University of Baghdad
College of Engineering
JE
JOURNAL OF ENGINEERING

Journal of Engineering

journal homepage: www.jcoeng.edu.iq

Volume 30 Number 10 October 2024

The Evolution of Street Structures: A Morphological Study

Dhirgham Alobaydi [1,*], **Mahbub Rashid** [2]

[1] Department of Architecture Engineering, College of Engineering, University of Baghdad, Baghdad, Iraq
[2] School of Architecture and Design, University of Kansas, Kansas, USA

ABSTRACT

Morphological structures of urban streets in Baghdad have been deciphered by using practical methodologies inclusive of data collection, digitization, and identification processes. This paper uses street pattern morphological analysis in a typical Middle Eastern city, in this case, Baghdad, from organic configurations to modern metropolitan sprawl. It is based on historical maps and satellite images, supported by field surveys. Six distinct street patterns have been identified that have influenced the formation of Baghdad's urban development and continuity, focusing attention on the ancient city configuration and current planning principles. Of great interest is the fact that there are calls for the retention of the urbanism historical fabric in the cities with new growth at the same time there are calls for methodologies that are responsive to the sociocultural energy characteristic of the cities in the Middle East. This study adds to the general body of literature on urban morphology and further provides detailed insight into the morphology of streets in Baghdad and other similar towns. The research, therefore, shows evidence of the need for recognizing street morphology roles in the form and function of urban landscapes and will advocate for environments reflective of historical context in line with the needs that modern urban life requires. Results will demonstrate how streets change based on influences from culture and socio-economic factors. They conclude that streets developed in the light of cumulative processes, directions, and scales of development. This research is taken up to comprehend urban morphology leading towards sustainable and culturally responsive designs.

Keywords: Streets, Morphology, Evolution, Urban form.

1. INTRODUCTION

Exploring the street patterns of Baghdad presents an interesting challenge, offering insights into the evolution of its urban landscape from ancient organic roots to contemporary metropolitan sprawl, see **Fig. 1**. This study delves into the morphological shifts of Baghdad's streets, from their historical beginnings to the modern era, utilizing exploratory morphological methods to unearth the characteristic structures and common themes that

*Corresponding author
Peer review under the responsibility of University of Baghdad.
https://doi.org/10.31026/j.eng.2024.10.12

Article received: 13/04/2024
Article revised: 09/07/2024
Article accepted: 22/07/2024
Article published: 01/10/2024

have shaped its urban form. The aim is to develop a methodology that extracts key insights from the built environment's history, aiding urban designers and planners in crafting informed design criteria. The urban fabric of Baghdad, like that of other Middle Eastern cities, has undergone significant transformation, particularly with the introduction of the gridiron street system in the early 20th century. The Gridiron street system was a product of the need for efficient movement and linking of different urban areas. It accommodated much space for vehicular traffic and created separate zones for pedestrians and vehicles. Its separation did improve safety and privacy but has received criticism for causing less vibrancy than is typical of historic centers where pedestrian and vehicular flows are integrated. With the expansion of Baghdad, the gridiron patterns were accepted, and the acceptance was a challenge and opportunity for urban design. Moving from the dense core of cities to suburban spread grids implies a change in paradigm concerning the role and functioning of streets. The shift brings out how important it is for streets to be considered more than just movement carriers; they need to be considered vibrant public spaces that host a variety of activities **(Mahdi et al., 2023; Albabely and Alobaydi, 2024; Al-Saaidy, 2024)**. It highlights the basic difference between designing for movement and accessibility, which is aimed at making user life more comfortable and making the environment pedestrian-friendly **(Clifton et al., 2008; Alobaydi et al., 2020; Mohammed and Alobaydi, 2020a, 2020b; Huang et al., 2024)**.

This study is based on Baghdad, but the findings can be applied to cities in the Middle East with these kinds of urban environments. A set of design guidelines is proposed based on the historical development of urban forms **(Al-Saaidy, 2020; ALslik and Majeed, 2014; Al-Khafaji and Al-Qaisi, 2012)**.

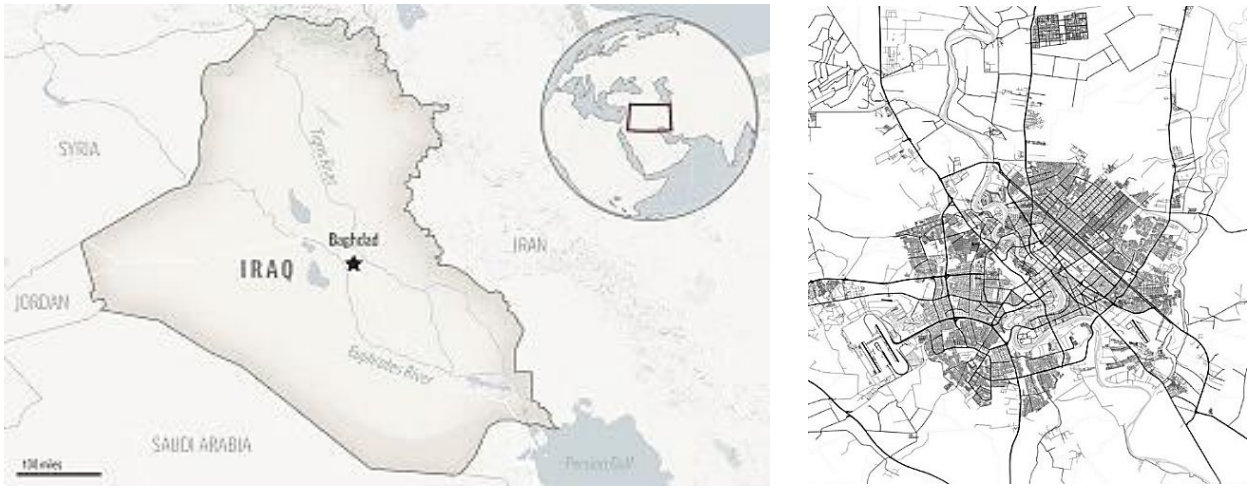

Figure 1. Showing the location of Baghdad, Iraq in the Middle East and the metropolitan area of Baghdad.

This research will attempt to analyze the development of the streets of Baghdad through its morphological phases toward an inference drawn from a relevant framework: one that is concerned to the essence of the Middle Eastern urban pattern and holds valuable insight for the future of urban planning and design practices.

This study is divided into three main parts. The first one presents the main topics and reviews the related studies and works. The second part offers an exhaustive explanation of the methods and techniques adopted to analyze the case studies, identifying the definitions

assumed as references. The last part describes and presents results and conclusions: it will display the different typologies of the streets, which have evolved in time, and how they have developed and extended.

2. METHODS

The methods, concepts, and techniques, for this study unfolded in three primary phases: collection and organization of data, digitization and preparation of data, and finally data analysis.

2.1 Collection and Organization of Data

This phase involved gathering essential data, maps, and documents that outline Baghdad's urban development from its foundation in AD 762–767 through the 1960s. Much of the early cartographic data derived from Western geographers who observed and documented Baghdad before, during, and after World War I **(Lapidus, 1973**; **AlSayyad, 1987; Saoud, 2002; Abu-Lughod, 2017)**. An exemplary instance is the 1853 map by Felix Jones, noted for its detailed representation of an Arab-Islamic city in the 19th century **(Fethi, 1977)**. Due to historical upheavals in Baghdad, only a limited selection of historical maps was available, leading researchers to also rely on narrative sources, manuscripts, and drawings to reconstruct map data. This study integrated nine such historical maps into four synthesized maps to illustrate significant urban transformations during the 1050s, 1850s, 1940s, and 1960s.

The criteria for selecting data focused on quality, integrity, and authenticity: ensuring the maps' accuracy, representation of fundamental urban elements, and validation by prior research and official Iraqi entities. These maps were sourced from a variety of academic and governmental institutions from Iraq and the United States.

The documentation was sparse from the 1970s to the 2000s due to political and security issues under the al-Ba'ath government. To bridge this gap, a satellite image from 2008 provided by Center of Urban and Regional Planning at University of Baghdad (CURP-BU) was utilized. The analysis categorized Baghdad's historical development into five distinct phases: formation, densification, colonial influence, modernization, and post-modernization. This paper argues that historical integrity in street patterns, from organic zigzag paths and hybrid grid systems to super-grid expansions, has been maintained while accommodating modern growth in a collaborative effort to create functional urban environments that also reflect cultural identity.

2.2 Digitization and Preparation of Data

The digitization process utilized ArcGIS (ArcMap 10.1 software) and unfolded in three steps. Initially, georeferencing aligned the historical maps with modern satellite imagery using unchanged landmarks and streets as control points. This alignment revealed discrepancies, particularly at the city's fringes, due to variances in historical cartographic techniques a notable limitation of this study. Subsequently, Baghdad's maps, inclusive of satellite imagery, were digitized into distinct layers for streets and land use. Applying space syntax methodologies, axial and segment maps were generated to depict Baghdad's street configurations across its historical phases. The final preparatory phase involved a thorough examination of urban structures, street configurations, and growth trends.

2.2.1 Study Scales

The study differentiated between the challenges inherent in assessing urban forms at a macro level versus the detailed scrutiny required for historic urban growth. With Baghdad's form evolving substantially over time, the areas of focus similarly expanded across different phases. The early phases (1050s and 1850s) were confined to Old Baghdad, covering an area of 6.5 km^2. The subsequent phase (1920s to 1940s) extended over 47 km^2, while the 1960s phase encompassed 65.7 km^2. The final phase analyzed, representing the metropolitan scale of Baghdad, spanned 379 km^2, necessitating a reduction in the drawing scale that limited the detailed representation of street and land use structural properties.

2.3 Analysis and Measurement of Data

This phase of the study consisted of three integrated steps: Representation, Definition, and Classification, each building upon the last to provide a comprehensive analysis of Baghdad's urban streets' evolution.

2.3.1 Representation

In the representation step, street structures from all examined historical phases were precisely redrawn. Utilizing AutoCAD-2020, we outlined the boundaries of each street as found in the identified maps, organizing these into distinct layers that reflect the chronological evolution of Baghdad's urban form and structures. This has been done by careful examination of historical maps and superimposed development over time. By closely studying these maps, we were able to uncover the evolving street patterns and urban structures that have shaped Baghdad's unique landscape. This historical perspective, in not only stressing the growth of the city, creates an opportune moment to derive further insights into the socio-cultural and economic factors that govern urban design. The study, through this elaboration, will bridge the past to the present for the urban design and planning fraternity to have a deeper view on how historical contexts could be of influence on the current urban form and how it presents the opportunity of saving the cultural identity of the city.

2.3.2 Definition

In the face of such a critical look at these maps, the changing patterns of streets and urban fabrics have, in a unique way, defined the landscape of Baghdad. This helps to read not only in terms of the growth of the city but also the lessons that one may derive from the socio-cultural and economic underpinnings contributed to the urban design. Through such a detailed analysis, the study, therefore, attempts to bridge the past and the present by giving urban designers and planners deeper insights into how the historical context can feed into contemporary urban development and the maintenance of the city's cultural identity. In addition to that we defined these patterns using terms and concepts from the foundational works **(Southworth and Ben-Joseph, 1995, 2004, 2013)**.

2.3.3 Classification

In the final classification step, our method was made to classify several urban structures and spatial organizations and growth trends that were analyzed from the redrawn maps. These

were characteristics and typologies well-established from existing studies, which provided a strong foundation for understanding both the historical and the current urban fabric of Baghdad. This step further gave us the ability to distinguish what was distinctive in the urban patterns of development in Baghdad, as further elaborated in subsequent chapters. These can be categorically classified to understand systematically the changes and continuous evolvement in the urban planning and architectural configurations of Baghdad. Therefore, they bring invaluable insights into the urban morphology of the city.
Together, all these steps form a single, coherent methodology of the investigation and interpretation of complex patterns and structures typical of Baghdad's urban environment. This approach emphasizes the city's historical continuity while also celebrating the radical alterations that have characterized the landscape's development over time.

3. RESULTS AND DISCUSSION

This section delves into the examination of urban street configurations through the lens of digitized maps, which have been derived from cartographic information spanning several decades: the 1050s, 1850s, 1940s, 1960s, and 2000s. This historical breadth offers insights into the evolving urban fabric of Baghdad. The study has delineated six distinct patterns of street layout:

- A deformed pattern
- An organic zigzag pattern with cul-de-sacs
- A hybrid of organic and grid patterns
- A hybrid of grid and incremental infills
- A hybrid of the super grid and interrupted parallels
- A hybrid of organic, composite, and deformed Grid

These street typologies draw upon the foundational work of Southworth and Ben-Joseph in 1995 and 2013. However, this investigation also brings to light previously undocumented patterns. A detailed description of each street typology follows, providing further elucidation on their characteristics and implications.

3.1 A Deformed Pattern

The traditional urban fabric of Old Baghdad, 1050-1850, had a series of streets that warped into patterns which might, at first sight, be termed irregular. These patterns took place under natural response to a variety of physical and soc-political elements such as geographical contour, distribution of political power, city ramparts, social stratification, and water **(Kostof, 1991; Alobaydi and Rashid, 2015)** The origin of the irregular patterns that make up the urban fabric of Baghdad is its gradual developmental processes that covered vast land areas. Land division is often related to the loyalties towards the ruling forces, such as the caliph, the nobility, or the sheik. Its rapid and uncontrollable development of Baghdad city led to these models, especially in the current informal settlements. These configurations were intended designed with knowledge of space hierarchy in correspondence with the social system of the Arab-Islamic society **(Hakim, 2007 and 2013)**. Each warped pattern had its characteristics, expressing a hierarchal, non-linear, and divided spatial configuration. These were the characteristics and the unique features of each pattern and thus, the pattern-specific features for Baghdad.
During the early morphological stages (1050s – 1250s), the street layout in historical centers like Old Baghdad, al-Kadhimiya, and al-Adhamiya, showcased a non-linear, idiosyncratic

pattern characterized by inward expansion. The division of the larger plots into new, irregularly shaped lots turned into a more complex and disjointed local street pattern. In spite of this disjunction at the local scale, the urban pattern at the larger scale still held together with minor streets feeding directly into the major thoroughfares. These principal routes facilitated access to central public spaces, including markets, religious sites, and civic institutions, situated on the outskirts of these organic historic clusters.

3.2 An Organic Zigzag Pattern with Cul-de-sacs

A new pattern emerged within the city of Baghdad, dividing the city into a quilt of irregularly shaped plots. These were broken, usually developed by natural settings, pre-existing pathways, main doorways, and central urban plazas. The result was that the main streets zigzagged along varying widths, therefore meandering and curving a disordered network **(Al-Ashab, 1974; Hakim, 1994 and 2007; Al-Haidary, 2009)**. This is a new pattern from the previous distorted configuration, showing the intensification of fragmentation, especially in the residential building's high density. Such accesses to private residential spaces significantly provide access to semi-public spaces, into which the movements from significant public squares are strategically channeled. These spaces are adequately shared by more or less knitted family groups or clans. Often, cul-de-sacs were lozenged. The dimensions of such deformed cul-de-sacs were dependent on the density of the residential cluster and the distance to the city core, thus providing a flowing transition from the public into the private space. The street pattern evolved to follow the city expansion according to large urban blocks or incremental fabric development, see **Fig. 2**. In the same manner, the dimensions and shapes of streets in the deformed patterns were designed to fit pedestrian and horse traffic dimensions. With the introduction of the process of modernization from the mid-1950s to the 1980s, the dimensions and shapes based on this deformed pattern fit have been modified to suit contemporary cities. Most of the deformed streets have been widened to meet current cities' dimensions and shapes **(Fethi, 1977; Bianca et al., 1984a and 1984b)**, as seen in **Fig.3**.

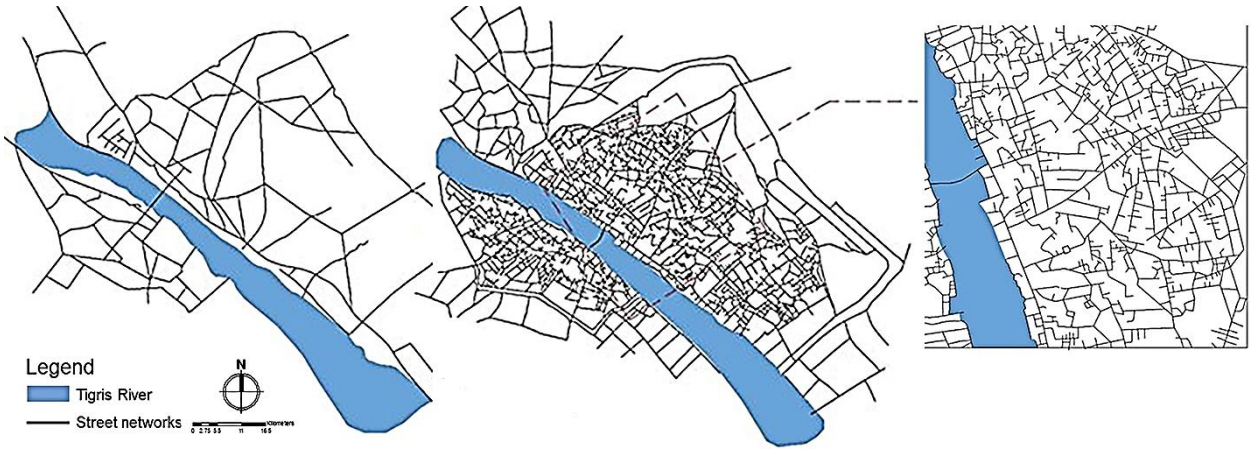

Figure 2. Configuration of organic zigzag and cul-de-sac street networks in the maps of Baghdad from the 1050s and the 1850s **(Alobaydi, 2017)**.

3.3 A Hybrid of Organic and Grid Patterns

The 1940s brought a new street pattern to Baghdad, integrating the historical, organically developed neighborhoods with more structured, geometric subdivisions. This pattern saw the elimination of cul-de-sacs in favor of an orthogonal grid system **(Bianca et al., 1984a and 1984c; Al-Rahmani, 1986)**. Main thoroughfares cutting through historical areas were evenly spaced, becoming more systematic towards the outskirts and city boundaries. Nevertheless, remnants of the zigzag networks persisted within the larger grid structure in historical areas like Old Baghdad and the historical centers of al-Kadhimiya and al-Adhamiya, see **Fig. 4**.

Figure 3. Residential organic roads (left) and widened streets (right) in the historic cores of Baghdad **(Alobaydi, 2017)**.

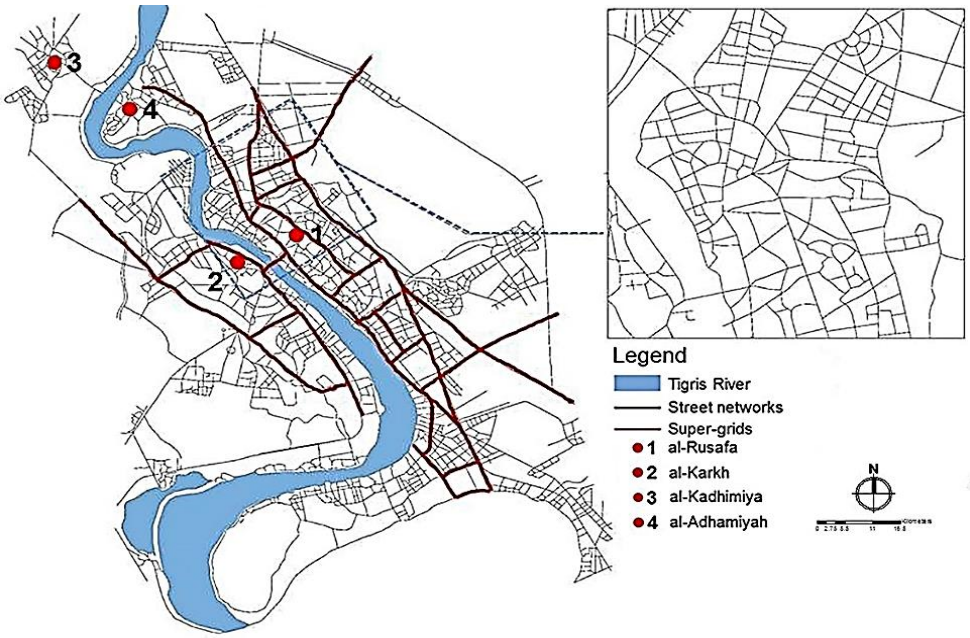

Figure 4. Baghdad's city layout exhibited a hybrid pattern of organic and gridiron street networks in the 1940s **(Alobaydi, 2017)**.

In the subsequent phase, the traditional organic and dead-end streets of these historical centers transformed through the introduction of an orthogonal grid system, aligning with contemporary urban planning standards of the 1940s. This period saw the emergence of a hybridized street pattern, blending the organic, meandering, and cul-de-sac streets with the more structured gridiron layout. While the gridiron system introduced long, straight streets that partitioned the dense historical cores into large, (almost) rectangular blocks, the original organic and cul-de-sac paths persisted within these larger grid structures, primarily serving pedestrian movements in the old city areas.

3.4 A Hybrid of Grid and Incremental Infills

Mid-20th-century developments, particularly in the southeast and northwest of Baghdad, introduced a pattern that entailed extensive land development. This was spearheaded by Doxiadis Associates, who envisioned a comprehensive blueprint for Baghdad's expansion, embedding a vast grid system that met the evolving urban and transportation requirements. It made way for the implementation of contemporary infrastructures—roads, parking spaces, and footpaths to ensure simple and smooth urban mobility **(Bianca et al., 1984a; Al-Rahmani, 1986; Pyla, 2008a and 2008b)**. The realization of this master plan had impacted upon the structure of suburban Iraq, as demonstrated in Sadr City, the al-Mansur district, and al-Adhamiyah and 9 Nissan districts along the Army Canal, see **Fig.5**.

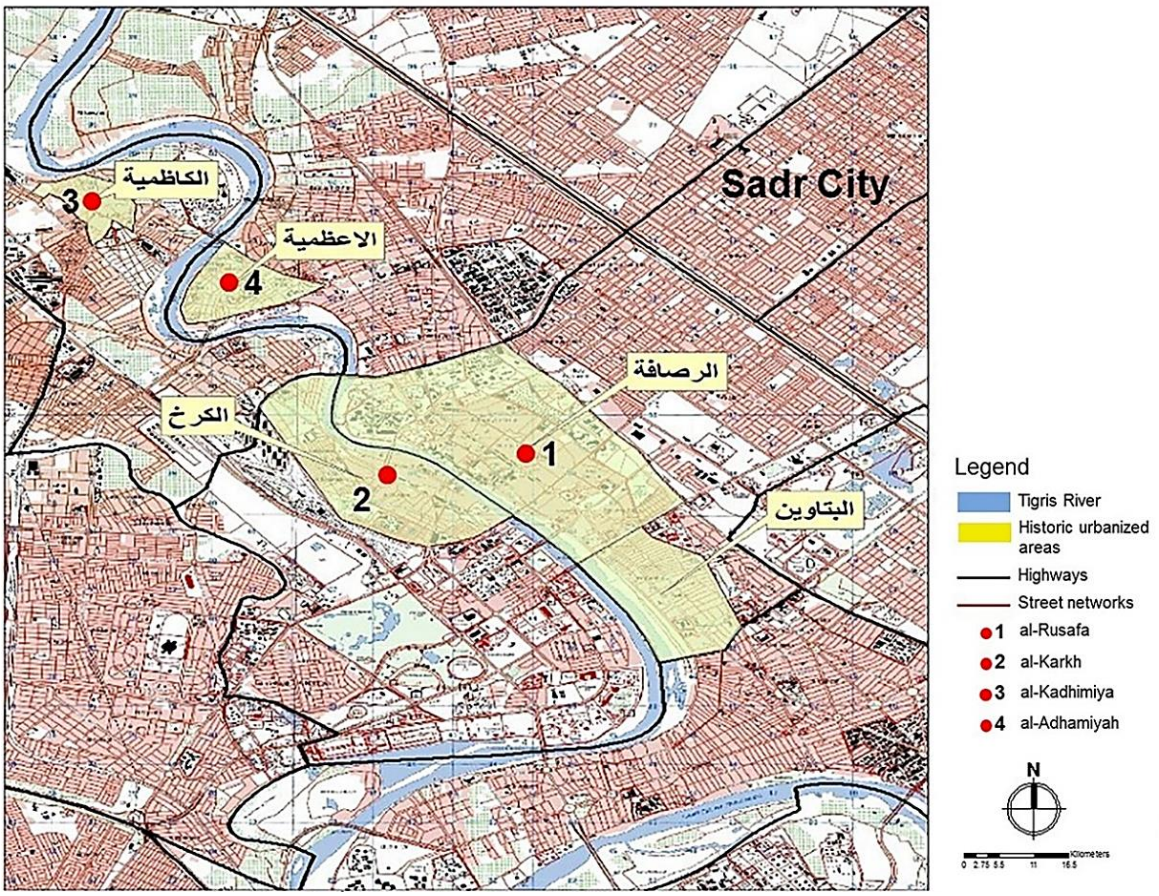

Figure 5. Gridded street patterns were implemented in Baghdad between the 1960s and 1980s **(Alobaydi, 2017)**.

3.5 A Hybrid of Super Grid and Interrupted Parallels

One of the largest urban modernization efforts during the mid-1950s, under the Iraqi Development Board (IDB), was to improve the road and mass transit networks in the city. The IDB came up with a super-grid that was much larger than any traditional grid, and it was designed for accommodating high volumes of traffic moving from the suburban areas into central Baghdad **(Al-Rahmani, 1986)**. This framework transformed large open spaces at the city's periphery into new suburban blocks, characterized by regular, rectangular layouts **(Gulick, 1967)**. The super-grid facilitated urban expansion through two distinct street patterns: interrupted parallel streets identified in the 1960s maps and incremental infills occurring from the mid-1980s to the 2000s, see **Fig. 6**.

The 1960s ushered in the fourth morphological phase, during which a gridiron pattern aimed at incremental development (i.e., gridiron with incremental infills) was adopted. This strategy was designed to manage and direct the swift urban expansion and sprawl occurring at Baghdad's fringes, particularly in southeastern districts like Sadr City (along the Army Canal) and southwestern areas including al-Mansur and al-Rasheed.

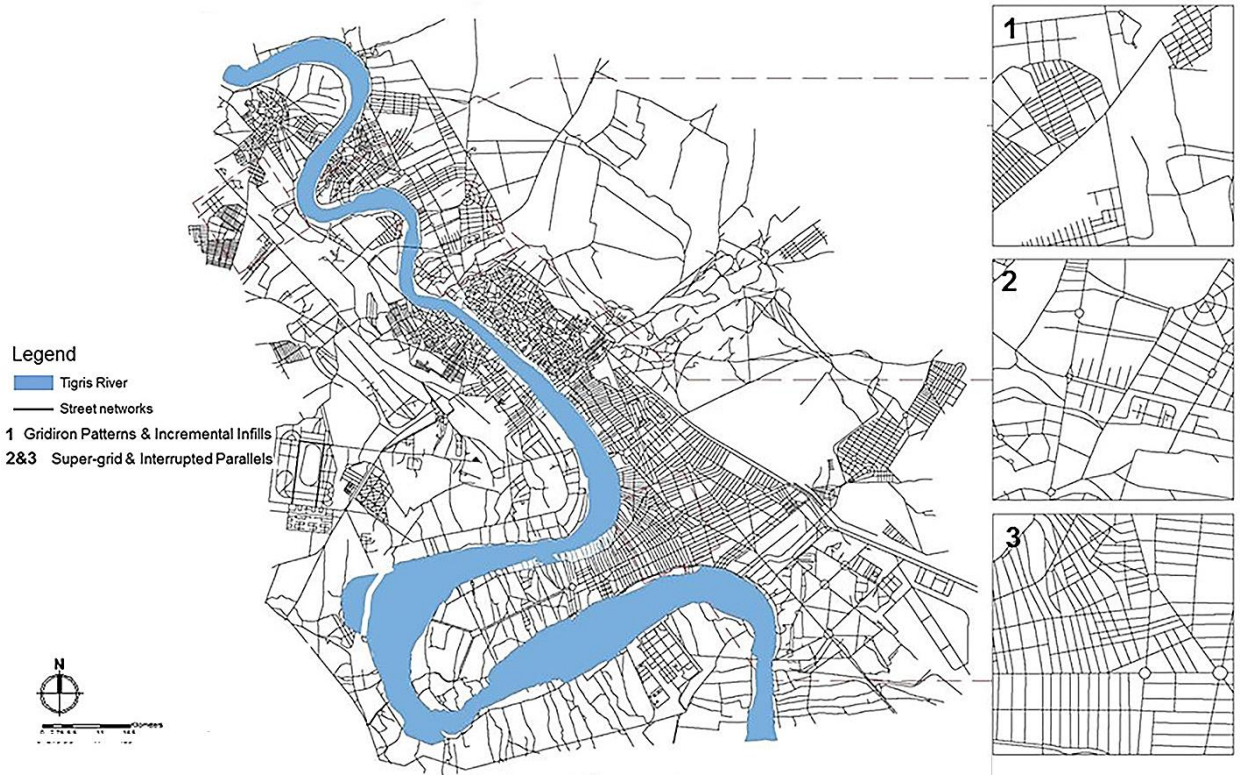

Figure 6. The pattern of hybrid of super grid and interrupted parallels of the street network **(Alobaydi, 2017)**.

3.6 A Hybrid of Organic, Composite, and Deformed Grid

The current phase of Baghdad's urban development features a novel street grid pattern, blending organic and deformed gridiron systems into a unique hybrid. This pattern is characterized by frequent turns and curves, bridging the gap between historical organic street layouts and newer, grid-based developments. The spatial qualities of this pattern vary, displaying more organic traits near historical centers like al-Kadhimiya and al-Adhamiya,

and adopting a more structured form in modern residential and industrial zones. The hybrid pattern seamlessly integrates various street configurations, from long roads with multiple access points to denser, organic networks, reflecting the diverse urban tapestry of Baghdad, see **Fig.7**.

In the most recent phase, a pattern characterized by an interrupted super-grid (i.e., super-grid with interrupted parallels) was established to facilitate the movement of high volumes of traffic over long distances, from suburban zones to Baghdad's central business district and back. From the mid-1950s to the mid-1980s, this super-grid partitioned extensive regions of Baghdad into rectangular blocks of varying sizes, with these empty plots being progressively developed from the mid-1980s through the mid-2000s.

Concurrently, a transitional pattern has emerged, bridging the gap between the central organic layouts and the peripheral gridiron structures. This evolving pattern exhibits a dynamic nature, appearing more organic in proximity to historical cores and more grid-oriented in areas between modern residential zones and the administrative/industrial sectors established in the mid-1980s, such as the al-Karkh, Karrada, and 9 Nissan quarters.

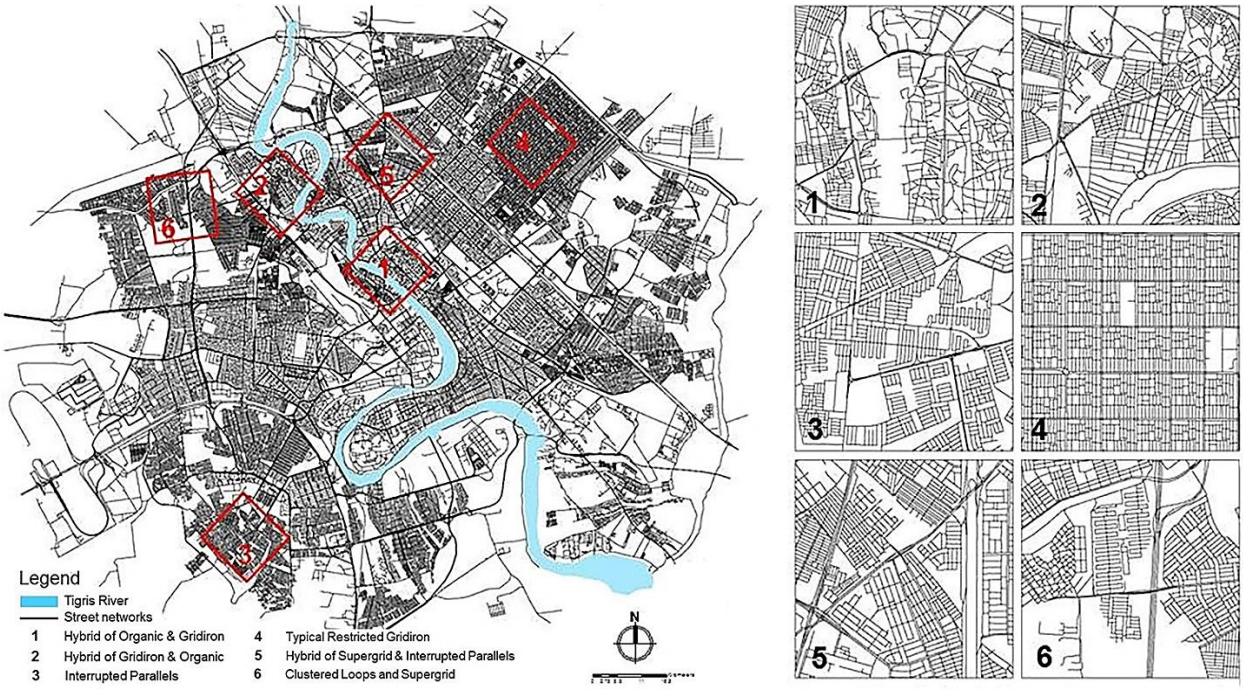

Figure 7. The pattern of hybrid of Organic and Deformed Grid of the street network **(Alobaydi, 2017)**.

4. IMPLICATIONS FOR URBAN DESIGN

In the early 20th century, the gridiron street system was introduced across various urban landscapes, including ancient Middle Eastern cities like Baghdad, to regulate movement and shape urban development. This system, designed for connecting urban areas through strict engineering standards for highways and underpasses **(Pyla, 2008a)**, allocated significant urban space to vehicular traffic, creating distinct pedestrian and vehicle zones **(Wilson, 1983; Southworth and Owens, 1992; Southworth and Owens, 1993).** However, this segregation, while enhancing safety and privacy, has been critiqued for reducing the

vibrancy seen in historic urban centers where pedestrian and vehicle flows blend seamlessly **(Southworth and Ben-Joseph, 1995 and 2013)**.

Baghdad's suburban growth introduced several challenges:

- Beltways and major highways intensified the separation between local and broader traffic movements.
- Residents became reliant on main roads and expressways for commuting, pushing the development of dense commercial and mixed-use areas to the city's edges, like in Sadr City and the 9 Nissan district.
- Suburbs became preferred residential areas due to these changes.

Transitioning Transitioning from compact urban cores to sprawling gridiron outskirts challenges Baghdad's urban designers and planners to integrate new gridiron roads with the city's historic lanes to improve accessibility and connectivity **(Alobaydi et al., 2016; Alobaydi and Rashid, 2017; Alsaffar and Alobaydi, 2023; Al Hashimi and Alobaydi, 2023)**. Despite early gridiron layouts achieving a connected urban fabric, their expansion has limited intersections, affecting accessibility but potentially streamlining traffic flow.

Urban designers and planners are urged to consider streets as essential public spaces for various activities, noting the lack of pedestrian paths, bike lanes, and green spaces in Baghdad's suburban design **(Kropf, 2009**; **Dempsey et al., 2010**; **Al-Akkam, 2012; Al-Akkam, 2013)**. This underscores the need to balance 'mobility,' or speed, with 'accessibility,' focusing on convenience and the promotion of pedestrian and friendly spaces; there were few studies that addressed this kind of issue, which are included but not limited to **(Albabely and Alobaydi, 2024)**.

5. DESIGN PRINCIPLES FOR URBAN ENVIRONMENTS

While the focus of our street pattern analysis has been primarily on Baghdad, the derived insights hold potential applicability across other cities in Iraq or Middle Eastern regions sharing similar urban characteristics with Baghdad. The morphological study offered enlightening perspectives on (1) the genesis, evolution, and expansion of Baghdad's street configurations, and (2) the essential physical characteristics and spatial considerations for enhancing street efficiency, moving beyond the early 20th century urban standards and practices, which were often adopted without tailoring to the local socio-economic and environmental context **(Gulick, 1967; Al-Ashab, 1974; Hakim, 1994)**. Based on the historical evolution of the six street patterns identified, we propose the following urban design guidelines:

- Preserve the unique organic street forms of historic centers, including narrow lanes and cul-de-sacs, essential for socio-cultural dynamics **(Hakim, 2007 and 2013)**. Avoid alterations like widening or modernization that compromise their character, emphasizing their role in serving community needs over vehicular traffic.
- Maintain the privacy of traditional neighborhoods with cul-de-sacs by preventing unsolicited intrusion, and respecting the Arab-Islamic tradition of decency. Regulatory bodies should safeguard the integrity of private, semi-private, and public spaces in these areas.
- Carefully integrate a hybrid of organic and gridiron patterns, ensuring they complement the urban network without disrupting historical areas. Reassess their design, including width and speed limits, for better harmony with the historic core, guided by Wheeler and

Beatley's principles on urban life as well as relevant studies **(Wheeler and Beatley, 2014; Næss, 2022; Farhan et al., 2022; Richardsen Moberg, 2024)**.

- Hybrid of Gridiron Patterns and Incremental Infills: Revising the criteria for this street system, predominantly found in Baghdad's modern suburbs and industrial areas, could mitigate its environmental and visual detriments.
- Limit the super grid system's expansion to control urban sprawl and prevent slum development at city edges, emphasizing professional insights over political directives in planning, as informed by historical challenges in disrupted zones **(Fethi, 1977; Al-Rahmani, 1986; Pyla, 2008a and 2008b)**.
- Mitigate urban deformation by informed initiatives that understand and respect the contrast between pedestrian-focused organic streets and high-traffic grid networks, addressing the complexity of integrating diverse street patterns, more concepts and practices can be seen in the works of **(Coleman et al., 2023; Gorgol, 2024; Wu et al., 2024)**.

6. CONCLUSIONS

This study analyzed the evolving street layouts of Baghdad, tracing the city's morphological changes from its organic origins to its modern sprawl. It examined the interaction between historical routes and modern grid systems, highlighting the persistence of traditional urban forms amidst rapid modernization. The study underscored that access has to be weighed against history's authenticity; it therefore recommended a model that embodies accessibility and mobility, on one hand, and the perpetuation of socio-cultural heritage on the other. This brings the findings to highlight the grid-iron street network in the newer suburbs against the narrow twisting lanes of historic districts and echoing the street's double function: being the 'channel of movements' together with its 'place functions of social interaction.' The proposed design interventions would enrich historic neighborhoods, thereby making inclusive and vibrant urban areas that are a tribute to the area's cultural heritage. The study detailed how the move was made from tight urban cores to sprawling suburbs, future challenges, and opportunities to develop this new growth. It underscored that the new growth shall be integrated with the existing urban fabric and bring out suitable design strategies for a Middle Eastern Urban Environment. This research not only enhances understanding of Baghdad's urban morphology but also offers valuable design insights for similar cities, addressing ongoing urban expansion and transformation challenges.

However, the study acknowledges its methodological limitations, primarily due to reliance on Western sources and historical documents, potentially limiting a critical review of Baghdad's urban characteristics. The research stops at 2003, missing the impact of subsequent socio-political dynamics, technological advancements, and planning strategies. Future research thus should employ advanced tools like Space Syntax Analysis (SSA) and Urban Network Analysis (UNA) with modern data to better understand recent urban developments in Baghdad.

Acknowledgements

This work was supported by the Central Library at the University of Baghdad and the Municipality of Baghdad in providing some data and sources.

Declaration of Competing Interest

The author states that there are no known financial conflicts of interest or personal relationships that could have influenced the work presented in this paper.

REFERENCES

Abu-Lughod, J.L., 2017. The Islamic City: Historic Myth, Islamic Essence, and Contemporary Relevance. In *Urban Development in the Muslim World* (pp. 11-36). Routledge. https://www.jstor.org/stable/163352?origin=JSTOR-pdf .

Al Hashimi, H., Alobaydi, D., 2023, March. Measuring spatial properties of historic urban networks. In *AIP Conference Proceedings*, 2651(1). AIP Publishing. https://doi.org/10.1063/5.0117077.

Al-Akkam, A. J., 2012. Towards Environmentally Sustainable Urban Regeneration: A Framework for Baghdad City Centre. *Journal of sustainable development*, 5(9), 58. https://www.ccsenet.org/journal/index.php/jsd/article/view/20020 .

Al-Akkam, A. J., 2013. Urban heritage in Baghdad: Toward a comprehensive sustainable framework. *Journal of sustainable development*, 6(2), 39. https://doi.org/10.5539/jsd.v6n2p39

Al-Ashab, K.H., 1974. *The urban geography of Baghdad* (Doctoral dissertation, Newcastle University). https://theses.ncl.ac.uk/jspui/handle/10443/1059 .

Albabely, S., Alobaydi, D., 2024. Analyzing Movement Densities in AlKarkh Districts: A Comparative Study. *Journal of Engineering*, *30*(04), pp.134-151. https://doi.org/10.31026/j.eng.2024.04.09 .

Al-Haidary, A., 2009. Vanishing point: the abatement of tradition and new architectural development in Baghdad's historic centers over the past century. *Contemporary Arab Affairs*, *2*(1), pp.38-66. https://brill.com/view/journals/jcaa/2/1/article-p38_4.xml .

Al-Khafaji, S.J.N., Al-Qaisi, S.B.M., 2012. The Characteristics of the Traditional Urban Configuration of ArabIslamic Cities through Form and Moral Values: Al-Kadhimiya as a Case Study. *Journal of Engineering*, *18*(10), pp.187-207. https://doi.org/10.31026/j.eng.2012.10.09 .

Alobaydi, D., Al-Mosawe, H., Lateef, I.M., Albayati, A.H., 2020. Impact of urban morphological changes on traffic performance of Jadriyah intersection. *Cogent engineering*, *7*(1), p.1772946. https://doi.org/10.1080/23311916.2020.1772946

Alobaydi, D., Bakarman, M.A., and Obeidat, B., 2016. The impact of urban form configuration on the urban heat island: the case study of Baghdad, Iraq. *Procedia Engineering*, *145*, pp.820-827. DOI: https://doi.org/10.1016/j.proeng.2016.04.107

Alobaydi, D., Rashid, M., 2015. Evolving syntactic structures of Baghdad: Introducing 'transect'as a way to study morphological evolution. In *The 10th Space Syntax Symposium (SSS10) from* (Vol. 13), pp. 40.1-40.14.

Alobaydi, D., Rashid, M., 2017. A Study of the Morphological Evolution of the Urban Cores of Baghdad in the 19th and 20th Century. In *Eleventh international space syntax symposium at Instituto superior Técnico, University of Lisbon, Portugal* , pp. 38.1 – 38.12.

Alobaydi, D.M., 2017. A study of the urban morphological processes of Baghdad: Implications and guidelines for urban design and planning in middle eastern cities. *Kansas, US: Faculty of the University of Kansas*.

Al-Rahmani, S.F., Wager, J.F., 1986. *Principles for Urban Renewal in Iraq: A Study to Develop Town Planning Principles for the Renewal of the Iraqi Cities with Particular Reference to Baghdad Central Area*. University of Manchester.

Al-Saaidy, H.J.E., 2020. Urban form elements and urban Potentiality (literature review). *Journal of Engineering*, *26*(9), pp.65-82. https://doi.org/10.31026/j.eng.2020.09.05 .

Al-Saaidy, H.J.E., 2024. A dramatic morphological transformation from a spontaneous, organic street pattern to pre-planned-based order: learning from Baghdad city. *Urban, Planning and Transport Research*, *12*(1), p.2287569. https://doi.org/10.1080/21650020.2023.2287569 .

Alsaffar, N.H., Alobaydi, D., 2023, March. Studying street configurations and land-uses in the downtown of Baghdad. In *AIP Conference Proceedings*, 2651 (1). AIP Publishing. https://doi.org/10.1063/5.0105420 .

AlSayyad, N., 1987. Space in an Islamic city: Some urban design patterns. *Journal of Architectural and Planning Research*, Vol. 4, No. 2, pp.108-119. https://www.jstor.org/stable/43029486

ALslik, G.M.R., Majeed, F.A., 2014. Succession of urban structures of the city of Baghdad. *Journal of Engineering*, *20*(12), pp.1-30. https://doi.org/10.31026/j.eng.2014.12.11 .

Beatley, T., Wheeler, S.M. eds., 2004. *The sustainable urban development reader*. London, UK: Routledge.

Bianca, S., Yamada, S., Fethi, I., and Lombardi, G., 1984a. Synthesis Report of Rusafa: Study on Conservation and Redevelopment of Historical Centre of Baghdad City, Vol. 2A, pp. 1-111. Baghdad, Iraq: Amanat Al Assima (Municipality of Baghdad).

Bianca, S., Yamada, S., Fethi, I., and Lombardi, G., 1984b. Synthesis Report of Rusafa: Study on Conservation and Redevelopment of Historical Centre of Baghdad City, Vol. 2B, pp. 1-135. Baghdad, Iraq: Amanat Al Assima (Municipality of Baghdad).

Bianca, S., Yamada, S., Fethi, I., and Lombardi, G., 1984c. Technical Report of Rusafa: Study on Conservation and Redevelopment of Historical Centre of Baghdad City, Vol. 3A, pp. 1-87. Baghdad, Iraq: Amanat Al Assima (Municipality of Baghdad).

Clifton, K., Ewing, R., Knaap, G.J., and Song, Y., 2008. Quantitative analysis of urban form: a multidisciplinary review. *Journal of Urbanism*, *1*(1), pp.17-45. https://www.tandfonline.com/doi/full/10.1080/17549170801903496 .

Coleman, A.F., Eisenman, T.S., Locke, D.H., and Harper, R.W., 2023. Exploring links between resident satisfaction and participation in an urban tree planting initiative. *Cities*, 134, p.104195. https://www.sciencedirect.com/science/article/abs/pii/S0264275123000070?via%3Dihub .

Dempsey, N., Brown, C., Raman, S., Porta, S., Jenks, M., Jones, C., and Bramley, G., 2010. Elements of urban form. *Dimensions of the sustainable city*, pp.21-51. https://pure.strath.ac.uk/ws/portalfiles/portal/122929756/Dempsey_et_al_2010_Ch2.pdf .

Farhan, S.L., Alobaydi, D., Anton, D., and Nasar, Z., 2022. Analysing the master plan development and urban heritage of Najaf City in Iraq. *Journal of Cultural Heritage Management and Sustainable Development*. https://www.emerald.com/insight/content/doi/10.1108/JCHMSD-07-2020-0101/full/html .

Fethi, I.A.W., 1978. *Urban conservation in Iraq: the case for protecting the cultural heritage of Iraq with special reference to Baghdad, including a comprehensive inventory of its areas and buildings of historic*

or architectural interest (Doctoral dissertation, University of Sheffield). https://etheses.whiterose.ac.uk/10302/3/455394_1.pdf .

Gorgol, N.K., 2024. What Is a Resilient Smart City? Blue–Green Infrastructure as a Strategic Feature of Smart Urban Form: Empirical Evidence with a Particular Focus on the Songdo IBD and Aspern Seestadt in Vienna. *Sustainability*, *16*(5), p.1758. https://www.mdpi.com/2071-1050/16/5/1758 .

Gulick, J., 1967. Baghdad: Portrait of a City IIM Physical and Cultural Change. *Journal of the American Institute of Planners*, *33*(4), pp.246-255.

Hakim, B.S., 1994. The "Urf" and its role in diversifying the architecture of traditional Islamic cities. *Journal of Architectural and Planning Research*, pp.108-127.

Hakim, B.S., 2007. Generative processes for revitalizing historic towns or heritage districts. *Urban Design International*, *12*(2), pp.87-99.

Hakim, B.S., 2013. *Arabic Islamic cities rev: Building and planning principles*. routledge.

Huang, G., Qiao, S., and Yeh, A.G.O., 2024. Multilevel effects of urban form and urban functional zones on housing prices: evidence from open-source big data. *Journal of Housing and the Built Environment*, pp.1-25. https://doi.org/10.1007/s10901-023-10109-y

Kostof, S., 1991. *The city shaped* (pp. 9-39). Boston, MA: Little, Brown and Company.

Kropf, K., 2009. Aspects of urban form. *Urban morphology*, *13*(2), pp.105-120.

Lapidus, I.M., 1973. The evolution of Muslim urban society. *Comparative Studies in Society and History*, *15*(1), pp.21-50.

Mahdi, H.J., Maythm, A.B., and Ubaidy, A.L., 2023. Evaluating Roads Network Connectivity for Two Municipalities in Baghdad-Iraq. *Journal of Engineering*, *29*(06), pp.60-71. DOI: https://doi.org/10.31026/j.eng.2023.06.05 .

Mohammed, L.R., Alobaydi, D., 2020a, March. Evolution of the urban form of historic hit citadel: deriving a schematic model for iraqi fortified cities. In *IOP Conference Series: Materials Science and Engineering* (Vol. 745, No. 1, p. 012180). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/745/1/012180 .

Mohammed, L.R., Alobaydi, D., 2020b, July. Studying Sustainable Actions of Syntactic Structures of Historic Hit Citadel: A Morphological Approach. In *IOP Conference Series: Materials Science and Engineering* (Vol. 881, No. 1, p. 012034). IOP Publishing. https://iopscience.iop.org/article/10.1088/1757-899X/881/1/012034/meta .

Næss, P., 2022. Compact urban development in Norway: Spatial changes, underlying policies and travel impacts. *In Advances in transport policy and planning,* 9, pp. 95-133. Academic Press.

Pyla, P., 2008a. Back to the Future: Doxiadis's Plans for Baghdad. *Journal of Planning History*, 7(1), pp. 3-19.

Pyla, P., 2008b. Baghdad's Urban Restructuring, 1958: *Aesthetics and Politics of Nation Building. Modernism and the Middle East: Architecture and Politics in the Twentieth Century*, pp. 97-115.

Richardsen Moberg, K., 2024. Environmentally friendly urban development: changes in decision-makers' attitudes, problem perceptions and policy preferences over three decades. *Journal of Environmental Planning and Management*, 67(4), pp.919-941. https://www.tandfonline.com/doi/full/10.1080/09640568.2022.2142539 .

Saoud, R., 2002. Introduction to the Islamic city. *FSTC Limited*. DOI: https://www.muslimheritage.com/uploads/Islamic%20City.pdf

Southworth, M., Ben-Joseph, E., 1995. Street standards and the shaping of suburbia. *Journal of the American Planning Association*, *61*(1), pp.65-81.

Southworth, M., Ben-Joseph, E., 2004. Reconsidering the cul-de-sac. *Access Magazine*, *1*(24), pp.28-33.

Southworth, M., Ben-Joseph, E., 2013. *Streets and the Shaping of Towns and Cities*. Island Press.

Southworth, M., Owens, P.L., 1992. *The Evolving Metropolis: Neighborhood and Street Form at the Urban Edge*. University of California. Institute of Urban and Regional Development.

Southworth, M., Owens, P.M., 1993. The evolving metropolis: Studies of community, neighborhood, and street form at the urban edge. *Journal of the American Planning Association*, *59*(3), pp.271-287.

Wilson, S., 1983. Baghdad Comprehensive Transportation Study, Final Report. *Kirkpatrick and partners.*

Wu, C., Wang, Y., Wang, J., Kraak, M.J., and Wang, M., 2024. Mapping Street Patterns with Network Science and Supervised Machine Learning. *ISPRS International Journal of Geo-Information*, *13*(4), p.114. https://www.mdpi.com/2220-9964/13/4/114 .

تطور هياكل الشوارع: دراسة مورفولوجية

ضرغام مزهر كريم العبيدي*[1]، محبوب رشيد[2]

[1] قسم هندسة العمارة، كلية الهندسة، جامعة بغداد، بغداد، العراق

[2] كلية العمارة والتصميم، جامعة كانساس، كانساس، الولايات المتحدة الامريكية

الخلاصة

تستكشف هذه الدراسة تطور البُنى التحتية للشوارع في بغداد، بدءا من التكوينات العضوية القديمة وصولاً إلى التوسع العاصمي (المتروبولي) الحديث، وتتناول فجوة مهمة في الدراسات الحضرية التي تختص بتحليل المورفولوجيا الخاصة بأنماط الشوارع في مدينة شرق أوسطية انموذجية. يستخدم هذا البحث منهجية عملية تشمل عدة مراحل متضمنة: جمع البيانات، والرقمنة، وعمليات التعريف وذلك لإستكشاف وفك ترميز البُنى التحتية المورفولوجية لشوارع بغداد الحضرية. إذ تم الاستفادة من الخرائط التاريخية وصور الأقمار الصناعية المعاصرة، مدعومة بالمسوحات ميدانية. حددت التحليلات ستة أنماط لشوارع مميزة تبرز تطور بغداد الحضري ومرونتها، وبالتالي يُسلط الضوء على التفاعل بين الأشكال الحضرية التقليدية وممارسات التخطيط الحديث. تتوصل الدراسة إلى أهمية الحفاظ على التاريخية الحضرية مع استيعاب النمو العصري، داعيةً إلى مبادئ التصميم التي تتسم بالدقة تجاه الديناميكيات الاجتماعية والثقافية للمدن الشرق أوسطية. اذ تسهم هذه الدراسة في الحوار المتعلق بمورفولوجيا التحضر، مقدمة رؤى للتخطيط الحضري والتصميم في بغداد والمدن المماثلة ، كما تُبرز أهمية دور مورفولوجيا الشوارع في هوية المشهد الحضري ووظيفته، داعيةً لبيئات تحترم السياق التاريخي مع تلبية احتياجات الحياة الحضرية المعاصرة. تشير النتائج إلى أن الشوارع قد تطورت بطرق تأثرت بالثقافة والتكنولوجيا والعوامل الاجتماعية والاقتصادية. وخلصوا إلى أن الشوارع تطورت بناءً على عمليات تراكمية واتجاهات ومقاييس التنمية. يمهد هذا البحث الطريق للدراسات المستقبلية، بهدف تعزيز فهمنا للدور الحاسم لتشكيل العمران الحضري في التصميم المستدام والمتجاوب مع الثقافة.

الكلمات المفتاحية: الشوارع ، المورفولوجيا ، التطور ، الشكل الحضري .