the spatial structure in proportion to the importance of that service. The more important and concentrated the service is, we find that it takes a central place. Consequently, the distance traveled to access services decreases [35].

2.3.3. Average Distance to the City Center

This indicator is closely linked to the distances traveled to access services and commercial centers, as well as the nature of the transportation modes available within the city. As we move closer to city centers, the diversity of transportation options increases, and the time required for trips tends to be longer due to higher congestion levels, as the number of users in central areas is greater compared to peripheral areas. This indicator plays a significant role in promoting urban sustainability by encouraging the use of environmentally friendly modes of transportation. Solutions such as dedicating special lanes for public transportation and non-motorized means can reduce travel time compared to private vehicle use, thereby motivating users to shift toward these sustainable options [36].

The indicator can be measured by determining the number of users, the volume of trips, the types of trips taken, and the daily frequencies of trips by type. It can also be assessed individually by calculating the distance traveled by each person to reach the central area and the time required for the journey. Thus, this indicator helps explain the population's tendency to concentrate near major transport hubs and nodes, aiming to maximize benefits and minimize transportation costs and travel times, particularly for reaching central parts of the city [37].

2.3.4. Spread Index

This indicator is based on the area of built-up urban zones and their concentration levels, specifically the building densities and the number of floors in urban areas. It also considers the distance of these areas from the city center. The spread index decreases as the rate of built-up areas and the density of buildings increase closer to the city center, indicating a higher level of compactness in the urban structure. Conversely, the spread (or sprawl) index increases when the extent of built-up areas and building densities decrease, along with an increase in the distance traveled from these areas to the city center. Thus, this indicator is particularly important as it reflects the impact of building density on travel distances, which is crucial for achieving sustainability within urban structures. It has been found that urban structures become more sustainable as they become more compact and as sprawl rates decrease, allowing for the performance of different cities to be compared based on variations in their urban form [38].

The spread index is used to compare the density scales of different cities by assessing the city's area. If the area of a city is equivalent to that of a circle, and the average distance traveled by an individual from a given point in the city to the center is equal to half the diameter of that circle, then the diffusion index (Equation 1) equals 1, representing an ideal, circular city form — the optimal case for achieving the ideal diffusion index [39].

$$P = \frac{\sum Di\, Wi}{\frac{2}{3}\sqrt{A/\pi}} \tag{1}$$

where P is Spread index, Di is the distance travelled to the central area, Wi is Weight by population density dependence, and A is the built-up area.

2.3.5. Land Prices

Land price is a very important indicator that is closely linked to the sustainability of urban structure. The higher the land price, the more it is a function of the availability of sustainability characteristics and quality of life in the area, due to the association of land price with density indicators, accessibility, and sprawl indicators, as land price is a function of these indicators. This explains why land prices are usually very high in central areas, and these areas are usually characterized by high densities, proximity, and provision of services. This can be compared with low-cost lands, which are usually far away, low-density, and located on the outskirts of cities.

It is worth noting here that there is an exception for the prices of lands overlooking main streets, especially commercial ones, as they enjoy easy access. Lands with commercial and financial functions occupy the highest-priced lands. The difference in land prices can also indicate the direction of future development of the city's spatial structure, as high land prices indicate a high level of demand for it [40].

2.3.6. Location of the Center in Relation to the City

The growth of the city greatly affects the growth of its center and vice versa. The central business district should be located in the middle to provide a suitable distance to reach all parts of the city and thus shorter travel distances. The direction of city growth usually affects the shapes and densities of its centers. Studies have found that the circular expansion of cities is the best and provides an opportunity to achieve greater sustainability when compared to other forms because it reduces distances to the city center. On the contrary, the longitudinal or linear expansion consumes larger areas and achieves greater spacing between parts of the city. Therefore, the location of the efficient center requires that it achieve compatibility in the distance index between it and other areas of the city, taking into account the density distribution of those areas within the city. The greater the distance between the center and the areas of the city with high densities, the less efficient the city structure will be, and vice versa [41].

2.3.7. Street Grid Pattern

The street network pattern is a fundamental characteristic of urban structure and an important indicator of the sustainability of urban structure. Highly connected networks are more walkable and provide a greater number of pedestrian path options. The increased number of nodes provides safe areas for transferring between public transport modes due to the proliferation of stops, as well as the possibility of providing the option of walking or cycling. In contrast, long streets with high speeds and few nodes encourage mainly the use of private transport modes [42]. Short streets contribute to slowing down vehicles and providing shorter distances between land uses. These factors work together to increase walkability and thus reduce pollution from private cars [43]. Therefore, streets should be designed as interconnected, dense, and multi-node networks to reduce the distances traveled for the journey from residential areas or work areas to public transport stations. Climatic conditions should also be taken into account to provide a suitable environment for pedestrian movement through shading, trees, drinking fountains, and seating areas, with a focus on ensuring that the width of the streets is appropriate for the volume of flows, population concentration, and trips [44].

3. Research Methodology

The research used the descriptive analytical approach based on presenting the important previous literature on the subject of sustainable urban structure as well as global experiences that have a sustainable structure. The aim of this is to reach the decisive indicators in measuring the urban structure that can be applied to any city in the world. Seven indicators were extracted and converted from conceptual indicators to measurable indicators using mathematical models to be more accurate in measuring the urban structure. Through these indicators, the difference can be accurately determined, and its impact on the sustainability of cities can be shown through its reflection on the distribution of activities, population, land uses, ease of access, spatial proximity, and land prices. Information on the urban structure of the cities of Kut and Hillah was obtained from government departments such as the Municipality and Urban Planning Department and the Central Statistical Organization, as well as field survey data. The indicators were measured using the Geographic Information Systems program and mathematical models associated with their spatial analysis in the Geographic Information Systems environment (see Figure 6).

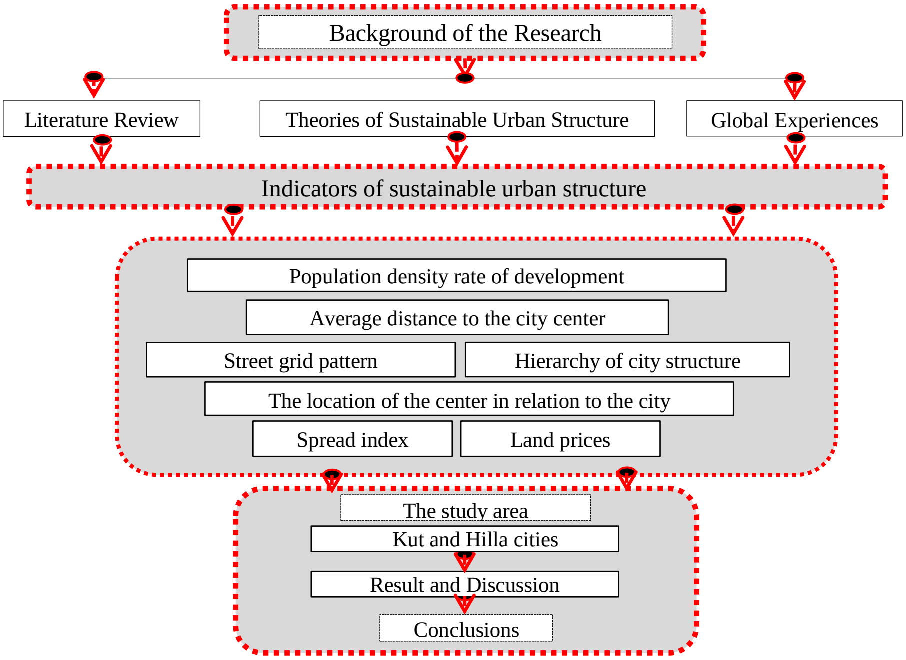


Figure 6. Research methodology

4. Methods

The study relied on the descriptive analytical approach of the literature and previous global experiences to extract the critical indicators of urban structure. Several methods were used to measure and analyze the practical aspect through spatial analysis based on quantitative methods and mathematical models in the environment of geographic information systems. Three-dimensional analysis was also used to represent spatially to clarify the variation in the values of spatial structure indicators that affect the achievement of city sustainability. The research will depend on the analysis of two cities (Kut and Hillah) that have different structures, considering that one of them has a river and the other does not. In addition to the difference in density rates, land use concentration, and street distribution pattern.

5. Case Study

Al-Kut city is located southeast of the capital, Baghdad, about 170 km from it, and it is the center of Wasit Governorate. This location made it a city of diverse functional relationships and interconnections, in addition to being located on the main road linking Baghdad and the southern governorates such as Nasiriyah, Basra, and Amarah (see Figure 7) [45].

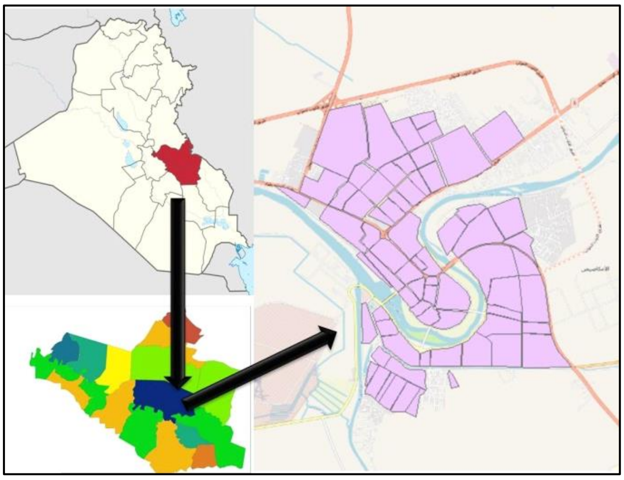


Figure 7. Location Map of Al-Kut City

Al-Hillah city is one of the important Iraqi cities located in the Middle Euphrates region and is 110 km from the capital, Baghdad. It is the center of Babil Governorate, which includes several administrative units. It connects the provinces of Najaf and Karbala to the capital, Baghdad, which is considered among Iraq's most important religious tourism cities (see Figure 8) [46].

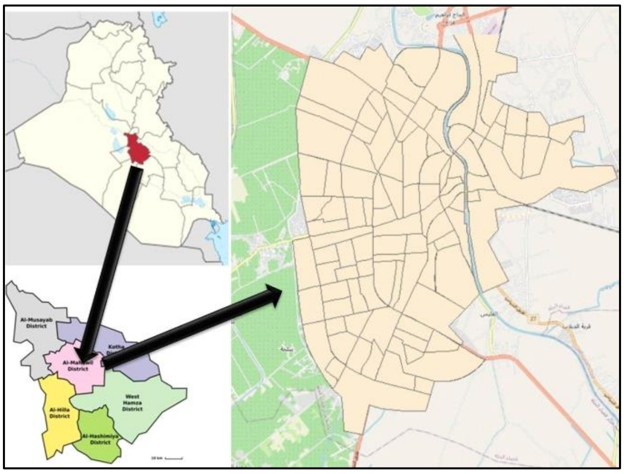


Figure 8. Location Map of Al-Hillah City

6. Results and Discussion

In this section, the seven indicators that were previously derived through the theoretical framework and previous experiences will be analyzed and discussed to reach accurate results about the nature of the urban structure for the cities of Kut and Hillah and to know the extent of achieving sustainability in each of them, which are as follows.

6.1. Population Density Rate of Development

Studies on urban structure have indicated that the appropriate standard for cities is 80-140 people/hectare [25], as this standard achieves balance in the urban structure. The city is not densely populated in cases of high densities that can cause congestion, poor health conditions, and pressure on infrastructure. It is not low-density, which leads to the lack of rationalization of urban land consumption and the spread of residential complexes over large areas, so the dominant feature is the spatial distance between uses. When analyzing the population density index, it was found that the total population density in Hillah City reached 95 people/hectare, which is a good density to achieve sustainability, unlike Kut City, where the index value reached 70 people/hectare. This means that Kut City needs to increase its density, population, and urban structure within its sectors. Table 1 shows the population densities in the cities of Kut and Hillah. Figures 9 to 11 represent a dimensional representation of the densities of the two cities.

Table 1. Density in study area

The cities	Area (h)	Population	Density p/h
Al-Kut	4414.11	309389	70
Al-Hillah	6504.63	617698	95

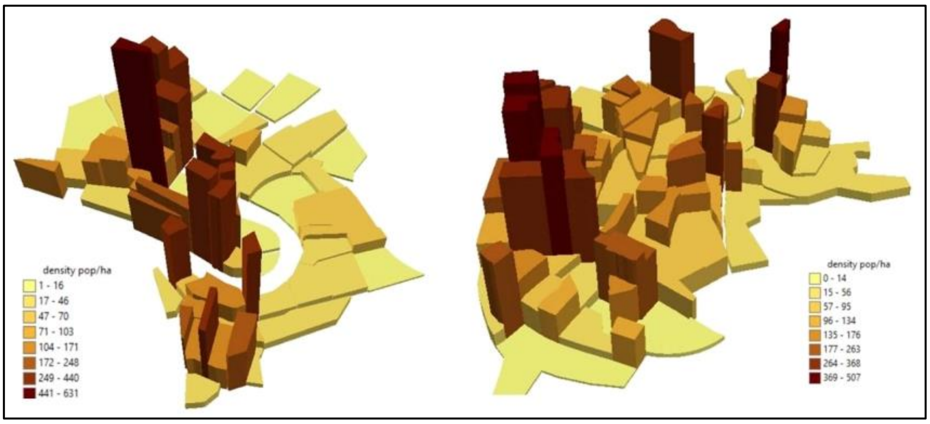


Figure 9. Dimensional representation of population densities in Al- Kut and Al-Hillah

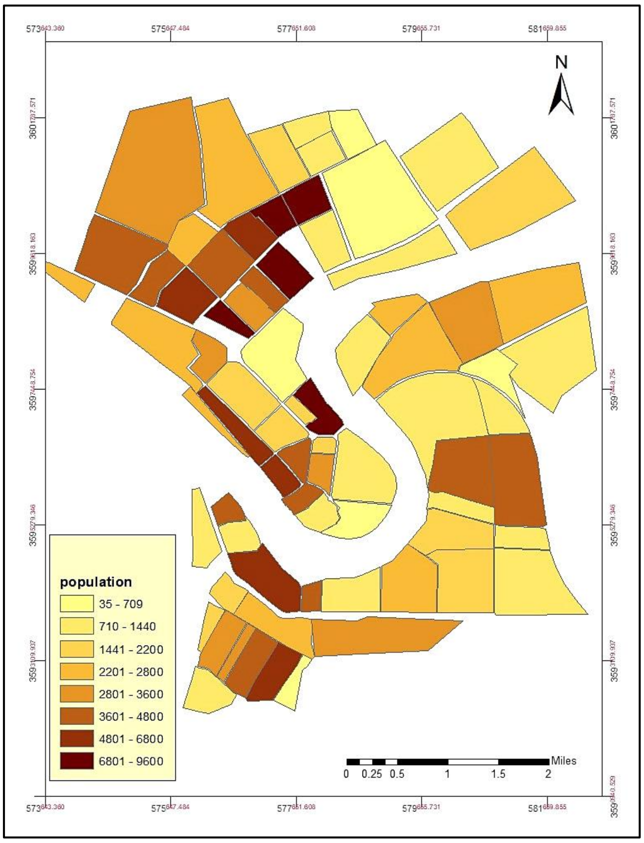


Figure 10. Density variation in Al-Kut City

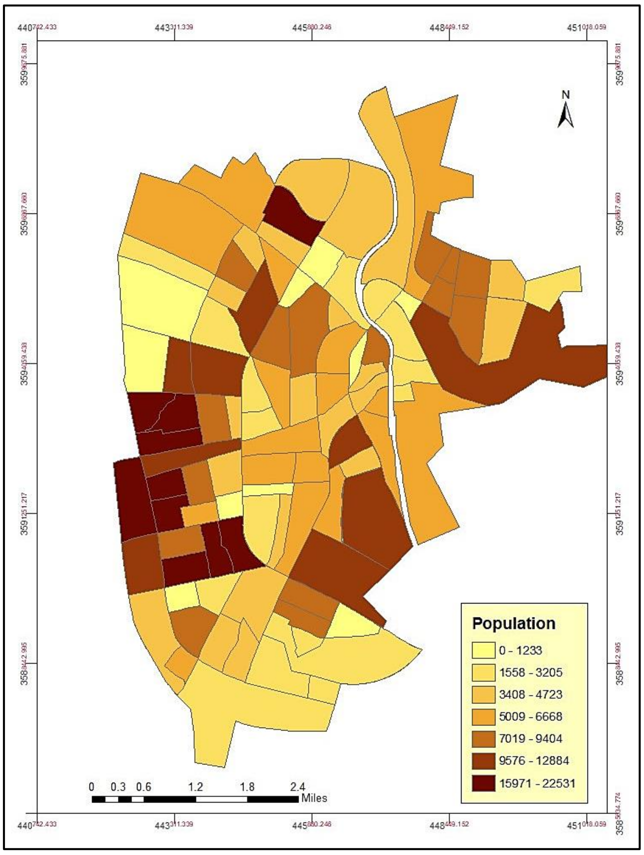


Figure 11. Density variation in Hillah city

6.2. Hierarchy of City Structure

In this analysis, we relied on calculating the distance to the city center and the density rate for each residential neighborhood in the city based on the Geographic Information System (GIS) and based on the coordinates of the center of each neighborhood and its population density and its relationship to the coordinates of the city center. Figures 12 and 13 were represented, and the correlation value between the two variables was calculated. Through the previous Figures 14 and 15, we notice a weakness in the gradation of the densities of commercial stores relative to the center in both cities. Also, the regression analysis shown in the figures in red confirms the imbalance in this relationship. Despite the low value of the index in both, Kut city is better because the value of the correlation square reached 0.1, while its value in Hillah city reached 0.001, which indicates the absence of any correlation between the average densities of the neighborhoods and the city center. The weakness in the value of this indicator explains the long travel distances traveled by most of the city's residents to reach service locations in the central areas, because the density rate within the different clusters of the city's structure is low and the distances traveled to reach them are relatively long. This causes an increase in the economic costs spent by residents on transportation, in addition to spending more time to obtain services.

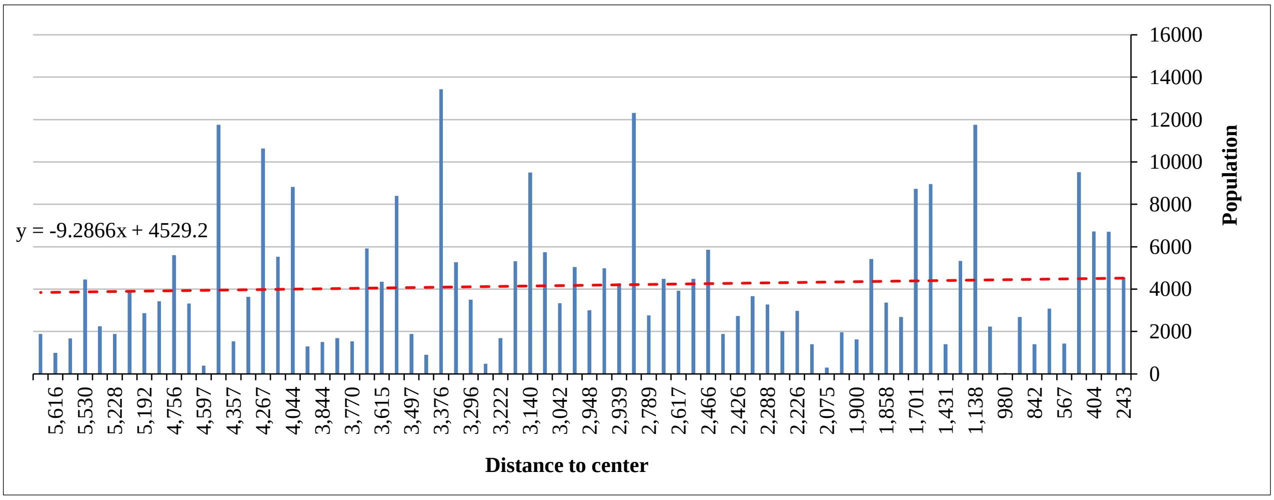


Figure 12. Hierarchical densities of neighborhoods in Al-Kut

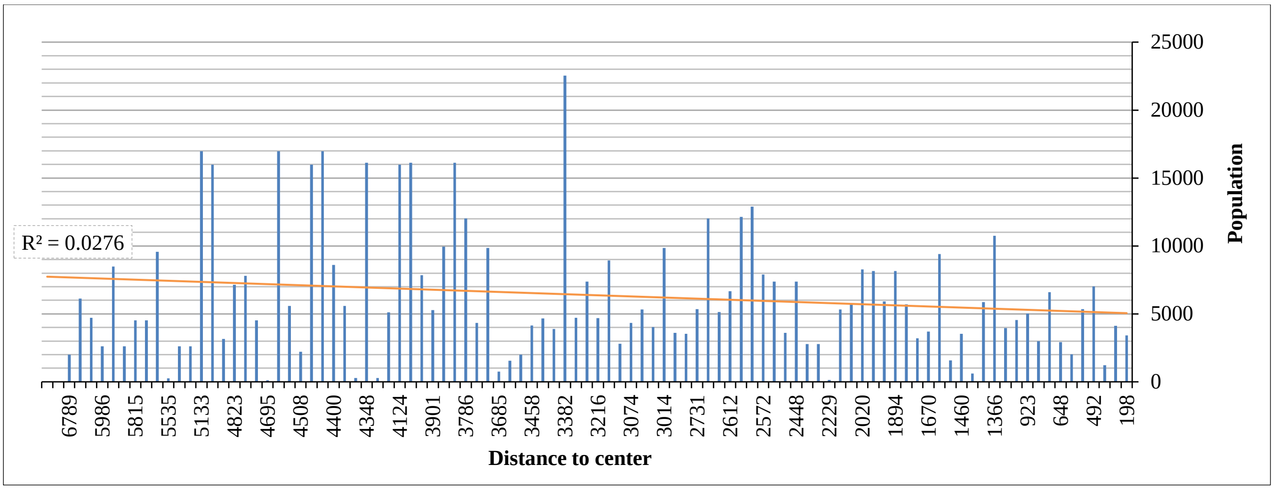


Figure 13. Hierarchical densities of neighborhoods in Al-Hillah

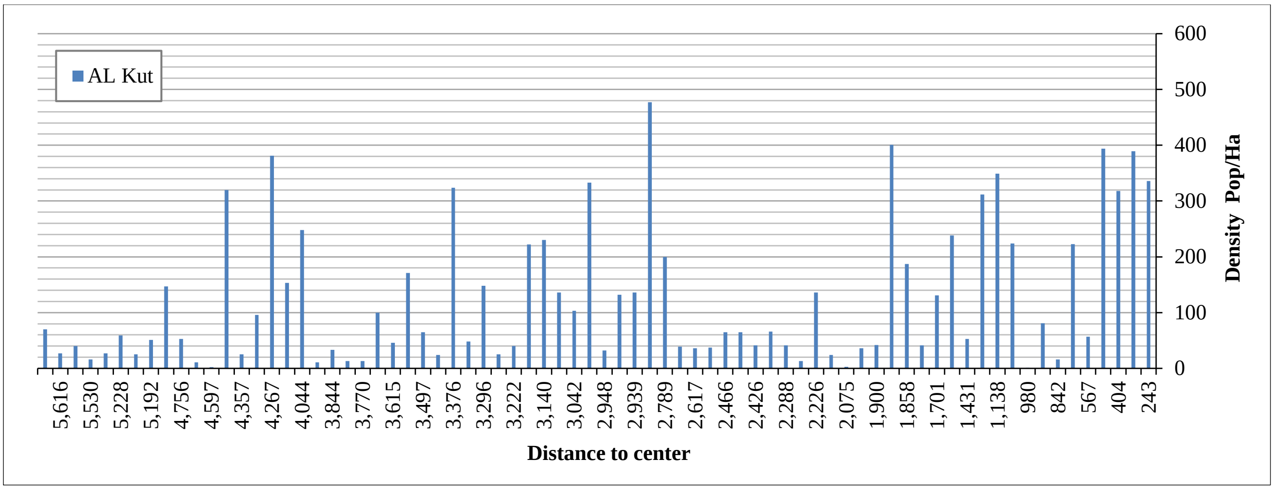


Figure 14. Gradient density of neighborhoods compared to their distance from the center in Al-Kut

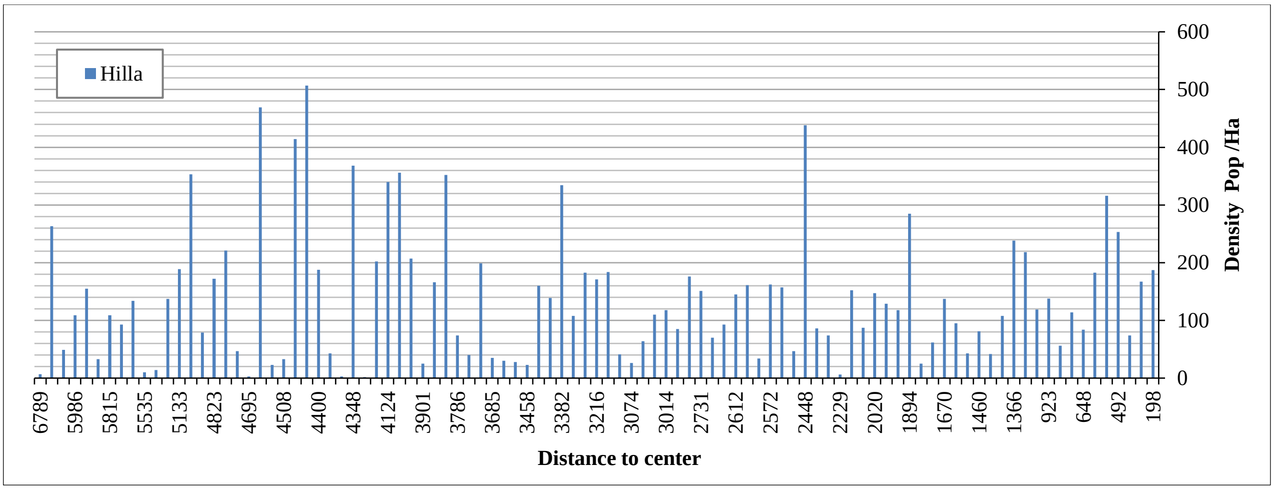


Figure 15. Gradient density of neighborhoods compared to their distance from the center in Al-Hillah

6.3. Average Distance to the City Center

In this index, two variables were adopted: the population of each neighborhood and its distance from the city center. Figures 16 and 17 were represented, and the correlation value between the two variables was calculated. The values showed a weak correlation for the city of Kut with a value of 0.008, while in the city of Hillah, an inverse correlation with a value of 0.03 was shown. The index of the average distance traveled per person to the city center was extracted by adopting the sum of the product of the population of each neighborhood by the distance traveled to the city center divided by the population (note the vertical red line in the two figures), as it is the basis for comparing the ease of access index between different cities. As in the values shown in Table 2, this indicates the similarity of ease of access in the two cities, which has an average value. Therefore, this index, especially in the city of Hillah, needs to be developed by raising density rates and creating new nuclei by increasing the physical proximity of these nuclei to the city center.

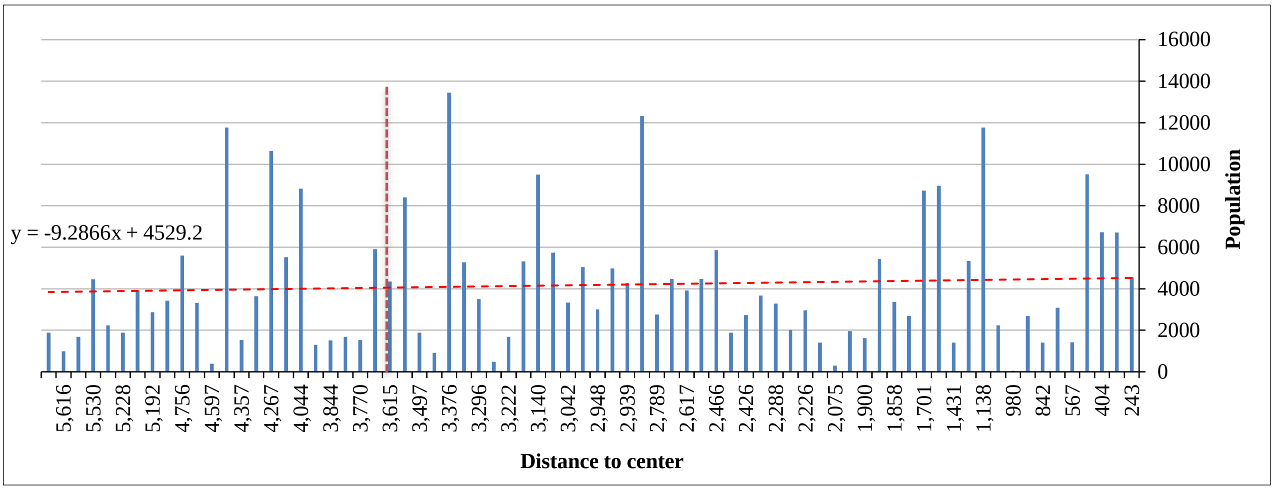


Figure 16. The average distance to the city center in Al- Kut

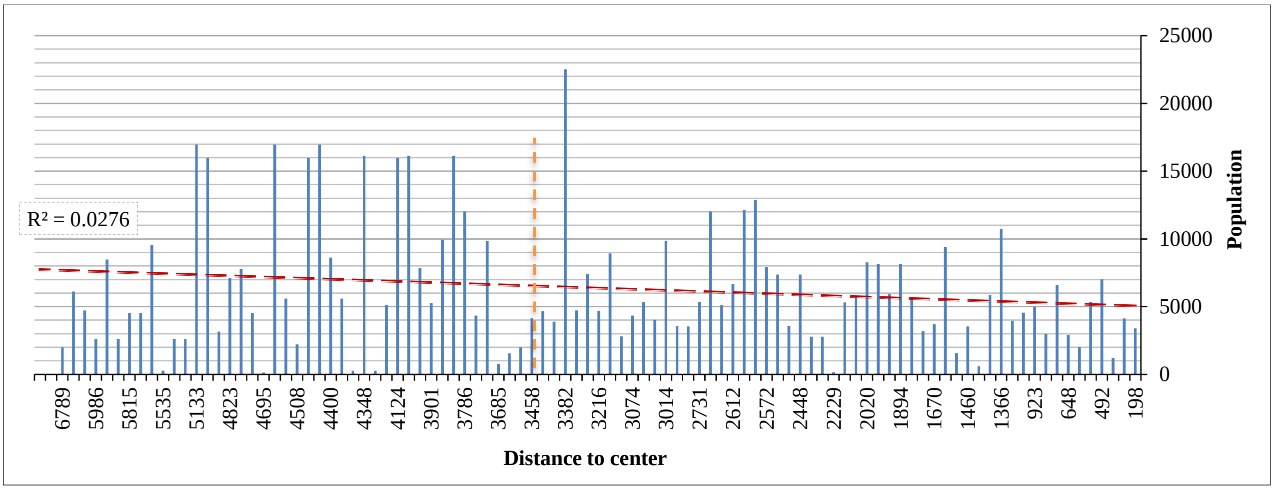


Figure 17. The average distance to the city center in Al- Hillah

Table 2. Density in study area

The cities	distance rate (m)	Population	The ratio
Al-Kut	2856	5616	0.508
Al-Hillah	3411	6789	0.502

6.4. Spread Index

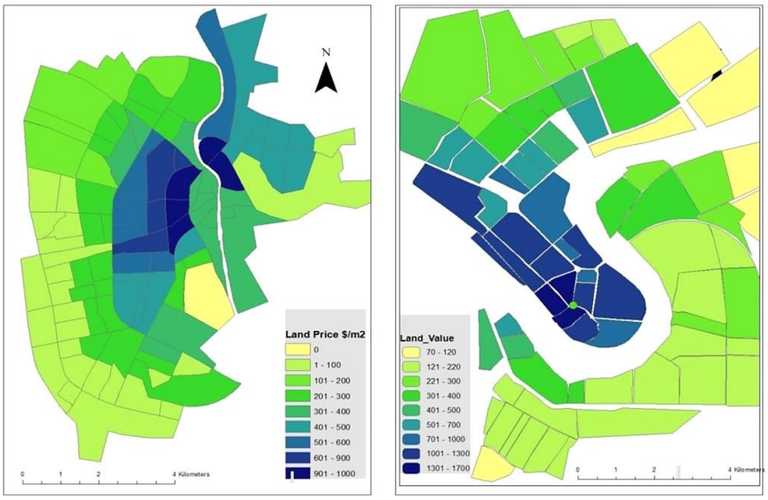
It was found that the values of the two cities for the diffusion index are close to 1, as it reached 1.001 in Kut city, while it reached 1.1 in Hillah city. This indicates that the diffusion rate is ideal because the shape of the two cities is close to the ideal cylindrical shape, with a relative advantage for Kut City over Hillah City. This indicator is very important in developing the urban structure and achieving sustainability for cities, because the central location of the center and the cylindrical shape greatly support shortening distances, but the main problem is the low-density rates and the weak multiplicity of nuclei that can increase the density of population and housing. In addition to that, it provides physical proximity and ease of access for the largest possible number of residents to city centers (see Table 3).

Table 3. Spread index

The cities	$\sum Di\, Wi$	Population	$\frac{2}{3}\sqrt{A/\pi}$	P
Al-Kut	2856	5616	0.508	2856
Al-Hillah	3411	6789	0.502	3411

6.5. Land Prices

From Figure 18, which illustrates the spatial distribution of land prices in Kut city, it is evident that the distribution is not ideal. Land prices in the northern part of the city are higher than those in the southern part, while the highest prices are concentrated in the city center, extending further northward. This pattern suggests that the city center has the potential to expand toward these northern neighborhoods, as higher land prices often indicate future increases in density. Such densification would enhance the urban structure of the city in the future, provided that other structural factors are also considered. In contrast, in Hillah city, high land prices are divided into two distinct zones: one located centrally, which has a positive impact, and another situated on the northern edge, which could have a negative effect if development density increases there in the future. This could disrupt the dominance of central densities and increase the sprawl index by creating two competing urban poles. Therefore, Kut city demonstrates a more favorable distribution in terms of land prices.



Al-Hillah Al-Kut

Figure 18. Land price gradient in Al- Kut city and Al-Hillah City

This indicator indicates the absence of a planned direction for development centers within the two cities. Also, the matter of development and concentration of densities is left to the reality of the situation and the stakeholders. Therefore, interest in improving the quality of services and ease of access to specific locations in the city can contribute significantly to increasing clusters and thus increasing land prices for these areas.

6.6. The Location of the Center in Relation to the City

The first stage in calculating this indicator is an attempt to determine the potential direction of expansion. It is usually expected that activity will increase in the central area at the expense of other parts to achieve the efficiency of the center in particular and the city in general. In addition to determining the appropriate central location of the center to the city. One of the tools of GIS analysis was relied upon, which is the (average center) analysis, to find the engineering center based on the population densities of the city as a whole. From Figure 19, we notice that the central point that represents the weighted average in the city of Kut is located 1425 meters north of the city center, while in the city of Hillah, the weighted center is located 1865 meters southeast of the city (see Figure 20).

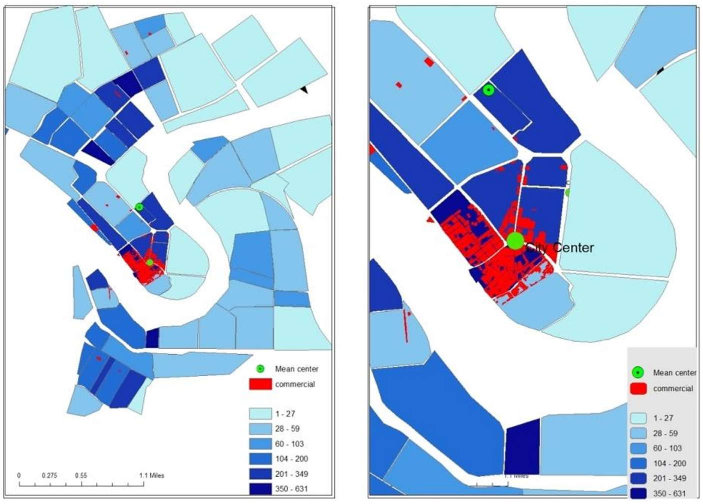


Figure 19. The Current Location and Weighted Location of Al-Kut City Centre

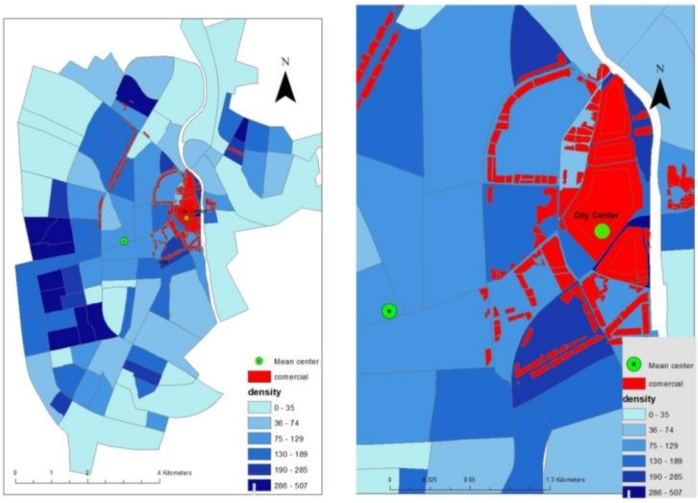


Figure 20. The Current Location and Weighted Location of Al-Hillah City Centre

This suggests a strong possibility for the center of Kut City to expand northward and for Hillah City to extend southeastward. The high densities in the northern part of Kut attract the urban center toward that area. In other words, the city center should shift toward these points to achieve more efficient urban development, ensuring that the center is located centrally, which would facilitate easier access and promote a better gradation of densities. This analysis indicates a deficiency in the efficiency of the urban centers in both Kut and Hillah. Ideally, the weighted center should align with the actual city center. However, it is observed that Kut exhibits a lower rate of deviation compared to Hillah, particularly when considering the city's farthest distance from its center, as detailed in Table 4.

Table 4. The Location of the Centre in Relation to the City

The cities	The difference between the two centers (m)	City limits from the center (m)	Creep ratio
Al-Kut	2856	5616	0.25
Al-Hillah	3411	6789	0.27

6.7. Street Grid Pattern

A well-structured urban layout requires that higher-ranked streets be connected to the city center, while lower-ranked streets should serve the outskirts. However, this criterion was not achieved in either of the two cities studied, as determined through spatial analysis using the GIS program. Figure 21 illustrates the street network hierarchy in Kut City. The spatial analysis of the street pattern revealed a defect in the sequence, with a failure to link the hierarchical gradation (highways and arterial roads) effectively to the city center. A similar issue was observed in Hillah City, where a defect in the street network hierarchy was also recorded (see Figure 22).

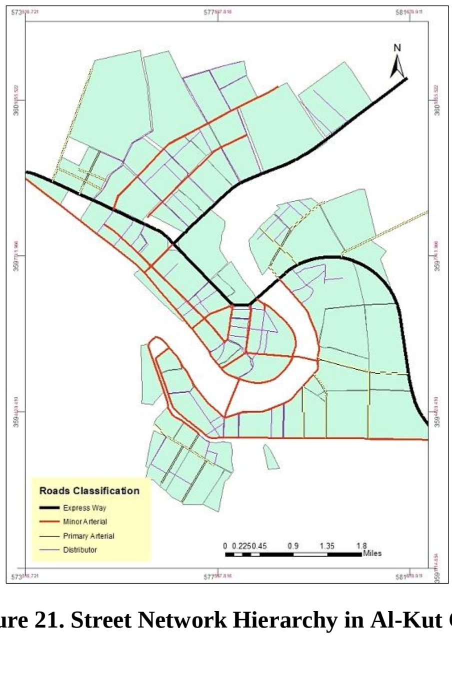


Figure 21. Street Network Hierarchy in Al-Kut City

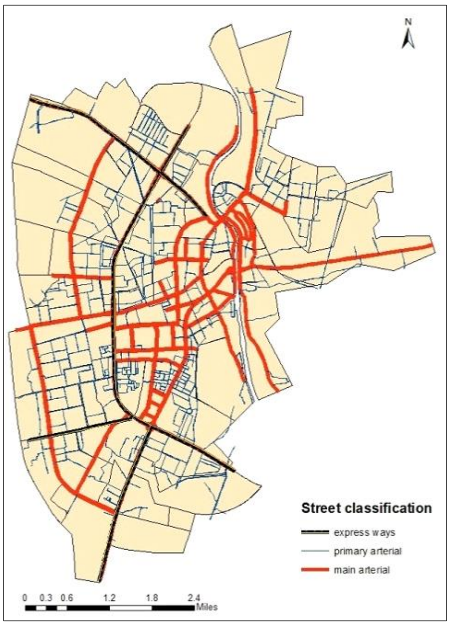


Figure 22. Street Network Hierarchy in Al-Hillah City

Therefore, the street connectivity in both cities is weak, with a lack of short, connected streets that would encourage walking. This deficiency in the street network hierarchy has resulted in poor overall interconnectedness. Moreover, the majority of the roads are wide (arterial and expressways), which promote a reliance on private cars rather than environmentally friendly modes of transportation such as walking, cycling, or public transit. These alternative modes are largely confined to the central area and its immediate surroundings. This is a significant indicator for explaining the high levels of pollution within the cities, primarily caused by vehicle exhaust emissions.

7. Discussion

After analyzing the structure of the two cities using seven indicators based on numerical values and spatial maps, a clear comparison was made, as presented in Table 5. Upon reviewing the indicator values, it becomes evident that the urban structures of both cities are far from achieving efficiency and the characteristics of a sustainable city. However, the structure of Kut City exhibits some features that could be further developed to attain certain aspects of sustainability. Achieving this, however, would require significant efforts from stakeholders and decision-makers within the city.

Table 5. Comparison Results Between Al-Kut City and Al- Hillah City

N	Indicators	Al-Kut city	Al- Hillah city	Notes
1	Population density rate of development	70	95	The standard of 80-140 person/ha was adopted. Al-Hillah city is better than Al-Kut city in this standard.
2	Hierarchy of city structure	0.1	0.001	There is a weak correlation between densities and the city center in Al-Kut city. But this connection is absent in Al-Hillah city.
3	Average distance to the city centre	0.008	0.03 inverse	The average distance to Al-Hillah city center is greater. But the percentage is almost equal if we take into consideration the area of the city. However, the association of population size with the city center in Al-Kut is better.
4	Spread index	1.00175	1.10351	From the application of the spread index equation, Al-Kut city is closer to the number 1, which is the ideal number for the shape of the city and is derived from the shape of the circle.
5	Land prices	Good distribution	Bad distribution	The distribution of the land market in Al-Kut city is better because it is concentrated in the city center and the areas close to the center, while in Al-Hillah city, part of the high prices are in the northern part, while will cause problems in the future when the densities increase in it.
6	The location of the center in relation to the city	0.25	0.27	The indicator shows the difference between the city center and the weighted center that achieves efficiency for the city. The percentage is greater in the city of Al-Hillah, but the percentage is almost equal if we take into consideration the area of the city.
7	Street grid pattern	Weak connection	Weak connection	Both cities under study suffer from poor hierarchy, poor connectivity, and poor encouragement of walking.

It can also be concluded from the table that the structure of Kut city is relatively better compared to the structure of Hillah city. The results show that it needs a lot of work on the level of density concentration and the creation of multiple nuclei, which reduce travel distances and bring destinations closer to access services. The quality of urban infrastructure, green spaces, services, and commercial facilities must also be increased, which would raise the value of the land and achieve its sustainability. It is worth noting that the importance of this study lies in revealing the reasons that societies suffer in environments that are not friendly to humans, which generally depend on low population and housing density rates, as they prefer horizontal housing at the expense of vertical housing and apartments, and they prefer to rely on private car traffic at the expense of public transportation and pedestrian traffic. They also prefer material costs and personal profits at the expense of social and environmental costs, in addition to giving priority to the interests of individuals over the interests of groups, especially in living and residential areas.

8. Conclusion

The indicators derived from the theoretical framework provided the possibility of measuring the urban structure of any city in the world. Based on the analysis of these indicators for the cities of Kut and Hillah, it was found that the two cities lack a distribution of population density, as most of the density is located far from the city center. This leads to longer travel times. The absence of a hierarchy of roads also led to insufficient communication between the city areas, due to its location on opposite banks of the river, as well as its structure that does not encourage sustainable transportation. Kut city witnessed social isolation between the two banks of the river due to the spread of its urban structure, which led to an imbalance in the distribution of services in favor of the northern part, which mostly accommodates the high-income population. On the contrary, this disparity is less evident in Hillah City.

In light of these results, the study recommends utilizing vacant lands within cities and increasing density in specific areas to enhance public transportation. This contributes to enhancing community interaction by providing entertainment venues, services, and job opportunities, thus reducing the need to travel in congested areas. The research also suggests enhancing connectivity between the two parts of the city by building additional bridges across the river, addressing the road hierarchy, and developing a comprehensive public transportation network. This study opens up research horizons in the field of urban structure to conduct detailed research for each of these seven indicators independently. This research enables us to identify detailed and accurate indicators related to stating their impacts on society, the environment, and economic aspects. It more accurately clarifies their connection and explains their role in achieving sustainability.

9. Declarations

9.1. Author Contributions

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

9.2. Data Availability Statement

Data sharing is not applicable to this article.

9.3. Funding

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9.5. Conflicts of Interest

The authors declare no conflict of interest.

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