AL-Bahir
Journal for Engineering and Pure Sciences
BJEPS

Volume 6 | Issue 1 Article 6

Linking Commercial Streets to The Sustainability of Urban Neighborhoods: AL-Adhamiya- Baghdad as a Case Study Analysis

Sarah Mohammed Jameel
Department of Architecture, Faculty of Engineering, University of Babylon, Babylon, Iraq

Raghad Ahmed Fadhil
Department of Architecture, Faculty of Engineering, Mustansiriyah University, Baghdad, Iraq

Recommended Citation
Jameel, Sarah Mohammed and Fadhil, Raghad Ahmed (2025) "Linking Commercial Streets to The Sustainability of Urban Neighborhoods: AL-Adhamiya- Baghdad as a Case Study Analysis," *Al-Bahir*: Vol. 6: Iss. 1, Article 6.
Available at: https://doi.org/10.55810/2313-0083.1085

ORIGINAL STUDY

Linking Commercial Streets to the Sustainability of Urban Neighborhoods: AL-Adhamiya—Baghdad as a Case Study Analysis

Sarah M. Jameel [a,*], Raghad A. Fadhil [b]

[a] Department of Architecture, Faculty of Engineering, University of Babylon, Babylon, Iraq
[b] Department of Architecture, Faculty of Engineering, Mustansiriyah University, Baghdad, Iraq

Abstract

This study concentrates on the connection between the commercial streets and the sustainability of neighborhoods by using Al-Adhamiya in Baghdad as a case study. The gap of knowledge lays in the limited realization of how the spatial features of commercial streets contribute to the sustainability of the neighborhood. The purpose of the study is to assess the current condition of the commercial streets for the sake of determining how their spatial characteristics contribute to the sustainable urban development in a quantitative way. The research used the mixed-method approach (analysis of previous studies and development of a theoretical framework combining the selected research vocabulary, quantitative analysis using computer programs of the research case study). The research uses DepthmapX 0.8.0 metrics, just like connectivity, choice, control, integration, intelligibility, synergy and visual graph analysis. These metrics are used to evaluate the permeability and social dynamics of the streets in the area of the study, which consists a historic and commercial centre presenting a mix of the traditional and the modern architectural styles. The study highlights the fundamental role of the commercial streets, such as Corniche Street and Imam Al-Azam Street, in enhancing accessibility and promoting social interaction, which are crucial elements in achieving the sustainable urban development. However, some challenges such as the hybrid nature of the urban fabric affects the intelligibility and synergy of the area. The study emphasizes the importance of the integrated urban planning in the improvement of connectivity and balance historical preservation with the urban expansion of long-term sustainability.

Keywords: Spatial analysis, DepthmapX 0.8.0, Intelligibility, Synergy, Visual graph analysis, Baghdad

1. Introduction

Achieving urban sustainability becomes the key priority for planners and urban designers in recent era, especially through the formation of residential neighborhoods which are easily accessible. Therefore, it is necessary to analyze the morphology of these neighborhoods by identifying the major spatial features of the commercial streets which support accessibility. Furthermore, this enhances an efficient environment at all levels, contributes in shaping the image of the place, and promotes it's social, economic and cultural identity, as well as strengthening the sense of belonging to the place.

A large number of studies have classified the concept and the features of commercial streets within cities. According to William Whyte, the commercial street works as the lifeline of the city where people converge. It is considered to be a vibrant area which requires renewal and maintenance efforts, the creation of pedestrian spaces, the promotion of environmental sustainability, and the regulation of traffic density. In addition to achieving the social and psychological needs. In the alte 17th and early 18th century, these streets are

Received 10 October 2024; revised 30 December 2024; accepted 31 December 2024.
Available online 30 January 2025

* Corresponding author.
E-mail addresses: sara.jameel@uobabylon.edu.iq (S.M. Jameel), raf87arch@uomustansiriyah.edu.iq (R.A. Fadhil).

https://doi.org/10.55810/2313-0083.1085

hubs for commercial activities, social interaction, and entertainment. When the industrial revolution rises, the concentration has been shifted towards developing the streets to accommodate the growing of population and the increasement in the number of vehicles. Nowadays, the global trend leans towards creating lively streets which offer comfort, safety, aesthetic appeal, a sense of cultural and spatial identity, and the capacity to attract people, thereby enhancing the quality of life in public spaces [1].

It is found that the commercial streets are the vibrant core of any city and they work as the hubs for entertainment, commerce and social interactions. They also reflect the culture of the area and they are used as a means to estimate the well-being of the residents. Therefore, they are considered as a common kind of public space which is accessible to the general public. Because of their nature, the commercial streets contribute to the well-being of users by providing welcoming, lively, and human-friendly environments with the minimal obstacles or discomfort [2].

Ref. [3] defines the commercial street as the pivotal part of the city which performs different activities and functions, just like: shopping, services and leisure. Urban commercial streets offer a wide range of street activities which can be classified into two major functions: place and accessible axis. As a "place", the commercial street works as a destination In itself, where the aim of the users of the street is to fully utilize the specific characteristics which are available in this street particularly, most of the time through walking. As an accessible "axis", the street provides a pathway for movement and it forms an integral part of the broader urban street networks and other special urban transportation networks. The users of this axis can move by using different means just like: private cars, buses, bicycles, or on foot. The key demand of the users is to follow a continuous linear path through the street network, and ensuring easy connectivity from the beginning to the end of their journey.

Ref. [4] says that commercial streets are often considered as one of the most prominent forms of public space and they constitute a significant portion of open public spaces in urban environments. Because of the social and the recreational activities that take place within the commercial streets, these streets are important to people's daily lives. They are designed to match these requirements and to play a positive role in economic development, as well as, to contribute in the social and the material well-being of the population and to foster a sense of community belonging.

Commercial streets are mixed-use spaces that supply opportunities for social interaction and various activities, with a special concentration on economic functions and they participate as key pedestrian areas. The identity of the city is often defined by its streets and public spaces and the image of the city is shaped by its squares, central roads, and neighborhoods. Streets can connect people to places, enhance the effectiveness of commerce, social interaction, and movement and they contribute to the cultural, economic and the political vitality of cities [5].

The space of the street represents a dynamic environment which connects more static spaces and it is bounded by the mases of buildings on each side. It is one of the most important visual elements in the urban environment through which the observe moves, with the elements of the urban environment that are arranged along and around it. The urban scene of the commercial street has several features as summarized by Ref. [6]:

- Vitality and activity to ensure that the street scene is attractive.
- Effectiveness and structural cohesion, with the facades of buildings which display in a way that draws people in, and to provide a sense of enjoyment and intrigue.
- Achieving an acceptable degree of enclosure, reflecting the relationship between the width of the space and the height of the surrounding buildings.
- The integration of form and function within the street space, which increases the number of users.
- The street should feature a shaded environment, offering protection from environmental and climatic conditions, contributing to a human-scale experience.
- The street should be visually appealing and provide necessary information.
- It should provide a sense of safety and clarity.

2. Materials and methods

2.1. The relationship between the sustainability of commercial streets and residential neighborhoods

Many studies have classified the sustainability of both the commercial streets and the residential neighborhoods separately. According to the question of the research; "why do we need efficient commercial streets within the urban environment?", this research aims to establishing a common link

between the indicators of sustainability for commercial streets and those for residential neighborhoods to derive the final indicators which can be measured quantitively, as will be explained in details within the research. See "Table 1".

Different options have been presented as a response to the need for successful streets. These opinions suggest that we require the creation of a unique local identity, fostering a sense of belonging and pride, in addition to the need for shaping and directing both the current and the future development. Furthermore, it is important to enhance the physical identity of the area and to improve the social integration (including accessibility) by providing connected routes among nodes and streets for leisure, walking and cycling. Other factors include: promoting biodiversity, restoring green infrastructure, and boosting shopping potential which in true increase the economic income and provide cultural, social and recreational activities. It is found that successful commercial streets also contribute for a butter realization of the cultural, the historical and the archeological significance of the identity of the place. The commercial streets offer accessible outdoor commercial services and improve the environmental opportunities for enjoying the connection with the natural world [3].

Ref. [2] identified a group of tangible and intangible features of sustainable commercial streets. The tangible features consist of the following characteristics:

- Accessibility
- Vitality
- Safety
- Diversity
- Quality and efficiency
- Functionality
- Comfort and enjoyment

The intangible features include a range of qualities, such as:

- Excitement
- Social interaction
- Clarity
- Cohesion
- Identity

Table 1. Sustainability principles of commercial streets (source: Authors based on the previous studies).

Sustainability principles of commercial streets		
Design dimension	Accessibility	Connectivity and permeability, Pedestrian mobility, Access and linkage, Directional signs.
	Safety	Dynamic streets, Safe sidewalks, security contract.
	Efficiency	Free movement, linear street layout & facilities organization.
	Functionality	Suitable organization & variation of facilities, easiness of usage and access by users.
	Diversity	Multiple choices of services and transits.
	Mixed use	Mixed use development, mixed land use.
	Pedestrian environment	Comfortable movement, clear sidewalk configuration.
Social dimension	Attractivity	Visual appearance for both of components & activities.
	Place identity	Image & identity, symbolic meaning, heritage value, historical meaning, monumental memory, encourage social interaction, dynamic spaces, welcoming spaces, attractive nodes.
	Liveability	Streets' control, pedestrian sociability.
	Visibility	Openness & comprehensiveness of components organization.
	Inclusion	Equal chances for use & access of all users.
	Cultural aspects	Sense of place, age of streets, cultural factors, personal space, demographic structure.
	Social aspects	Needs, variety of activities, availability of kiosks, extension of curb side commercial effectiveness, connectedness.
Environmental dimension	- Enhance the protection from climate & pollution. - Waste management & recycling. - Place location & surrounding. - Local retail. - Buildings proportions & orientation. - Streets & buildings orientation. - Natural daylight. - Minimize the urban heat island effect.	

A study Ref. [7] indicated that the characteristics of environmentally sustainable commercial streets are achieved through a framework consisting of four main dimensions: economic sustainability, environmental sustainability, social sustainability, and design sustainability. The study employed a strategy focused on urban street design standards within the framework of sustainability, utilizing the Prisma meta-analysis method. The research followed three rounds of the Delphi Technique to gather expert opinions on the indicators, resulting in the identification of 19 key attributes. These included environmental sustainability (adaptation, reducing urban heat island effects, comfort, pollution reduction, ecological balance, and supporting green life). Social sustainability encompassed (equity, safety, accessibility, diversity, and cultural heritage). Economic sustainability involved (intensive land use, efficiency, job creation, and increasing property value). Finally, design sustainability included (urban concepts). These dimensions contribute to enhancing sustainable urban streets and, consequently, advancing the city's sustainable development. The study concluded that these extracted attributes and indicators will assist urban planners and experts in making optimal design choices for new or redeveloped urban streets, ultimately improving sustainability and urban aesthetic performance.

A study Ref. [8] aligns with previous research in several aspects, as it assessed the current state of commercial streets in the city of Shkodër, Albania, by applying a comprehensive approach to enhance their functionality, aesthetics, and sustainability. This was achieved through the implementation of the "shared streets" approach, which aims to transform streets into shared spaces that harmoniously accommodate commercial activities, pedestrians, vehicles, and cyclists. The study identified a set of design principles for sustainable urban streets, including ground-level street design, infrastructure, accessibility, vibrancy, urban street edges, transportation patterns, environmental comfort, historically valuable buildings, public art, and visual aesthetics.

A study Ref. [9] categorized the key concepts for evaluating sustainability in commercial streets and public spaces into three main dimensions: Design Configuration, Activity, and Environmental Aspects. These dimensions were linked to six essential factors that must be achieved within commercial streets: Place Identity, Mixed-Use Development, Pedestrian Environment, Accessibility, Safety, and Green Environmental Aspects. The study concluded that these concepts are closely tied to transforming traditional streets into vibrant, activity-rich spaces designed to serve current generations without compromising the rights of future generations.

It is found that the concept of neighborhood planning dates back to 1915 when Robert E. Park and E.W. Burges present the idea of the "neighborhood" as an ecological concept with certain implications for urban planning. After that, various concepts and ideas of neighborhoods have emerged. Neighborhood planning represents a process of developing a shared vision or it is a method for making the residents involved in solving the problems of neighborhood. It is a process in which the residents can gain a realization of their neighborhood, imagine a shared future, and develop some strategies to shape it in the best way, while ensuring its long-term protection. The purpose is to encourage the social and the economic future investments towards creating sustainable neighborhood [10].

A sustainable neighborhood is a multi-purpose area where the aim of the residents is to live and work in both the present and the near future. It has been demonstrated that incorporating the principles of sustainability into the design of sustainable neighborhoods is useful, as many issues faced by cities are cumulative in nature because of the poor planning at the micro level. Analyzing the scale of neighborhood can assist in developing an effective and a sustainable local infrastructure [11].

A sustainable neighborhood should possess a set of key characteristics, as outlined by Ref. [12]: **Balanced**: It should contain an integrated mix of suitable homes of various types to support a diverse range of family sizes, ages, and economic incomes.

- **Well-connected**: A sustainable neighborhood features a clear and well-understood street and space layout that facilitates easy movement between different destinations, neighboring areas, and other parts of the city.
- **Safe and secure**: The neighborhood should be an attractive and safe place to live, with well-maintained buildings and public spaces.
- **Environmentally respectful**: A sustainable neighborhood respects its natural environment, efficiently uses available resources, and leverages its surroundings as a positive asset.

UN-Habitat has outlined five principles for sustainable neighborhoods [13]:

1. **Adequate street space and an efficient street network**: The street network should comprise at least 30 % of the total land area.
2. **High density**: The neighborhood should have a population density of no less than 15,000

people per square kilometer, or 150 people per hectare.
3. **Mixed land use**: At least 40 % of the land area should be allocated for economic activities within any given neighborhood.
4. **Social diversity**: Housing should be available at a range of price points to accommodate a wide spectrum of income levels, with 20–50 % of the ground floor area designated for affordable housing.
5. **Land use allocation**: Single-function blocks should occupy less than 10 % of any neighborhood.

The aim of the five principles which are promoted by UN-Habitat is to enhance the sustainable development by creating livable, safe, and efficient neighborhoods. Sustainable neighborhoods have the following characteristics:

- **Vibrant streets**: These principles support and encourage active street life by enabling a variety of activities. The focus on high density and mixed land use fosters a lively street environment. High population density generates increased demand for services, thus activating thriving city streets that meet the physical and social needs of residents, while fostering a safe and dynamic urban life.
- **Walkability**: A sustainable neighborhood promotes walkability as a crucial step in attracting people to public spaces, reducing congestion, and supporting the local economy. Lively streets encourage people to walk and cycle.
- **Housing availability**: Sustainable neighborhoods support affordability in economic activities, housing, and services by promoting proximity, reducing costs, and providing services to a diverse range of residents. See "Table 2".

Table 2. Neighborhood sustainability principles (source: Choi, 2024 [12]).

Neighborhood sustainability principles	
Environmental sustainability	Land use & allocation.
	Natural & built forms.
	High density.
	Accessibility & connectivity.
Social sustainability	Quality of life.
	Social capital.
	Safety & security.
	Social mix.
	Land use specification.
Economic sustainability	Efficiency & viability
	Affordability
	Transport & travel

2.2. Spatial analysis of commercial streets

The structure of the city is formed by its urban street network, the composition of the city realized through a hierarchically arranged street patterns and the design of the residential neighborhoods which are based on the model of the neighborhood unit. Within this context, the street network in a neighborhood is considered as one of the most significant factors which is affecting the urban development, as it plays an important role in determining the quality of life in the city.

Spatial analysis is a method that is developed by Bill Hillier and his research team in the 1970s to describe and quantitatively analyze spatial configurations, from the residential scale to the urban level. This method allows for the evaluation of accessibility and the expected perception of streets and alleys which make up the overall street network. It is considered as a valuable means for analyzing cities and making informed decisions in urban design and planning studies. Spatial analysis concentrates on the interaction between the society and the spatial configurations which shape it. The analytical data reflect the patterns of settlement, the relationship between streets and buildings, and the integration of open and closed spaces with the social structure of the area. An important feature of this method is its ability to demonstrate how both the historic and the modern spatial models function visually, and it allows for comparison and prediction of issues of the future and solutions in studies of design [14].

The principles of spatial configuration are found in human-centered science which analyzes the relationships between the spatial structures and the social, the economic and the environmental dynamics. These relationships include different aspects such as: patterns of movement, social interaction, use of land, social diversity, and urban growth. The essential information that is related with the spatial configuration has a philosophical nature, as it is proposed by Bill Hiller, who refers to the concept of space as "Newtonian space". This concept represents the idea of linking different parts of space and function as a "machine" which are spatially unified at its core. This notion is clearly articulated in his book "Space is a machine" which makes a shift from the structural realization of space to the concept of "Space as a machine" through the introduction of the theory of spatial configuration. The principles of spatial configuration, depend on the morphological analysis of the urban structure by utilizing the topological spatial relationships that take place between the components of the urban

environment (such as mass and space). This analysis is conducted through the mathematical tools that connect these components to some extent, and it is known as "spatial representation". It involves studying and analyzing the relationship between the elements of urban structure, considering both the global and the local relationships, and using what is referred to as "graph theory" [15].

Spatial analysis depends on a group of metrics which are based on the methodology that is used for measurement for the sake of achieving the desired quantitative results. This process is considered the temporal stages of the development of the city and it conducts a morphological analysis through various topological and sectional metric map. The analysis makes use of the software DepthmapX 0.8.0, which is designed for such measurements. This software produces three types of morphological analysis:

- **Metric**: Represents the shortest distances.
- **Topological**: Represents the least number of turns within pathways.
- **Geometric**: Also known as angular, representing the smallest angular changes within pathways.

The principles of space analysis begin by representing movement and occupation within spaces, followed by the fundamental functions, where permeability is a key characteristic of the functional plan structure. This is represented through the **convex map** and the **axial map**. A convex space refers to a space in which a straight line can be drawn without crossing the space's boundaries, typically represented by the interior spaces of buildings. In contrast, the axial space represents the shortest straight axial lines that can be drawn within the urban space, offering a representation of the movement axes and spaces within the urban network. These axial lines also serve as lines of sight [14].

The software *DepthmapX 0.8.0* provides an analysis of several metrics, including: connectivity, integration, control, choice, depth, number of nodes, density, intelligibility, and synergy. This software assigns specific values to these metrics which are often represented by a color gradient. This allows for an effective visualization of relationships within spatial networks. The analysis is conducted by inputting specific radius values which are determined by the research. For example, a radius of 400 m is set to measure the effectiveness of the metrics for pedestrians and children in accessing schools, a radius of 800 m is used to evaluate the access of pedestrian in public transportation. The analytical capabilities of the program are based on the theory of the city and in particular the concept of "distributed centrality" which is an important thing in realizing the structure of sustainable cities. The program helps to uncover the fine local structures that are not immediately visible to the naked eye, thereby it enhances the structural understanding of the city [16].

Recently, the use of spatial analysis has gained popularity in the field of architecture, urban design, and transportation. The theory of spatial is an effective means that is used for analyzing the social logic of space and it works as a general predictor of the patterns of movement and the levels of interactor between people in urban environments, as well as their social and economic behaviors and relationships. Consequently, it helps to form an understanding of the accessibility of the network of the street and it measures its permeability with other parts of the city [1].

The study by Ref. [16] employs the theory of space syntax to examine the level of connectivity and to understand the relational dynamics between the configuration of the network of the street and the informal settlement patterns along with the probabilistic distribution of the movement of pedestrian through the axial analysis and the visual graph analysis. The study measures variable values such as accessibility, integration, permeability, and walkability to conduct an analysis of the Kampung Taman Sari in Indonesia.

Furthermore, Ref. [17] conduct a spatial analysis of the Esentepe area in Istanbul by analyzing the spatial accessibility of the street network in its current state. This happens by creating axial maps of the neighborhood and then generating integration and connectivity maps to assess accessibility that is based on the plan of future development for the same neighborhood. The results are compared between the current and future states to understand the accessible features of the street network in the neighborhood. The study conclude that the values of integration and connectivity increase in comparison with the existing conditions. Thus, spatial analysis works as a guiding tool, it highlights the important issues such as: the selection, the design, and the development of settlements in urban planning, while the axial system aids in assessing the areas of social interaction for residents.

The study by Ref. [18] aims to analyze the values of intelligibility, which reflect the accessibility and the spatial features of the streets in the Orcanik Orker area of turkey by using the spatial analysis. The methodology of the spatial analysis provides tools for examining the logistic properties of spaces and its analysis is conducted in three stages. In the first stage, the values what are related with the street

fabric are examined by using the spatial integration maps, and by using that data which is collected from the area of the study for the sake of identifying the regions with high and low values of integration in the street fabric. In the second stage, visibility graph analysis is applied for determining the visible areas within the street fabric. The final stage involves the evaluation of the historic region. The study concludes that the streets with social and cultural functions, traditional architectural patterns, commercial areas, and community centers exhibit values of high integration and they are effective in the spatial configuration.

2.3. Research methodology

The primary objective of this research is to formulate an accurate quantitative approach to test the potential for achieving sustainability in residential neighborhoods by examining the spatial characteristics of the commercial streets within them. The research aims to highlight the relationship between commercial streets and the sustainability of the neighborhoods they are part of, and to inform stakeholders and urban developers about the important quantitative measurement mechanisms that provide an accurate assessment of the studied streets and identify areas that require current and future development.

The research adopts a mixed-method approach through a methodology composed of several key steps:

1. **Literature Review Analysis:** The research begins with an analysis of previous studies, particularly those related to concepts such as "commercial streets," "residential neighborhood sustainability," and "spatial analysis of commercial streets." The best practices in these fields were explored to establish the theoretical foundation for these concepts.
2. **Development of the Theoretical Framework:** Based on insights gained from an in-depth study of the literature, the research developed a conceptual framework and proposed a set of indicators to establish an effective relationship between the research variables. A set of indicators was selected for commercial streets and residential neighborhoods to be measured quantitatively through spatial analysis. This constitutes the research's new contribution to knowledge and a step toward advancing the quantitative measurement of these concepts.
3. **Analysis of the Selected Case Study (Al-Adhamiya District):** A set of indicators was chosen for quantitative measurement, using the program *DepthmapX 0.8.0* to evaluate several provided metrics, including connectivity, global and local integration, control, choice, density, intelligibility, synergy, and Visual Graph Analysis. This analysis aims to highlight the economic, social, and cultural significance of the area, as it represents a key urban node with historical importance and a role in the urban formation of Baghdad. See "Table 3", "Fig. 1".

2.4. Case study description (AL-Adhamiya District—Baghdad)

Al-Adhamiya is located in the northwest of Baghdad, covering an area of approximately (26) square kilometers. It is one of nine administrative districts within the city. The area derives its name from Imam Abu Hanifa Al-Nu'man, who was buried there and was referred to as "The Great Imam," giving the district its name, Al-Adhamiya. The district features a blend of architectural and urban styles, ranging from traditional to modern, creating a temporal snapshot of its public spaces over different historical periods and reflecting the changes the city has undergone.

In addition to its cultural significance, Al-Adhamiya's urban location is notable, as it is bordered by the Tigris River on three sides, forming a peninsula. Its strategic position connects different parts of Baghdad, linking to Kadhimiya via the Imams Bridge, to Mansour through Al-Adhamiya Bridge, and to the city center via Imam Al-Azam Street [19].

Morphological Development Stages of Al-Adhamiya [20]:

1. **First Morphological Stage (From inception to 1920):** At this stage, the Mosque of Abu Hanifa Al-Nu'man was the heart of the city, and the city's expansion radiated from this core. The

Table 3. Elected commercial street's sustainability indicators for quantitative analysis (source: Authors, 2024).

Elected commercial street's sustainability indicators for quantitative analysis		
Design dimension	Sustainability Indicators	Space syntax indicators
	Accessibility	Connectivity, Integration
	Safety	Choice, Control
	Functionality	Integration
Social sustainability	Attractivity	Intelligibility
	Visibility	Intelligibility, Visual Graph Analysis
	Liveability	Control
	Inclusion	Synergy

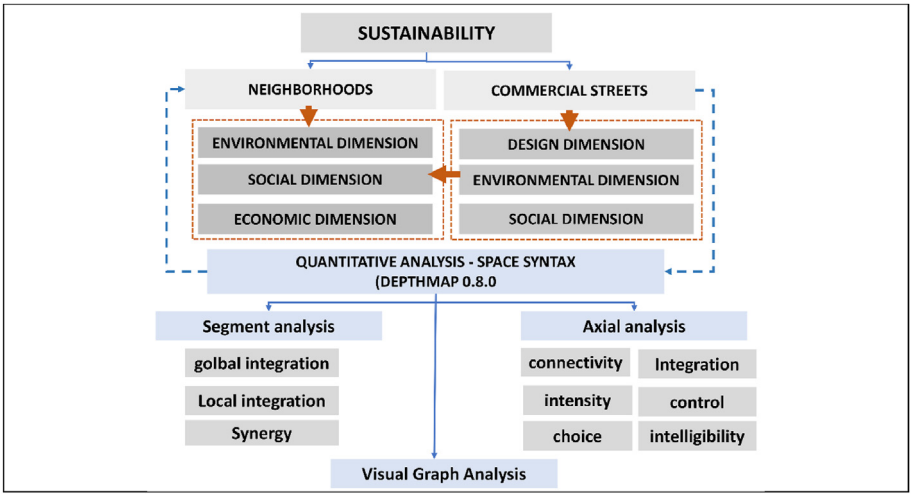

Fig. 1. General structure of the research (source: Authors, 2024).

main markets, residents, and some religious educational institutions were drawn to this area, leading to urban development around this nucleus. A key feature of the streets during this period is their organic layout, characterized by narrow, winding alleys connecting the streets.

2. **Second Morphological Stage (1920–1936):** Al-Adhamiya consisted of residences surrounding the shrine of Imam Abu Hanifa, and the area began to gradually expand and change. With the discovery of oil, there was a qualitative shift in expansion, accompanied by a diversification of uses, including economic, commercial, and industrial activities. New streets were created to align with the evolving urban landscape, including Imam Al-Azam Street and Omar bin Abdul Aziz Street, which became key commercial streets in the area.
3. **Third Morphological Stage (1936–1956):** This stage saw the expansion of roads and bridges to facilitate the movement of residents between the two sides of the city. Wide, straight streets were built within the residential neighborhoods, such as Corniche Street along the Tigris River, and streets like Street 20 and Safina Street. These developments contributed to the rapid growth of commercial and economic activity in the region.
4. **Fourth Morphological Stage (1956–2024):** This stage witnessed the construction of several bridges, enhancing the area's commercial and social prominence. Preservation and restoration work was carried out on the Mosque of Abu Hanifa Al-Nu'man and surrounding heritage buildings, including restoration projects by the Paul Service Company in 1973. See "Fig. 2(A) and (B)", "Fig. 3(A) and (B)".

3. Results

The results related to the measurement of the "choice" metric show that the highest value (95,075), is recorded for Corniche Al-Adhamiya Street, due to the multiplicity and permeability of visual and movement axes from the surrounding areas. This is followed by moderate values along Embassy Street (the service street for Corniche Al-Adhamiya), which is perpendicular to Corniche Street, with a recorded value of (7,941). Street 20 follows with a value of (7,469), representing favorable values for commercial streets in the area. Imam Al-Azam Street recorded a value of (5,717). See "Fig. 4 (A)".

The "connectivity" metric also registers high values, with the highest being (27) on Corniche Street. This indicates a strong accessibility indicator, showing that the area is highly accessible for both pedestrians and vehicles. This is followed by important commercial streets such as Safina Street, which leads to the shrine of Imam Abu Hanifa Al-Nu'man, and Street 20, with a value of (24), followed by Embassy Street. This suggests that the study area exhibits effective connectivity in terms of commercial activity, communication, and presence. The lowest connectivity value was recorded for Shabab Street, which leads to the Royal Cemetery. This is due to its predominately educational activities and isolation from commercial activity. See "Fig. 4 (B)".

The measurement of the "integration" metric shows the highest value of (2.610), which is considered high and favorable. This is attributed to the increased axial movement and visual connections with surrounding areas, as well as the studied streets' connections to other parts of the city. The integration nuclei, represented by commercial

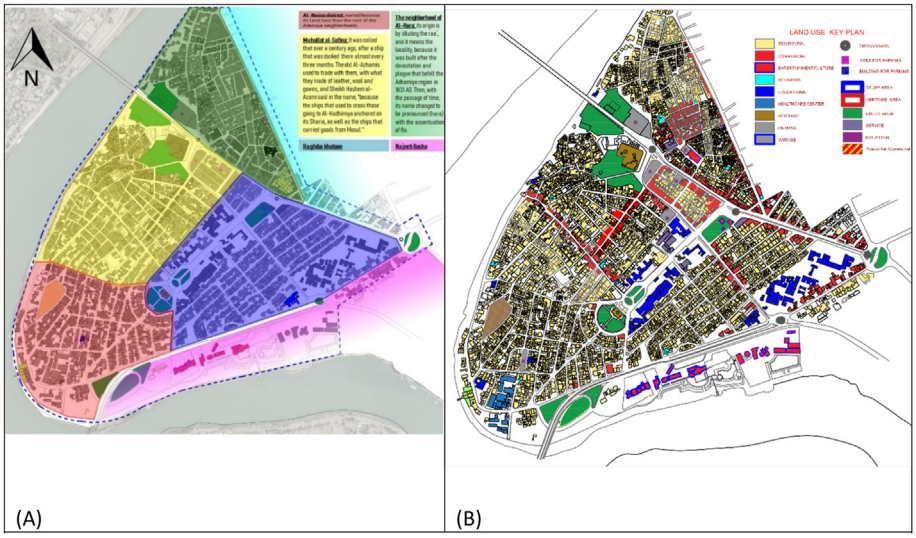

Fig. 2. (A) Urban neighbourhoods within the case study area, (B) land uses within the case study area (source: Authors, 2024).

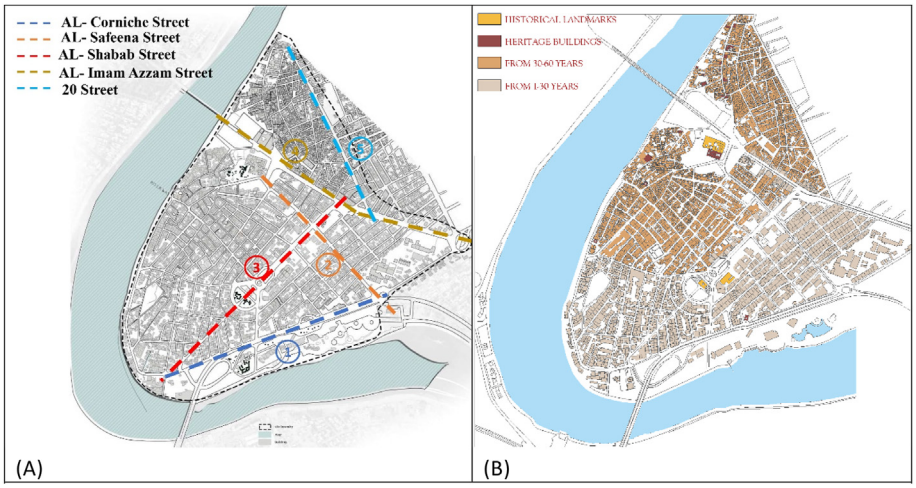

Fig. 3. (A) Commercial streets within the case study area, (B) buildings condition within the case study area (source: Authors, 2024).

streets in the area, exhibit a branched and parallel linear form. The highest value was recorded on Embassy Street, due to its multiple connections with the network of commercial streets in the area, followed by Shabab Street with a value of (2.57). Moderate values were recorded for Corniche Street at (2.46) and Imam Al-Azam Street at (2.45), indicating that the area enjoys a good level of social interaction and economic activity, as well as its proximity to other city streets. The lowest value was recorded on Street 20, at (2.10), due to its relative isolation. See "Fig. 5 (A)".

The measurement of the metric integration index at radii of (400, 800, and 1200 m) shows that the highest integration value at a (400-m) radius is within the central core of the studied area, as it represents the center of the Adhamiya district. Its streets are highly centralized, requiring few transitions to move between them. The integration core begins to expand at an (800-m) radius, encompassing the commercial streets surrounding the center, which are areas of social interaction and meetings, in addition to their commercial nature. The peak integration values are recorded at a (1200-m) radius, where the studied streets reach high values. This indicates that they possess high movement permeability and a good level of social interactions and mixed-use activities. The further the distance within the radius for the observer, the more alternatives and options are available to access the intended streets. See "Fig. 5 (B)".

The results of the "Intensity" metric show that the highest value is (0.945) on Embassy Street, followed by Corniche Street and Shabab Street, both with a

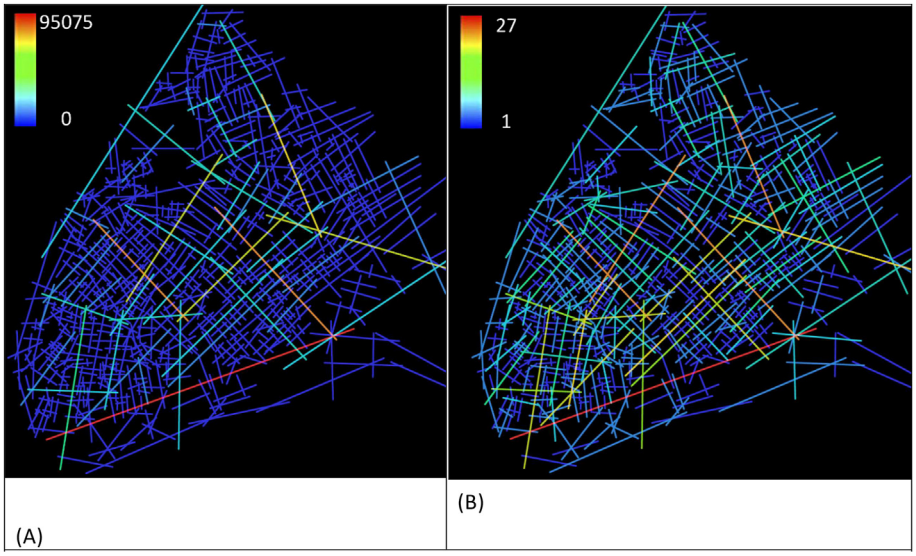

Fig. 4. (A) Choice measurement related to axial analysis, (B) connectivity measurement related to axial analysis (source: Authors, 2024).

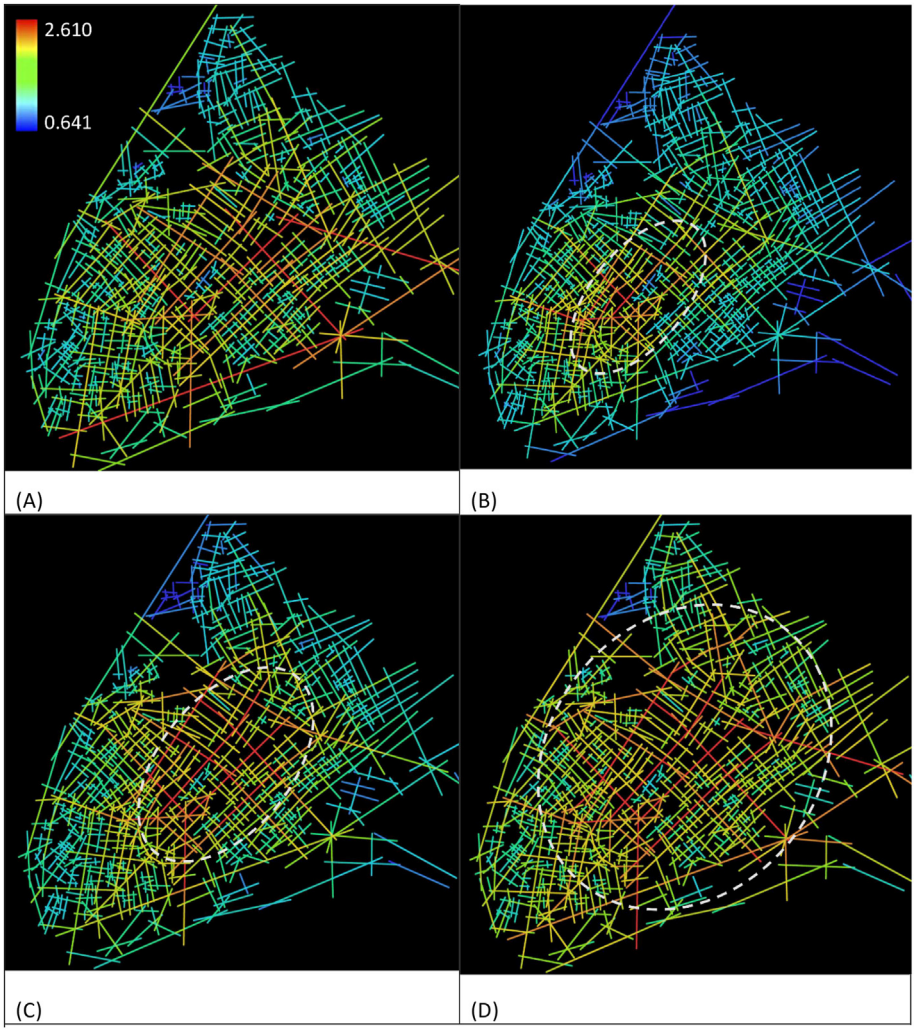

Fig. 5. (A) Integration HH measurement related to axial analysis, (B) integration (400 m) measurement related to segment analysis, (C) integration (800 m) measurement related to segment analysis, Integration (1200 m) measurement related to segment analysis (source: Authors, 2024), (D) Integration (1200 m) measurement related to segment analysis.

medium value of (0.93). Streets 20 and Imam Al-Azam Street recorded lower values of (0.82) and (0.84), respectively. These streets exhibit high movement and usage density due to the diverse range of activities and the abundance of markets, as well as Corniche Street's direct view of the Tigris River. See "Fig. 6 (A)".

The results for the "control" metric show that the highest value recorded is (6.869) on Corniche Street, due to the multiple intersecting grid streets perpendicular to this street. The value then gradually decreases, with Safina Street at (5.43), followed by Street 20 at (4.34). Additionally, Imam Al-Azam Street shows a value of (3.56), and Embassy Street records (3.85). These values indicate that the studied streets enjoy a good level of permeability and accessibility through their surrounding areas, as well as providing alternative connectivity through adjacent spaces. See "Fig. 6 (B)".

The "intelligibility" metric recorded a relatively low value of (0.3881), indicating a reduced ability to understand the unified whole through its parts. This is attributed to the hybrid nature of the urban fabric (a mix of organic and grid patterns) in the study area, transitioning from traditional, organically patterned residential areas to newer, grid-planned ones. As a result, there is no clear, cohesive image of the area as a whole. See "Fig. 7 (A)".

The "synergy" metric, which represents the direct relationship between the smallest and highest global integration radii, recorded a value of (0.5412). This indicates that the area's urban network exhibits a moderate degree of cohesion and balance. See "Fig. 7 (B)".

The map produced by the Visual Graph Analysis shows that the highest values of visual clarity, represented in red, are found on Corniche Street. This is due to its commercial and recreational nature, not only at the level of Adhamiya but also for the city of Baghdad as a whole, given its openness to the Tigris River and its popularity. Next in terms of visual clarity is Imam Al-Azam Street, due to its social and cultural significance, hosting numerous religious social events and serving as a gathering place for social interactions during holidays and Fridays. Additionally, its year-round commercial activity further enhances its clarity. Following that is Shabab Street, which shows a moderate value due to its strong linear axis, wide street layout, and cultural significance. The lower values, represented in blue on the map, are found in the internal streets and alleys of the residential areas, most of which are characterized by their traditional organic layout. See "Fig. 7 (C)"

4. Discussion

The results of the spatial analysis which are conducted on the Al-Adhamiya district reveal several important findings concerning the relationship between the commercial streets and the neighborhood sustainability. First, the high values which are recorded in metrics such as: choice, connectivity, and integration (i.e. particularly in Corniche Street) underscore the essential role of this street in promoting the accessibility and the movement within the district. Corniche street, with its direct connection with the Tigris River and surrounding urban areas, demonstrates how well-planned commercial streets can enhance both the pedestrian and the vehicular movement and these streets can contribute to the overall vibrancy and functionality of the area.

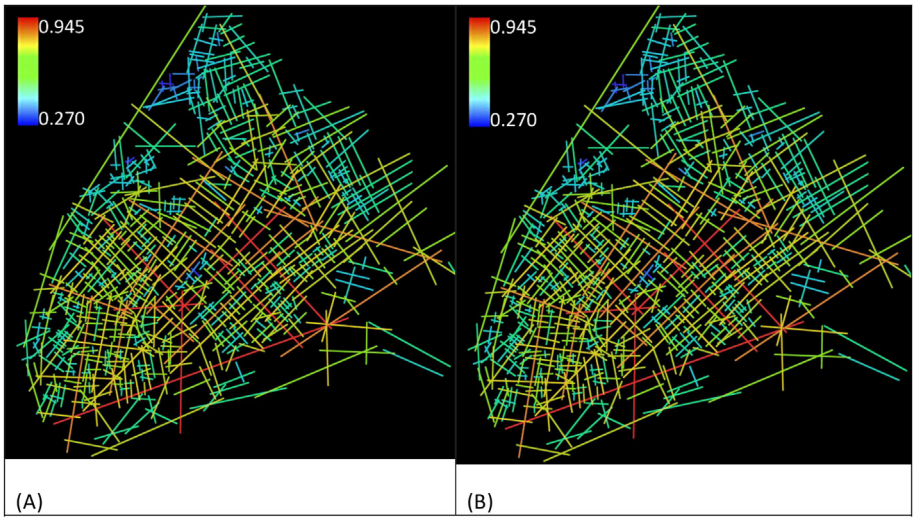

Fig. 6. (A) Intensity measurement related to axial analysis, (B) control measurement related to axial analysis (source: Authors, 2024).

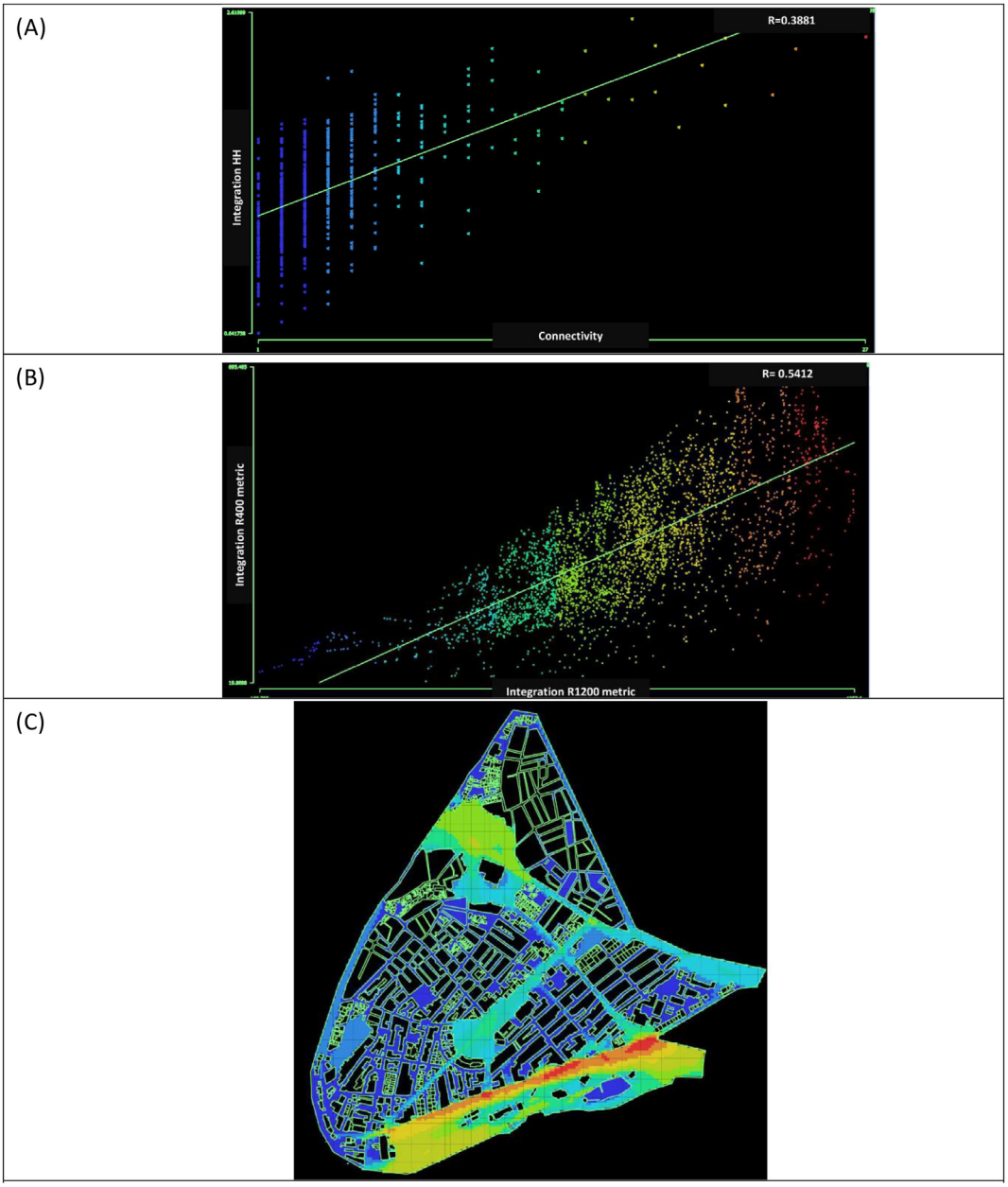

Fig. 7. (A) Intelligibility measurement related to axial analysis, (B) synergy measurement related to segment analysis, (C) visual graph analysis (source: Authors, 2024).

The values of high connectivity which have found in streets like Safina and Imam Al-Azam Street highlight the importance of these streets as commercial and social hubs. These streets do not only facilitate the movement but also work as an important space for the social interaction and the cultural exchange, especially during the religious events and the holidays. This connection between the physical infrastructure and the social dynamics is essential in achieving the sustainable urban development.

However, the value of low intelligibility relatively points to the challenges in the spatial cohesion of the area. The hybrid nature of the urban fabric, which combines the patterns of the traditional organic street with the newer grid layouts, leads to a fragmented perception of the neighborhood as a whole. This suggests the need for strategies of more cohesive urban planning which integrate these different urban patterns in a way that enhances the overall legibility and navigability of the district.

Moreover, the value of moderate synergy indicates a balanced but not fully optimized relationship between the street network and the broader urban movement. This finding potentially refers to the improvement in terms of enhancing the integration between the local and the global street networks. By addressing these spatial inefficiencies, the area can improve its social and economical interactions and it make it more resilient and sustainable in the long term.

The results of visual graph analysis, particularly for Corniche Street and Imam Al-Azam Street, reinforce the significance of these streets as visually and socially prominent areas. It is found that their high visual clarity and accessibility make them crucial focal points for both the commercial activity and the social engagement. In contrast, the lower visual clarity in the residential alleys and the internal streets reflects the more secluded and the traditional nature of these spaces, which contributes to their lower integration with the broader street network. Generally speaking, these findings suggest that while Al-Adhamiya benefits from the strong commercial streets while support the economic and the social activity, there are opportunities for enhancing the spatial cohesion and the integration of its urban fabric. By concentrating on improving the intelligibility and the synergy of the street network, urban planners can promote the sustainable development in the district and what ensures that its commercial and residential areas work in harmony to support the well-being of its residents.

5. Conclusions

- The study emphasizes the crucial role of commercial streets in supporting the sustainability of urban neighborhoods by enhancing accessibility, social interaction, and economic vitality. Through spatial analysis, tools like DepthmapX are utilized to quantitatively assess these streets, with metrics such as connectivity, integration, and permeability offering valuable insights into their functioning within the urban landscape. This data is crucial for urban planners and developers in designing effective spaces.
- Al-Adhamiya, a district in Baghdad, is highlighted for its cultural and historical significance. The blend of traditional and modern urban styles, coupled with its strategic location near the Tigris River and landmarks like the Mosque of Abu Hanifa, has made the area a vibrant commercial and social center. The spatial characteristics of streets, such as Corniche and Imam Al-Azam, including layout and visual clarity, are shown to significantly impact neighborhood accessibility and functionality, contributing to sustainable development.
- However, the district's hybrid urban fabric, which mixes organic and grid layouts, presents challenges for spatial intelligibility, impacting the overall coherence of the neighborhood. This underscores the need for integrated urban planning to enhance connectivity.
- The research suggests that future urban development should focus on improving street integration and connectivity. By balancing historical preservation with modern growth, strategic planning can further boost the social and economic vitality of neighborhoods, promoting long-term sustainability.
- The research suggests a set of ideas for future studies by taking advantage of the quantitative analysis method and applying other analysis programs that measure another set of urban indicators related to urban vocabulary, or studies that propose comparing the results of quantitative analysis between two or more areas, or studies that address both quantitative and qualitative analysis and comparison between them to give a clear picture of the future urban development path of areas, especially areas of historical and commercial importance of cities.

5.1. Research limitation

The study on the relationship between commercial streets and neighborhood sustainability in Al-Adhamiya, Baghdad, encountered several limitations. First, the research heavily relied on quantitative spatial analysis using DepthmapX 0.8.0, which, while effective, may not fully capture the qualitative aspects of human behavior, social interactions, and cultural dynamics within the studied urban spaces. Additionally, the hybrid nature of Al-Adhamiya's urban fabric, characterized by a mix of traditional organic patterns and modern grid layouts, posed challenges in achieving a cohesive spatial analysis. The data collection process was also constrained by the availability of up-to-date urban planning documentation and historical records, which may have affected the accuracy of the spatial representation. Moreover, external factors such as socio-political instability and limited accessibility to certain areas restricted field surveys and on-site observations. Finally, while the study provided valuable insights into spatial integration, connectivity, and intelligibility, it did not account for long-term urban development plans or anticipated demographic changes, which could influence future urban dynamics. These

limitations suggest the need for further studies integrating both quantitative and qualitative approaches to provide a more comprehensive understanding of the relationship between commercial streets and neighborhood sustainability.

Data availability statement

The data supporting the findings of this study are available within the manuscript. Additional data, including raw datasets or analysis outputs, can be obtained from the corresponding author upon reasonable request.

Ethics information

The paper has not been published or submitted and is not considered for publication by any other journal, that the study described by the paper is original, and the presentation of other materials does not violate any other author's rights.

Funding

This research received no external funding. The study was conducted as part of the academic requirements of the authors' institutional affiliation.

Conflict of interest

The authors declare no conflicts of interest related to this study. The research was conducted independently, and no financial or personal relationships influenced the outcomes.

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