

Pedestrian accessibility complementation assessment in historical urban environments: Kadhimiya historical city, Iraq as a case study

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Abstract: Temporally, contemporary and historical cities respond to challenges. This response varies between positive and negative, which makes them suffer from multiple urban problems. It requires appropriate and effective solutions to solve these problems by complementing the morphological system that has changed and transformed. This research aims to assess accessibility Complementarity in the northern and northwestern parts of Kadhimiya city through an analysis of the morphological structure of the urban fabric, and to focus on walking as a primary mode of transportation in organic cities. Accessibility within the study area was assessed using Space Syntax and Geographic Information System methods.

Initially, maps representing the open areas of the city were prepared from satellite imagery and then digitised and scaled using AutoCAD 2021 software. Then, the axial and sectoral analysis was carried out in the depthmapX 0.8. Some geometric and topological metrics were calculated using the Space Syntax Tool Kit with depth map X. The main results were discussed in terms of spatial cognition and morphological characteristics. The urban problems arising from these transformations were diagnosed, as this will provide a new approach to design strategies for intervening in and complementing the case study fabric to address deficiencies and weaknesses in the studied urban area, ensuring equitable accessibility of all users and visitors.

Keywords: accessibility, complementation, space syntax, Urban Morphology.

1. Introduction

Urban environments have faced several difficult and complex challenges, ranging from economic, social, political, ecological, cultural and technological challenges. (Ali Madanipour, 2001) These challenges range from urban expansion, population growth, and migration to increasing poverty and inequality, to the impact of crime and violence, to natural disasters and climate change. (Kanchana, 2022) The city will continue to face these increasing challenges at different levels, which it responds to by addressing the shortage through changes in the deep structure and transformations in the surface structure, using urban design theories, strategies, and tools. (Ismail, 2023) Historically, the city has been shaped by its powerful contexts. Today, it is the turn of the service community to shape the city in its image, transforming it into a centre for the exchange of ideas, goods and services through new technologies. (Madanipour, 2003)

Urban researches aims to explore the link between effective urban design and the value it adds to cities. Good urban design is a critical component of the urban development process, as it can generate benefits for all stakeholders involved in creating and utilising the built environment. (Bastida, 2021) The benefits of good urban design are divided into direct benefits (usually

economic) to those responsible for investing in and sustaining development (whether from the public or private sectors); and indirect benefits (social and environmental) that accrue primarily to others and to society as a whole. (Graham Bannock, 1998) Urban design provides the opportunity to revitalise and make better use of historical heritage, through contextual Complementation with important structural and natural features, greater attention to environmental features - especially in accessibility, walkability and heritage revitalisation - complements social value. (Matthew Carmona, 2002)

The common feature of qualified urban spaces is to provide an environment that is rich in living standards, protects and preserves elements of identity, and flexibility and diversity compatible with current conditions (Senthilkumaran Piramanayagam, 2019), So The basic condition for creating such qualified and successful urban spaces is the reflection of urban design work on urban spaces, and discussing and evaluating the quality of urban design is the (level of success) for cities within the scope of urban management. (Doğan, 2019) Re-assessment of historical urban environments provides a good starting point for developing future visions and plans by identifying strengths that must be built upon, as well as gaps and weaknesses that must be investigated further to reach a complete problem diagnosis and remedy. (Salvatore Fundarò, 2022) Historical environments in Iraq were exposed to many forces (political, economic, and unbalanced modernisation) that pushed them towards physical transformation, which calls for a re-evaluation of urban environments that have undergone new morphological changes. (Sabeeh Farhan, 2020)

This research aims to assess accessibility complementarity in the northern and northwestern parts of the historic Islamic city of Kadhimiya. This is particularly relevant after the fourth morphological transformation occurred in the last decade. The study will focus on diagnosing deficiencies and weaknesses related to ease of access in this urban area.

2. Urban complementation

The notion of complementation appears in various philosophical and scientific fields, including African philosophy, medicine, mathematics, statistics, physics, genetics, economics, law, and the psychological and social sciences. It is a fundamental principle of human nature. Any system striving for an ideal state requires complementarity, and this is how the degree of complementarity within that system is measured. There are degrees of complementarity that vary according to the principles and ideals the system seeks to achieve. (Kimmerle, 2016)

Complementarity is governed by relationships among the parts of systems, mediated by influences such as intervention, substitution, stimulation, construction, change, and transformation, to reach an ideal systemic state (or at least a better one). At the same time, complementarity is characterised by its comprehensiveness and the multiplicity of therapeutic and preventative methods and approaches. This is achieved by focusing on the active and supportive relationships between the elements of systems in order to enhance, concentrate, strengthen, and improve quality. Complementation is the product of evolving social tendencies resulting from control, adaptation, community participation, interaction, and social cohesion, leading to an advanced or ideal state. (Mustafa T. M. Ismail, 2023)

The idea of complementation suggests the need for a new system that takes the context in which it operates, transcending mere completion and union with its surroundings. This symbiotic relationship can be seen in the thinkers of African philosophy and their environment. (Asouzu, 2004)

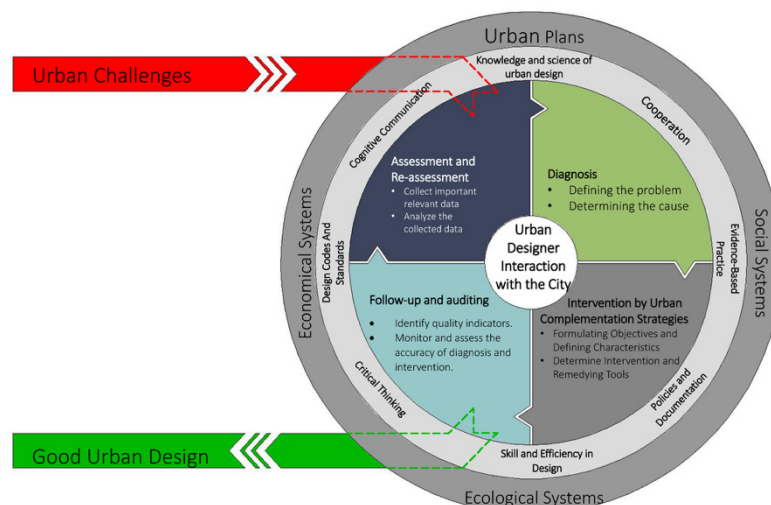
Complementary architecture results from blending local design languages. A pattern language is a collection of formal directions for how humans interact with constructed spaces. These rules come from practical solutions that have been sophisticated over time, shaped by local culture and natural conditions. (Lev, 2019)

Complementary architecture involves analysing traditional techniques in the context of vibrant urban environments to rediscover sustainable, accurate, and environmentally appropriate solutions for the present. The vast majority of traditional vernacular architecture and formal architecture produced before the twentieth century is complementary architecture, as are many works inspired by contemporary movements such as contextual architecture, indigenous architecture, organic architecture, or new urbanism. (Speck, 2021)

In urban planning and design, the term complementarity appeared directly and implicitly. The concept of complementarity emerged in the writings of Everett Majors on polycentric regional cities at the functional level of urban land uses. (Meijers, 2008) The concepts of hierarchy and Complementation were given particular emphasis in this study, as they relate to different aspects of urban development. The study highlighted that the various sectors of a city are complementary, and that their organisation can provide insight into socio-spatial dynamics. (Lambooy J. G., 1969) The functional interconnectedness of city areas depends on differences in layers of Complementation, or sectors in the hierarchy. The presence of these hierarchies does not necessarily imply a hierarchy of centres. Complementation may include spatially different hierarchical patterns, as there is both Complementation within and between job. (Lambooy J. , 1998).

Urban Complementation is the process of responding to urban challenges to complete and fulfil the changing systems that make up the city (see Figure 2). It is a fundamental principle that governs the city's formative nature. Advanced human social tendencies drive this process toward a better systemic state (see Figure 1). Urban Complementation involves effective, supportive relationships among the system's elements. It is contextual, comprehensive, multi-layered, and uses therapeutic and preventive methods and approaches. It has both quantitative and qualitative characteristics that can be measured and observed. (Ismail, 2023)

Figure 1: urban Complementation Methodological framework



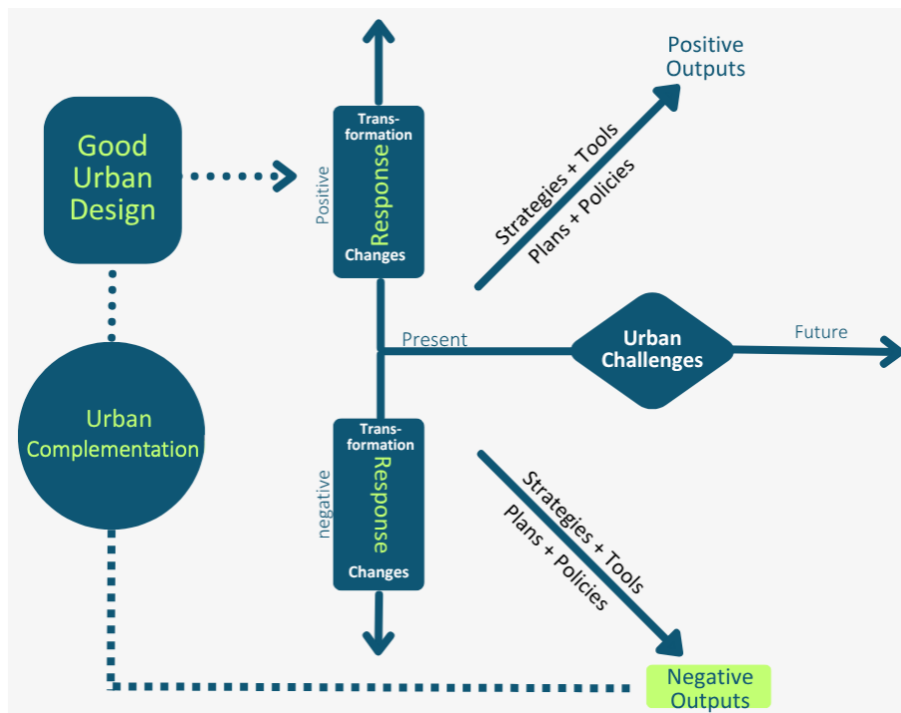
The notion of urban Complementation is distinct from the concept of urban Infill in: Urban Infill occurs at the physical dimension of the built environment, i.e. filling with buildings, while urban Complementation occurs at several layers in the city; Urban infill occurs by demolishing and rebuilding used-up parts or adding to vacant lands in the built urban environment, while Complementation seeks to compensate for the existing deficiency in the urban environment. (AlHasany, 2018)

Urban Infill policies aim to increase density in urban areas, while complementation policies seek to improve the quality and efficiency of the urban environment. Urban Infill requires proactive trust from residents to develop, whereas Complementation relies on the community's efforts and participation. (NLC, 2021)

There is a possibility that urban infill policies will have a negative impact if they are subject to an unregulated political-economic context (Nancy Brooks, 2011). When we trace the roots of Complementation, we see it as the reciprocal of the characteristics of the ideal urban image or urban quality.

According to the "Nursing Care Plan" Methodology, which adapted from treatment processes in complementary medicine, appeared as one of the foundations of urban Complementation at several layers (Spatial organisation and urban network, Urban Transportation, Urban Spaces, Urban land use, Urban Ecology, Urban infrastructure, Historical Urban environments, Artistic and cultural creativity, Urban legislation) within the city. (Ismail, 2023).

Figure 2: urban Complementation Response



3. Urban Spaces Accessibility Assessment

Urban life is humanity's most incredible experience to date. Cities are constantly evolving and adapting to their climates and economies. The cities we see today are not necessarily the ones we imagine, but innovation pushes us to rethink our visions of urbanisation. Therefore, future-oriented urban design values that complement the quality of life must be proposed to make our

urban areas more vibrant. (Bastida, 2021) Public urban spaces are the fundamental element and backbone of any city. They represent the city's identity and are the open spaces accessible to the general public. It represents the core of daily urban events and social and economic interactions. (Caves, 2005) A common feature of well-designed urban spaces is the provision of a rich environment that supports high living standards. The basic condition for creating such qualified and successful urban spaces is the reflection of urban design work in urban spaces; discussing and evaluating the quality of urban design are the indicators of the level of success for cities designed within the scope of urban planning. (Doğan, 2019).

Urban assessment is a valuable tool that can help us better understand and address challenges and unique opportunities in any urban area. Unlike other types of assessments, urban assessment focuses on forward-looking processes that can guide urban design strategies. (URBAN, 2019)

Assessing the physical characteristics of the built environment is a fundamental requirement for complementing, improving, and enhancing the functional, spatial, cognitive, and social dimensions. The assessment is achieved through standards and indicators related to the characteristics of the built environment, the study of human behaviour, interaction, and urban activity, as well as qualitative values and user satisfaction. (Ward, 2026)

Assessment involves analysing the elements and interactions of urban systems in the context of urbanisation, decentralisation, and local governance. By monitoring the dynamic factors that drive urbanisation, we can better understand the impacts, implications, and opportunities for strategic activities and programs that can help to mitigate challenges confronting urban areas. (USAID, Urban Links, n.d.) Moreover, urban assessment can help create an enabling environment for local economic development and job creation, while providing high-quality, locally-funded public services that protect the environment. It also aims to ensure that urban systems are flexible, integrated, and responsive, and works to mobilise local resources in urban areas. (USAID, URBANLINKS, 2019)

Assessing the physical features of the built environment is a basic condition for complementing, improving, and enhancing its functional, spatial, social, and cognitive dimensions, through standards related to the characteristics of that environment, studying human behaviour, interaction, and urban activity, with a focus on qualitative values and population satisfaction. (Stephanie Gamache, 2017)(Mustafa T. M. Ismail, 2023) Assessing urban public spaces and modifying and complementing them to meet contemporary needs is necessary because public spaces significantly affect community and public psychological health. (Mehta, 2014)

Through the values that urban design adds to complement the quality of life in the city, several trends have emerged among contemporary urban design theorists and practitioners regarding the contributions that constitute good urban design.

Kevin Lynch presented seven concepts that represent the ideal picture of the performance of the city and urban space, as follows: Vitality (designing attractive events); the sense of place; security and safety; The suitability and degree of matching of the place between the form and patterns of behavior; access to people, services and events; The control or degree to which those who use or occupy the space create easy access to places and events; Efficiency that related to the costs of making and maintaining the place; fairness, which is the distribution of resources among users. (Abbas, Lectures in Urban Design Trends, 2019)

In 1985, Bentley and McGlenn summarised the attributes of good urban design with seven concepts: character, continuity, enclosure, quality of public realm, ease of access, clarity, adaptability, and diversity. (Ian Bentley, 1985) Gehl developed 12 concepts or principles for the

ideal urban image of open public spaces, which he classified into three principal axes: protection, Comfort, and Delight.(Seema Praliya, 2019).

Thus, characteristics of public spaces discussed by urban theorists and practitioners, including ease of access, give the place a high quality, which creates greater opportunities for residents to be attracted to it.

Accessibility refers to the idea that every individual should have the right to access public spaces; these spaces should be designed so that they are usable by everyone. (Tatal, 2018) People should be able to move around freely in their daily lives and take part in all public activities. In other words, accessibility is the ease of reaching a particular destination. (Jefferson Hishiyama, 2012)

The methods used to evaluate accessibility are crucial in shaping mobility and urban development, as they influence people's decisions about where to locate and how to travel. (AK, 2018) When accessibility is low, mobility to the destination requires travelling long distances, taking up a lot of time, incurring high costs, and facing other obstacles and limitations.(Awada, 2007)

Based on the above, we can define Accessibility Complementation as a process of responding to the challenges people face in completing and fulfilling the transforming, changing system of mobility and access to urban amenities, as this process is the product of evolving social and human tendencies to achieve an accessible, fair, efficient, and sustainable urban environment.

Assessing and re-assessing accessibility is crucial for transportation, planning, and urban design studies, especially in historical urban environments that are still subject to morphological transformations. (Pereira, 2021) At the same time, there is pressure to expand community services and accelerate technological development while avoiding negative impacts on physical, social, and ecological infrastructure. (Ismail, 2023).

Assessing and re-assessing the accessibility process reveals the impact of emerging interactions among mobility, development, and urban land-use policies. (Gregório Luz, 2022) It shows how well individual and community needs, cohesion and social integration are met through people's access to community services. (A Church, 2000) It also indicates the range of options for obtaining the services required to achieve well-being and increase people's satisfaction. (Karen Lucas, 2016) Furthermore, it explains the extent of equal opportunities and the achievement of social justice by extrapolating the spatial dimensions of urban space. (Wee, 2022)

Taking into consideration that individuals' ability to access and obtain urban amenities and services varies according to their physical and mental health condition - healthy people, people with chronic diseases, people with disabilities or special needs, or according to age groups - the ageing, youth and children. (Cristina Sampedro, 2024)

Therefore, achieving ease of access is a joint integration between people's ability to use means of transportation, the spatial distribution of activities and population, and the spatio-temporal connections of the mobility network. (Miller, 2018)

There is a set of techniques and theories for analysing spatial planning and patterns of human activity in urban areas; that is, through analysis, a link is made between space and society. We can divide these metrics into Place- based measures, Person-based measures, Distance-based measures, Time-based measures, Gravity-based / Hansen-type measures, Topology /Infrastructure-based measures, Isochrone Mapping, and Space Syntax theory. (Martin Dijst, 2002)

Space syntax analyses how people use and move through different spaces, and how they develop and talk about them. It is based on two primary principles: first, that space is not just a backdrop for human activity but an integral part of it. (UCL, 2024); and second, that space is primarily determined by its configuration. This means that what happens in any given space, whether a room, a corridor, a street, or a public space, is fundamentally shaped by the relationships between that space and the next space connected to it. (Akkelies van Nes, 2021)

The space syntax method involves calculating configurative spatial relationships in the built environment and provides methods for finding spatial answers to questions. (Bill Hillier J. H., 1984)

Space syntax can provide a spatial perspective on how buildings and settlements shape social relations, demonstrating the social organisation of settlements across different cultures. (Bill Hillier A. T.-P., 2010) Space syntax is a powerful method that accurately measures the relationship between every public space and street segment in a built environment. It confidently calculates the to-movement potential (closeness) of each street segment to all others, as well as the through-movement potential (betweenness) of each segment. These accessibility potentials are precisely weighted by three distance definitions: metric, topological, and geometrical. Each type of relation can be confidently calculated at different radii from each street segment to provide an accurate understanding of the city's street and road network. (Bill Hillier S. I., 2005)

Space Syntax analysis empowers urban practitioners and designers to effectively diagnose existing issues, evaluate accessibility strengths and weaknesses, and proactively implement remedial urban tools and strategies

4. Methodology

This research aims to assess pedestrian accessibility -As a fundamental element of the spatial organisation layer- in the northern and northwestern parts of the Kadhimiya Historical City, see Figure (5a).

Analysing the choice, integration and connectivity of the transformed urban fabric (the fourth transformation) see Figure (5b). The analysis is based on information imported from the geographic information system using GIS ArcMap 10.8 software. The maps were arranged by scale, digitised in AutoCAD 2021, and then analysed in DepthMap 0.8.

Space syntax theory evaluates the numerical relationships between the spatial structure of the urban fabric and how people use and interact with it. It analyses pedestrian movement and its role in establishing social interactions within the fabric. (Bill Hillier J. H., 1984)

Depth Map software creates axial lines within movement areas, and axial maps measure the lengths of these axes. At the intersection points of the axes, each axis is segmented at a specific angle to form an angular segment map. Integration, choice, and connectivity values are then analysed to classify the results from the highest to the lowest level, such as thermal image.

The correlation between integration and choice values determines accessibility, and this relationship is calculated using NAIN (normalised angular integration) and NACH (normalised angular choice). (B. Hillier, 1987)

$$\text{Whereas: } NACH = \frac{\log(\text{Choice}(r)+1)}{\log(\text{Total depth}(r)+3)}, NAIN = \frac{1.2\sqrt{\text{Node count}(r)}}{\text{Total depth}(r)+2} \quad (\text{Bill Hillier T. Y., 2012})$$

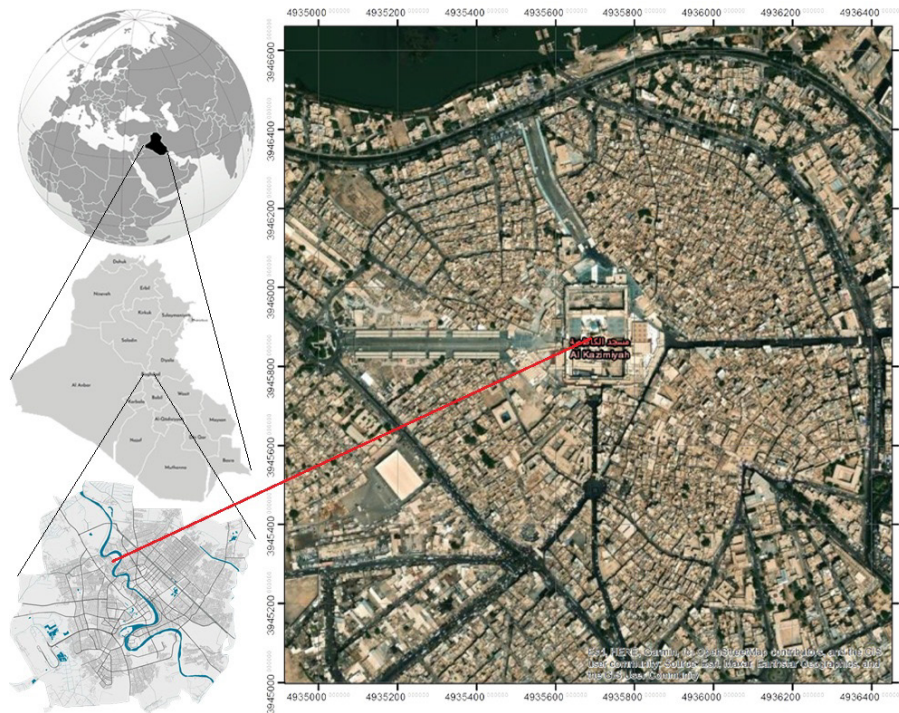
Where:

Normalised Angular Choice (NACH) is a metric used by Bill Hillier, according to Space Syntax Theory, for measuring urban spatial networks by identifying segments that act as major connectors, specifically formulated to eliminate the bias where segregated (peripheral) designs appear to have more "choice" than integrated (central) ones. It calculates the logarithmic ratio of angular choice to total depth, providing a more accurate, scale-independent assessment of traffic flow potential. (W. Hillier, 2012)

Normalised Angular Integration (NAIN) is a Space Syntax key metric used in Urban spatial analysis. This metric quantifies how connected or accessible each street segment is within the entire urban system by considering the total number of direction changes required to reach all other segments and normalising this measure to allow comparisons across different urban systems or cities of varying sizes. (W. Hillier, 2012)

One-step connectivity analysis is crucial for assessing the level of connectivity of selected streets to their nearby ones. Main paths are the definitive routes people select for travelling through and between urban areas. This analysis reveals the interconnected relationship between main routes and local path networks (Nes, 2009).

Figure 3. case study (Al-Kadhimiya) geographical location.



5. Case study

Al-Kadhimiya Historical City is an urban area located on the Karkh side of the capital, Baghdad. It was named after the shrine of Imam Musa Al-Kadhim, the seventh grandson of the Muslim's Prophet. Positioned 5 km north of Baghdad, it sits on the western side of the Tigris River, adjacent to Al-Karkh, as Figure 3. The founding of Al-Kadhimiya dates back to the fourteenth century. The area is characterized by two-story dwellings surrounding the Al-Kadhimiya shrine, see Figure (6b), along with small mosques, schools, shops, baths, workshops, Khans and modern hotels, see Figure (6a). This historical center has maintained its physical form relatively well compared to

other parts of Baghdad, with an organic, tree-like layout. It is circular with a radius of approximately 500 meters, covering an area of around 60,000 square meters, and a population density of 600 people per hectare (Al-Dalawi, 1975).

Old Kadhimiya has undergone several morphological transformations in the 20th century due to urban challenges, reflecting different stages of change. See Figure 4a, Figure 4b, Figure 4c, and Figure 4d :

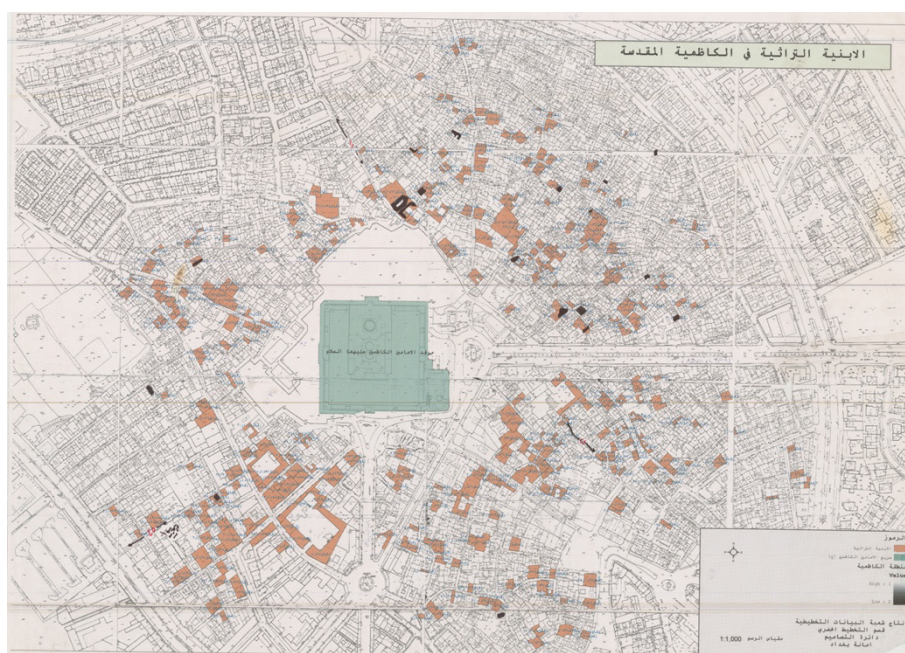
- The first morphological stage, which extends until 1940:

Al Kadhimiya underwent modernization processes that began in 1869 when it was connected to (Al Karkh)-the western side of Baghdad- by a tram, which led to clear radical morphological changes in the southern edges. (Al-Kaissi, 2017, p. 671)

Figure 4a. Maps of morphological transformations of case study in 20th century



Figure 4b. Map of Al-Kadhimiya in 1980, Ref: (Mayorality of Baghdad)



- The second morphological stage: It extends from 1940-1975:

Al-Kadhimiya was connected to the north-eastern side of Baghdad (Al-A'dhamiya side) by a permanent bridge in 1957. In addition, traffic axes were created towards the east (Bab Al-Murad Street) and the south (Bab Al-Qibla Street) by demolishing parts of the urban fabric, especially in the Al-Shuyukh, Al-Qatana neighborhoods and on the eastern side of the Holy Shrine. As a result, clear commercial and residential developments occurred, especially in the southern and eastern sectors. (Al-Kaissi, 2017, p. 672)

Figure 4c. Satellite imagery of Al-Kadhimiya in 2007, Ref. (Mayorality of Baghdad)



Figure 4d. Satellite imagery of Al-Kadhimiya in 2022, ref: http://www.chengfolio.com/google_map_customizer



Figure 5a. Study Area Boundaries

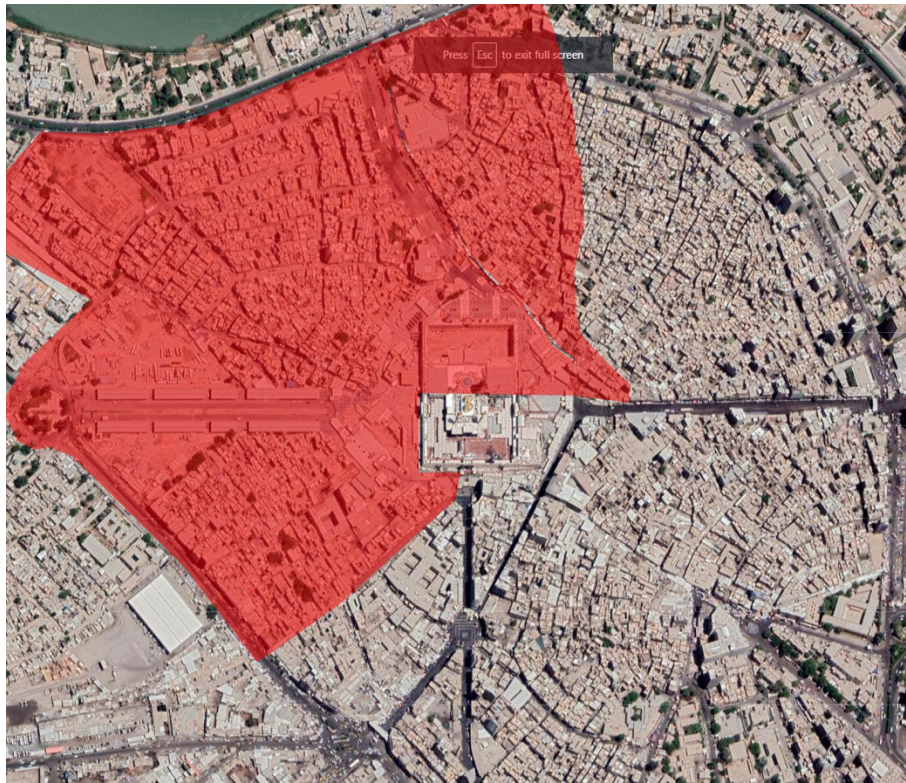


Figure 5 b. Transformed Fabric in 4th Stage

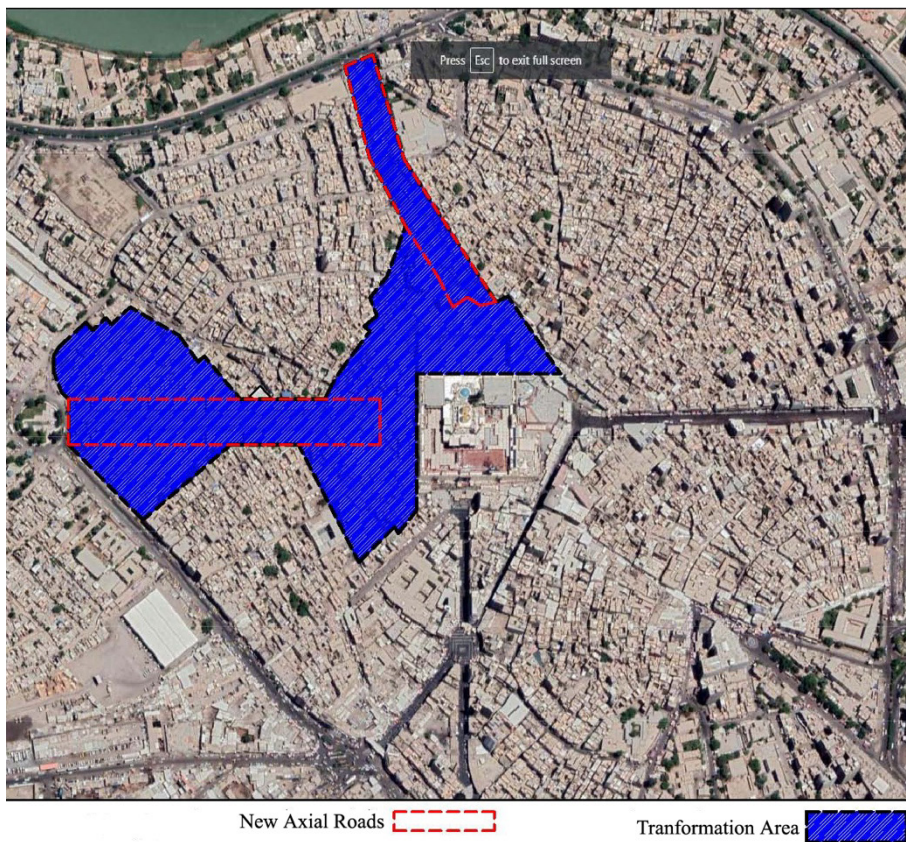


Figure 6a. study area land use

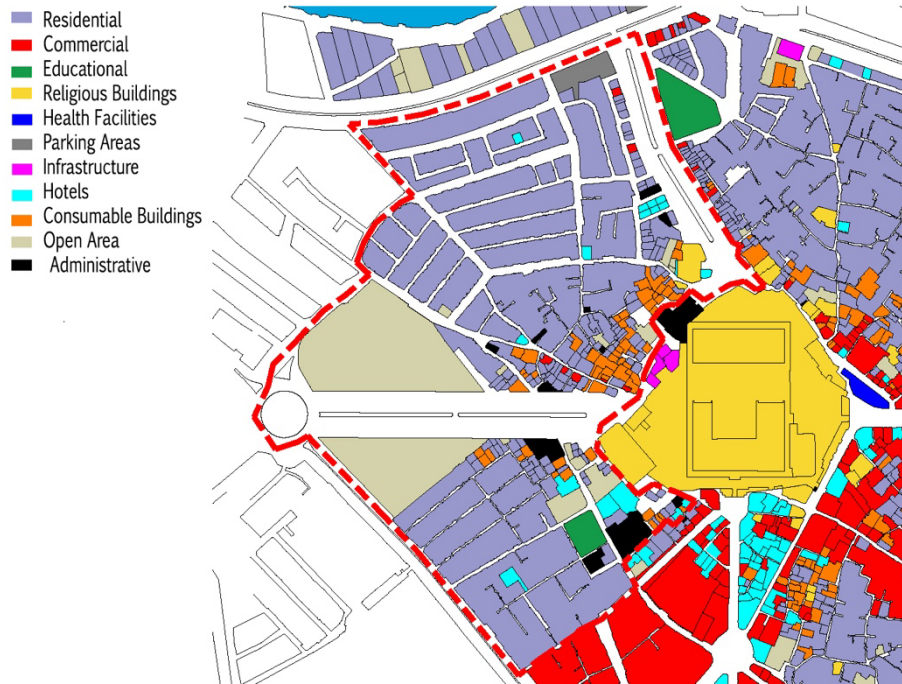
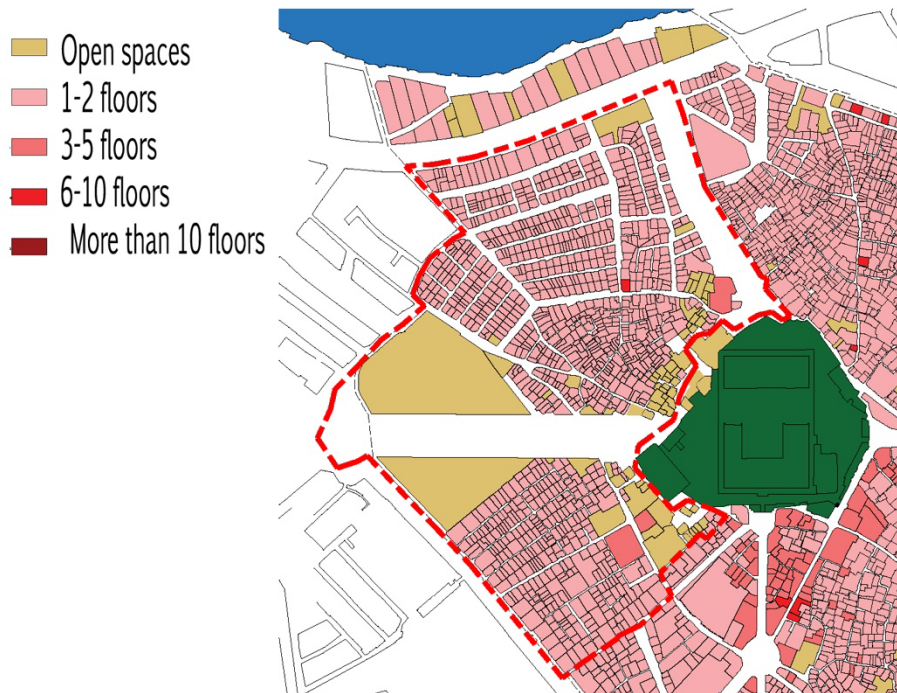


Figure 6b. study area Building Heights



- The third morphological stage: It extends from 1976-2003:

During the 1980s, the planning concept of Al Kadhimiya underwent a radical change due to demolition operations around the Al-Kadhimi Shrine. As a result, 9 hectares of the old urban fabric were demolished, giving way to the construction of modern multi-storey buildings that did not harmonize with the urban historical context. This demolition created a large open space around the shrine, making it difficult to discern the place and its identity. Furthermore, the open space destroyed the human scale of the urban fabric. The new roads built in this area altered

the spatial and movement systems, giving precedence to car traffic over pedestrian movement. Additionally, these roads disrupted the boundaries between semi-private, private, and public spaces, impacting the residents' privacy. (Warren, 1980).

The old city responded in an uncontrolled morphological transformation to the security challenges, and the Pluralism of visions for new development projects and proposals that were not completed, which made the old city what it is now

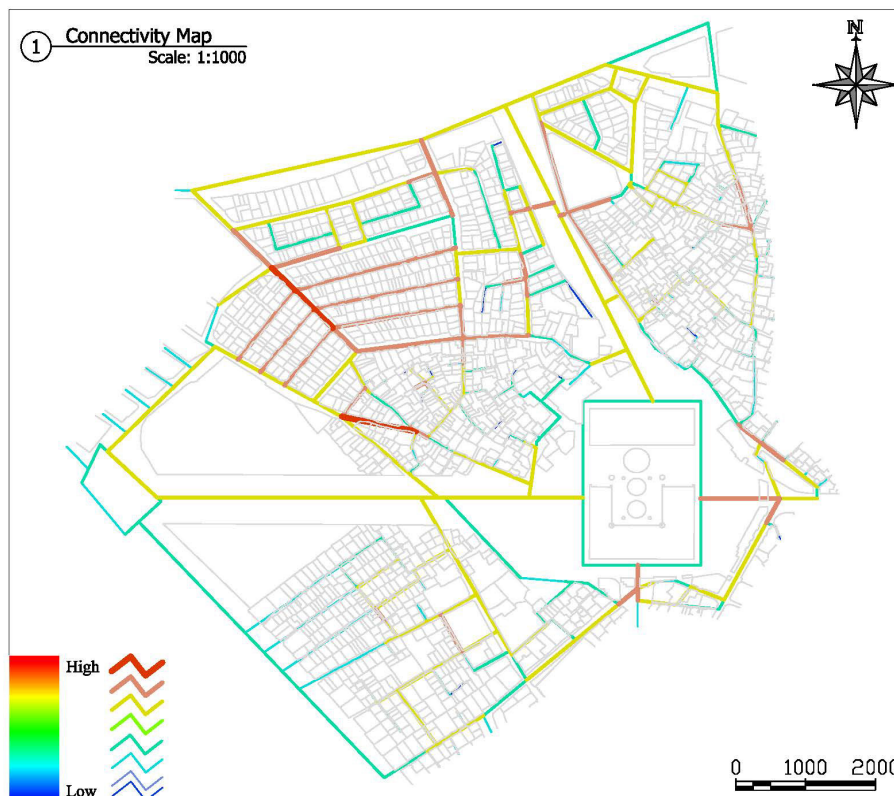
- Fourth morphological stage: after 2003:

In recent years, Iraq has witnessed changes in the political and economic context, which have a clear impact on the transformation of the context of the urban fabric of Iraqi cities in general and the city of Kadhimiya in particular, this impact is due to the city's religious significance and the ongoing expansion around the holy shrine.

6. Results & Discussion

The integration, choice, and connectivity values were calculated by analysing the metric segment map within a radius of R_n . It is observed that these values are concentrated along the main movement axes linking the main core (Holy Shrine) with the main transportation routes (outside the organic fabric). According to the results, the integration value is highest at axis 42, average at axis 100, and lowest at axis 377. The choice value is highest at axis 45, average at axis 380, and lowest at 0. The connectivity value is highest at axes (6, 33, 34, 35) and lowest at the dead-end axes. There are 426 line strings and 427 node counts in the study area. Figure 7a, 7b, 7c, 7d depict the maps created based on the integration, choice and connectivity values of the pedestrian pathways network of Al kadhimiya.

Figure 7a. Connectivity Map



According to the research methodology, to represent the accessibility in the north and northwest of Al Kadhimiya city, we should understand the level of accessibility in the study area. The correlation matrix of NACH (Rn) and NAIN (Rn) had been interpreted in the star graph model in figure. 8a and scatter plots in Fig. (8b), which showed the value of intelligence (R2) according to the equation ($y=ax + b$) given in the depthmap X software with the coefficient and constant (b).

Figure 7b. NACH Map

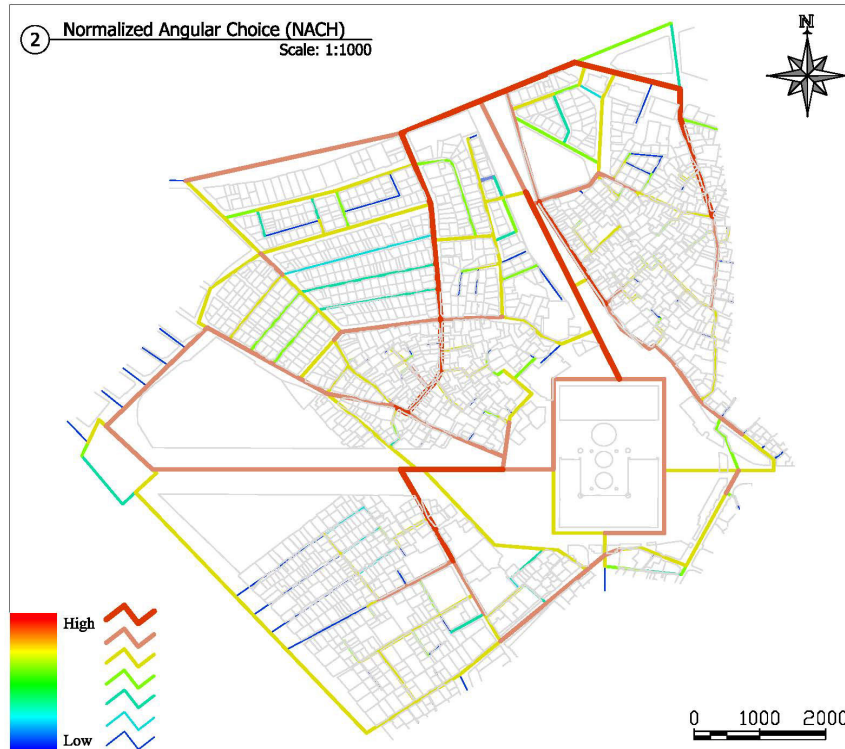


Figure 7c. NAIN Map

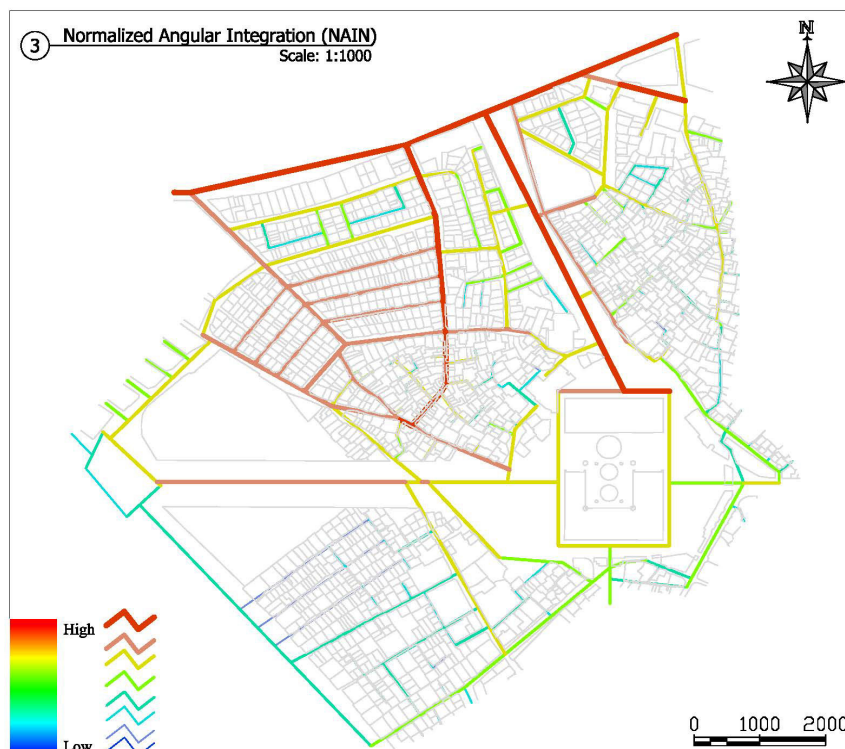


Figure 7d. T1024 Total Depth 400 metric map

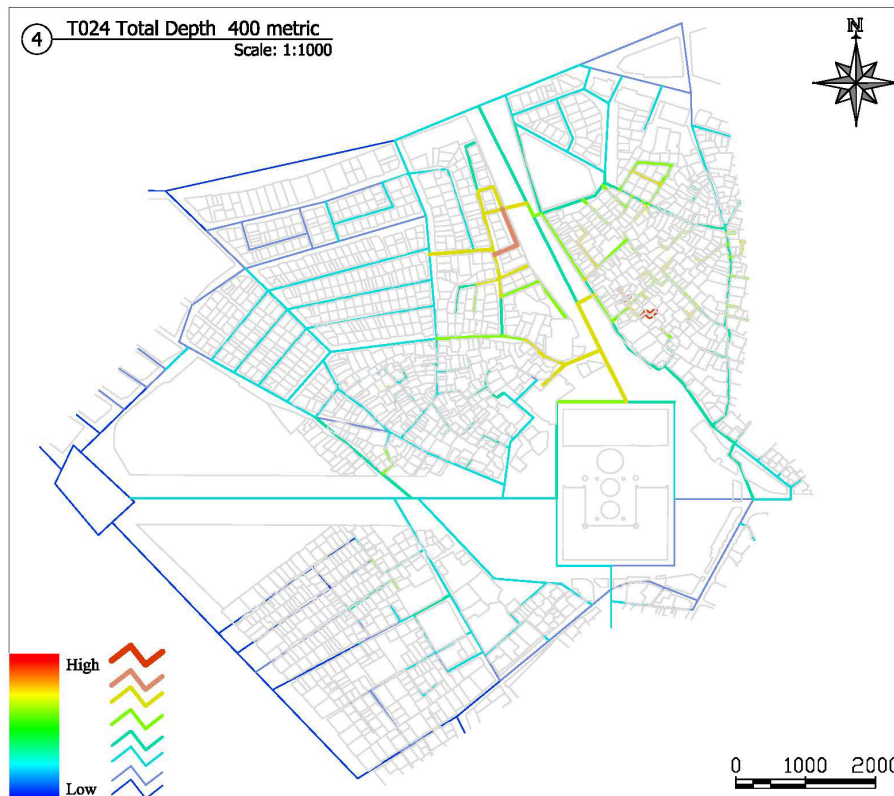
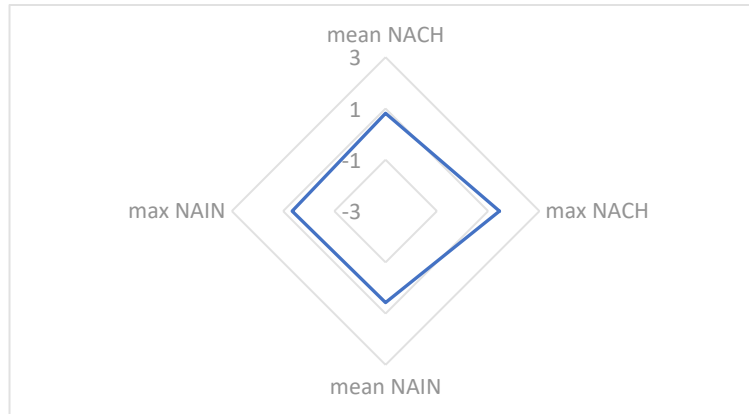


Figure 8a. Star Graph Model, and scatter plot of Correlation matrix between NAIN & NACH

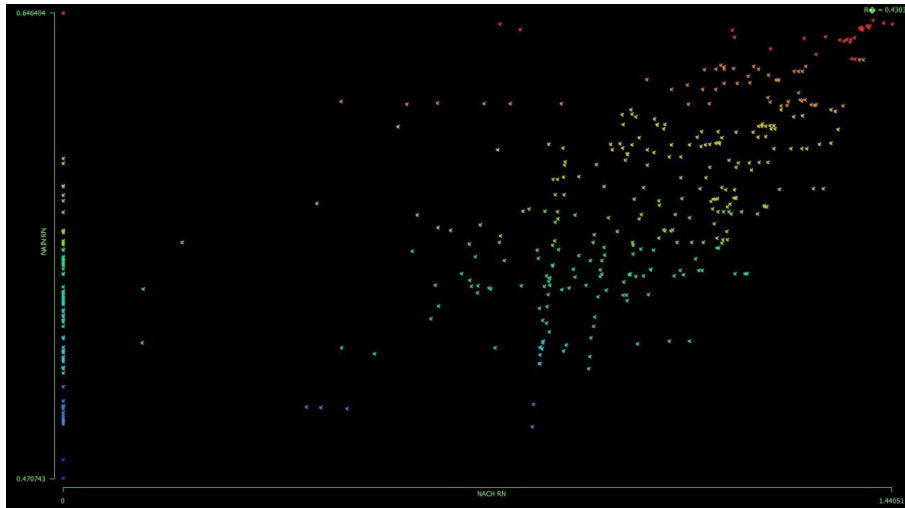


As shown in Tables 1 and 2 below, the range of the intelligence value was between 0 and 0.5, indicating that the ability for spatial recognition is generally weak. The study revealed that the value of (R²) is 0.43, despite a positive relationship between integration and choice, i.e. the study area has a weaker accessibility from within the fabric than from outside.

To investigate the relationship between NAIN and NACH, a Pearson product-moment correlation coefficient (R) was computed. Preliminary analyses were performed to ensure that the assumptions of normality, linearity, and homoscedasticity were not violated. (Cohen, 1988).

The results revealed a statistically significant positive correlation between the two variables ($r = 0.656$, $n = 426$, $p < .001$). According to Cohen's (1988) guidelines, this represents a moderate to strong effect size. The extremely low p-value (1.06×10^{-39}) indicates that the probability of this correlation occurring by chance is virtually zero, thereby providing robust evidence for the hypothesised relationship.

Figure 8b. Scatter plot of Correlation matrix between NAIN & NACH



In Figure 8a, the vertical axis represents the mean NACH (top) and mean NAIN (bottom) at a specific distance from the city centre. In contrast, the horizontal axis represents their maximum NACH (right) and maximum NAIN (left). Each measure is a standard score on the same scale, with a range of about 0, where the negative minimum is at the centre, and the positive maximum is at the edge. Since most areas in cities are part of the background network, the mean values reflect the potential for movement within the background (integration with little through-movement). In contrast, the maximum values represent the potential for movement within the foreground network. The mean and maximum NAIN measures tend to co-vary, meaning the angle between them remains fairly constant, whereas the mean and maximum NACH measures do not co-vary and reflect the city's pattern.

The above analysis indicates that the creation of a new northern movement axis connecting the holy shrine to the city's circular car movement axis has significantly enhanced global integration. Nevertheless, this axis has unfortunately led to the isolation of the eastern and western regions in the city's genetic system, as it has cut off connections with the rest of the axes, enforced by a security fence that restricted movement and land-use changes on both sides. At the same time, the new, highly integrated western movement axis isolated the urban areas on the northwestern side from those on the southwestern side. At the same time, this axis became a backyard for the city centre (the holy shrine) and served specifically its movement and logistical supplies. That caused isolation in the north-east, north-west, and south-west residential areas within the city's genetic system. In conjunction, the new axes have significantly limited the range of choice from the outer fabric to the Centre, while simultaneously streamlining choices from within the fabric. The new movement axes reduced connections between parts of the old fabric, affecting movement and access within the old city.

Table 1. shows the values of normalised choice, integration and connectivity.

Radius	Value	Mean	Minimum	Maximim	STD. Dev.	Correlation coefficient
n	NACH	0,81389	0	1,44051	0,46846	0,656
n	NAIN	0,57053	0,47074	0,6464	0,03869	0,656
n	Connectivity	3,28806	1	6	1,09669	

Note: *** $p < 0.001$

Table 2a. Demonstrates a Pearson product-moment correlation coefficient between NAIN and NACH.

Regression Statistics	
Multiple R	0,656
R Square	0,430336
Adjusted R Square	0,428995
Standard Error	0,354409
Observations	427

Table 2b. Shows the Analysis of Variance of normalised choice, integration and connectivity.

ANOVA	df	SS	MS	F	Significance F			
Regression	1	40,32613	40,32613	321,0532	6,89E-54			
Residual	425	53,38244	0,125606					
Total	426	93,70858						
	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	-3,71733	0,253468	-14,6659	1,07E-39	-4,21554	-3,21913	-4,21554	-3,21913
X Variable 1	7,942201	0,443254	17,91796	6,89E-54	7,070959	8,813444	7,070959	8,813444

7. Conclusions

This study found the structural variation patterns as a small organic urban fabric. It exhibits a stronger focus on choice than on integration, and a more pronounced foreground than background structure. Based on the assessment and diagnosis conducted by the research, it has been determined that the study area requires an urban complementary intervention strategy to solve the problems of deficiency and weakness in pedestrian mobility, integrated with the whole historic urban fabric of the city, and compatible with the laws and urban plans established for that area.

These strategies must have comprehensive, applicable, and practical characteristics that are encouraging, intelligent, and sustainable, employing innovative, interactive, and contextually dynamic approaches. These strategies aim to enhance public understanding of urban form, provide visual, spatial, and psychological cues, localise ideas and symbolic images of place, and strengthen urban management and governance. Specifically, these strategies include:

- Preserving, organising, and maintaining roads and public spaces by raising security fences, maintaining facade finishes, walkways, pathways, and roads in accordance with the heritage context, and reconnecting and modernising existing urban transport networks.
- Enhancing the city's mental image through mechanisms that activate reference maps and signage, integrate them into spatial representations, and utilise Geographic Information Systems (GIS) technologies.
- Employing smart governance through mechanisms that adopt sustainable behaviour and design practices and utilise information and communication technologies (ICTs).

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8.1. AI disclosure

During the writing of this article, the author used Grammarly to improve the language and grammar of the manuscript. After using these tools, the authors reviewed and edited the content as needed and assume full responsibility for the publication's content. The technical content, data interpretations, and conclusions were generated entirely by the human authors, who verified all sources.

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