Wasit Journal of Engineering Sciences
Journal homepage: https://ejuow.uowasit.edu.iq
Vol. 14 No. 2 June 2026, pp.222-236
https://doi.org/10.31185/ejuow.v14i2.853

ISSN 2305-6932
Original Research

Morphological Transformations in Old Rusafa: A Spatial-Structural Analysis for Urban Revitalization

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Received Feb. 16, 2026 | Revised Mar. 9, 2026 | Accepted Mar. 19, 2026 | Online Jun.1, 2026

ABSTRACT

Urban growth pressures have profoundly reshaped the spatial structure of historic city centers, often leading to fragmentation and a decline in morphological coherence. In Baghdad's historic core, particularly Old Rusafa, successive planning interventions transformed the traditional pathway network from an organic, river-oriented system into longitudinal and grid-based configurations. However, it remains unclear whether these transformations represent a complete rupture from the historic fabric or a reconfiguration of inherited spatial structures. This study addresses this gap by examining the diachronic evolution of Baghdad's pathway network and evaluating the extent to which modern streets retain underlying morphological continuity. Using the space syntax methodology, the research analyzes integration, connectivity, choice, and intelligibility across four clearly defined historical phases to trace shifts in movement structure and spatial hierarchy. The results demonstrate that several modern routes, despite their formal modernization, remain structurally aligned with earlier pathways and continue to play a significant role within the overall network. This indicates the persistence of a latent morphological framework that continues to shape contemporary movement patterns in Old Rusafa.The study argues that urban modernization altered the physical form of Baghdad's historic center without erasing its structural logic. By revealing this continuity, the research provides an analytical basis for context-sensitive urban regeneration strategies and demonstrates how configurational analysis can inform targeted and sustainable interventions in historic city centers.

Keywords: Baghdad Old Rusafa, Morphological transformations, Space Syntax, Urban Pathways, Urban injection, Urban regeneration

1. Introduction

Historic city centers are continuously reshaped by successive phases of growth, planning interventions, and infrastructural transformation. These processes often alter the orientation and hierarchy of urban pathways, affecting movement patterns, spatial coherence, and the functional role of historic cores. In Middle Eastern cities, such transformations are particularly complex due to the layering of organic fabrics, modern planning schemes, and large-scale infrastructural projects. Baghdad's historic center provides a critical case for examining these dynamics. Over time, its pathway network evolved from an organic structure oriented toward the Tigris River into longitudinal and later grid-based configurations influenced by successive planning decisions and modernization initiatives. While these transformations have been extensively documented from historical and descriptive perspectives, their structural implications for the continuity of the pathway network remain insufficiently explored. A key research gap concerns whether modern streets in Baghdad's historic center—particularly in Old Rusafa—represent a complete morphological rupture or a reconfiguration of inherited spatial structures. Existing studies have addressed Baghdad's urban history and planning phases;

however, few have systematically examined the deep spatial logic of pathway orientation across multiple historical stages using quantitative spatial analysis.

To address this gap, this study employs the space syntax methodology to analyze integration, connectivity, choice, and intelligibility across four clearly defined morphological phases. This approach enables the identification of persistent spatial structures embedded within modern street configurations and allows for a structural reading of urban transformation beyond formal or visual change.

Beyond diagnosis, the study links spatial analysis to an applied urban regeneration framework through the concept of urban injection. By identifying structurally significant routes, nodes, and degraded spaces, the research demonstrates how configurational analysis can inform targeted, context-sensitive interventions aimed at revitalizing historic centers while preserving their inherited spatial logic. Accordingly, this research aims to trace the evolution of pathway orientation in Baghdad's historic center, evaluate the continuity of its morphological structure, and translate analytical findings into an operational regeneration strategy. The study contributes to urban morphology literature by offering a spatially grounded model for understanding and revitalizing historic city centers in the Middle Eastern context.

2. Theoretical Framework

2.1. Urban Growth and Historic Centers

Urban growth represents a cumulative process through which cities expand and reorganize their spatial structure over time, influencing land use, density, and movement systems. In historic centers, successive phases of growth—whether organic or planned—often create tensions between inherited urban fabrics and modern interventions, leading to fragmentation and shifts in spatial hierarchy [6], [11]. Such transformations may weaken spatial clarity and disrupt established movement patterns if they are not structurally integrated within the existing urban network [12], [13]. Baghdad's historic center exemplifies this condition, where pathway orientations evolved in response to changing planning paradigms rather than through spontaneous growth. The historical walls of Baghdad played a central role in shaping the structure of the urban network. As shown in Figures 1 and 2 below.

Figure 1. Baghdad Map In (1853-1*854*)

Figure 2. Baghdad Map In (1908)

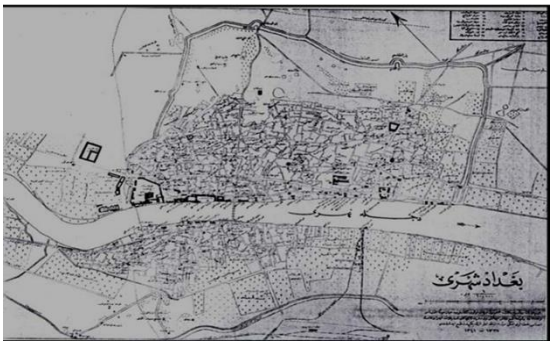

Figure 3. Baghdad Map In (1919)

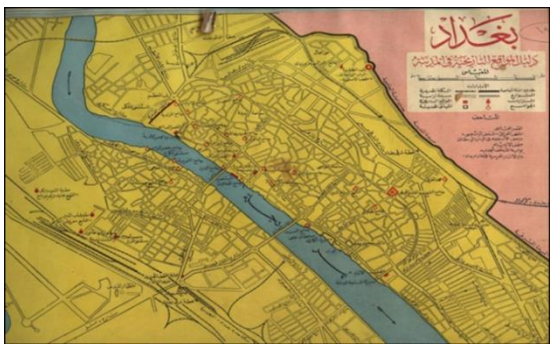

Figure 4. Baghdad Map In (1952)

2.2. Urban Expansion Patterns in Baghdad

The early stages of the disintegration of the walled city and the transition from an organic urban pattern to a more linear configuration parallel to modern streets such as Rashid and Kifah are reflected in the map prepared by Muhammad Amin Zaki (1919). These transformations are further supported by studies examining the morphological evolution of the city [8]. As shown in Figures 3 and 4 above.

Previous studies identify three dominant patterns of urban expansion that shaped Baghdad's morphology: infilling within the historic core, edge expansion following the removal of the city walls, and outward growth associated with mid-twentieth-century modernization [4], [14]. These patterns correspond to a diffusion–coalescence process, in which incremental spatial changes gradually produced a restructured yet interconnected urban system.

2.3. The Role of Historical Walls

The historical walls of Baghdad played a decisive role in organizing early movement systems and limiting spatial expansion. Their removal—particularly the demolition of the Rusafa wall in 1869—marked a structural turning point, enabling the emergence of new longitudinal routes parallel to the Tigris River [15], [16]. Cartographic evidence from the early twentieth century demonstrates that this transformation altered route orientation while maintaining partial continuity with earlier path structures [8].

2.4. Twentieth-Century Morphological Transformation

Major twentieth-century planning interventions, including Rashid Street and new river crossings, reconfigured Baghdad's urban network by introducing wide, high-capacity axes into the historic fabric. While these projects enhanced regional connectivity, they also reduced the spatial integration of traditional alleyways and contributed to the fragmentation of local movement systems [5], [16]. This phase represents a shift from a predominantly organic morphology toward a more linear and hierarchical urban network. As shown in Figure 4 above.

2.5. Paths in Urban Theory

Paths constitute a fundamental element of urban structure, shaping both movement and spatial perception. Kevin Lynch emphasized their role in enhancing urban legibility, while Roger Trancik highlighted their importance in structuring lost and residual spaces within cities [13], [17]. Building on these concepts, Bill Hillier's Space Syntax theory provides a quantitative framework for analyzing how path configuration influences natural movement through measures such as integration, connectivity, and intelligibility [3].

2.6. Urban Formation Models in Baghdad

Mackie's models of urban formation describe Baghdad's transformation through successive structural paradigms, ranging from traditional organic fabrics to large-scale modern interventions [15]. These models help explain how new infrastructural layers interact with inherited spatial systems, rather than entirely replacing them.

2.7. Space Syntax and Morphological Genotype

Within this framework, Space Syntax enables the identification of a city's morphological genotype—the underlying spatial logic that persists despite formal change. Previous research demonstrates that many contemporary routes in Baghdad retain structural characteristics of historical pathways, reflecting long-term configurational continuity within the urban network [2], [3], [5]. This concept provides the theoretical foundation for interpreting spatial analysis results and linking them to targeted urban regeneration strategies.

3. Study Area: Old Rusafa

Old Rusafa represents one of Baghdad's oldest and most significant historic urban cores, forming the eastern nucleus of the city since the Abbasid period. Its early development began in 151 AH/768 CE, when Caliph Al-Mahdi established a reception and administrative center near the shrine of Imam Abu Hanifa, triggering

sustained urban and commercial growth in the area [15]. This early phase generated an organic urban fabric structured around mosques, markets, and narrow alleyways, forming the initial morphological framework of Rusafa.

A major structural shift occurred in the nineteenth century with the demolition of the Rusafa wall in 1869, marking the transition from a confined walled city to a more open system that allowed edge expansion [16]. Subsequent modern interventions in the early twentieth century—most notably the construction of Rashid Street, the river embankment, and later the Martyrs' Bridge—introduced new longitudinal axes parallel to the Tigris River, altering traditional movement patterns and spatial hierarchy [16], [18].

Following the 1936 master plan, further modernization projects such as Al-Kifah Street and Al-Khalifah Street intensified this transformation. These interventions resulted in the removal of large portions of the traditional urban fabric and divided central Rusafa into five longitudinal sectors parallel to the river [5]. Consequently, spatial integration shifted from the historic alleyway network toward modern high-capacity streets, leading to fragmented connectivity within the old fabric, as confirmed by space syntax analysis [2], [3].

Today, Old Rusafa constitutes a complex, multi-layered urban structure in which Abbasid, Ottoman, and modern planning systems intersect. This layered morphology—characterized by both fragmentation and latent spatial continuity—makes Rusafa a critical case for applying space syntax methodology. It also provides a strong spatial foundation for testing urban injection strategies aimed at reconnecting fragmented pathways and enhancing the integration of inherited historical structures within contemporary urban systems**.**

4. Research Methodology

This study adopts an analytical–synthetic methodology that integrates historical cartographic reconstruction with quantitative spatial analysis to trace the morphological transformation of Baghdad's historic center and translate analytical findings into an applied urban injection framework.
The methodology is structured into five sequential stages.

4.1. Historical Maps Collection and Reconstruction

These patterns were linked to the transformations that Al-Rusafa's urban fabric underwent in the 19th and 20th centuries, consistent with studies that addressed the morphological evolution of Baghdad [2]. These changes reflect the gradual transition from a predominantly organic urban structure toward a more structured and hierarchical network influenced by modern planning interventions. They also reveal how successive layers of development reshaped movement patterns while preserving elements of the historic spatial framework. As shown in Table 1 below.

Table 1. Historical Maps Collection and Reconstruction

Map / Source	Year	Description	Processing / Use
Abbasid and Ottoman walls	–	Historical city walls of Baghdad	Digitized and georeferenced in GIS for route network reconstruction
Rashid al-Khoja	1908	Map showing street network and key urban elements	Converted to GIS and used to extract the network of that period
Muhammad Amin Zaki	1919	Early 20th-century map of Baghdad	Digitized for comparison with previous phases
Baghdad Master Plan	1936	Modern planning interventions, wide streets	Integrated into GIS to assess morphological transformations
Morphological Phases	1854, 1908, 1919, 1952, later	Chronological maps showing urban evolution	Standardized reconstruction of route networks for spatial analysis

4.2. Urban Growth Patterns in Al-Rusafa

Urban growth in Al-Rusafa occurred through successive spatial processes that reshaped the historic urban fabric over time. These processes included infill development within the historic core, edge expansion following the removal of the city walls, and outward growth driven by modern planning interventions. Together, these patterns contributed to the reconfiguration of the urban structure while maintaining partial continuity with earlier spatial systems, as summarized in Table 2.

Table 2. Urban Growth Patterns in Al-Rusafa

Phase	Pattern Type	Description	Morphological Implication
Early Phases	Infilling	Development of vacant plots within the existing urban fabric	Strengthened the organic, compact structure of Al-Rusafa
Post-Wall Demolition	Edge Expansion	Growth along the former city edges after the removal of the walls	Extension of urban boundaries and integration of new streets
Mid-20th Century Modernization	Outlying Growth	Expansion toward peripheral areas during modernization	Creation of wider streets, partial fragmentation of historical fabric

4.3. Spatial Analysis Using Depth Map X

Depth map X an open-source software developed by Turner at University College London, was used. It is one of the most important tools for analyzing urban networks according to the Space Syntax methodology [19].
The following indices were extracted explains the values of different spatial indicators used to measure the urban structure in the Rusafa area over several years. It includes the analysis of integration, connectivity, choice, and activity intensity, highlighting the evolution and structural shifts in movement patterns and urban expansion over time.

4.3.1. Integration property Values of Al-Rusafa Route Network

1.Integration measures the connectivity of routes within the urban network, with higher values indicating more central and well-connected areas.
The results of the integration analysis are summarized in Table 3, while the spatial distribution of integration values across the study area is illustrated in the analysis maps presented in Figures 5, 6, 7, 8, and 9.

Table 3. Integration Values for the Study Area

Year	Min Integration	Max Integration	Interpretation
1853–1854	0.484	3.367	Low integration overall; centrality concentrated in specific areas of Rusafa.
1908	0.725	0.818	Slight increase in integration; key areas becoming more central.
1919	0.861	3.504	Significant increase in integration; vital areas more connected.
1952	0.749	2.837	Decrease in integration; some neighborhoods lost connectivity due to unregulated expansion.
2025	0.910	4.318	Projected increase; anticipated urban projects will enhance connectivity and sustainability.

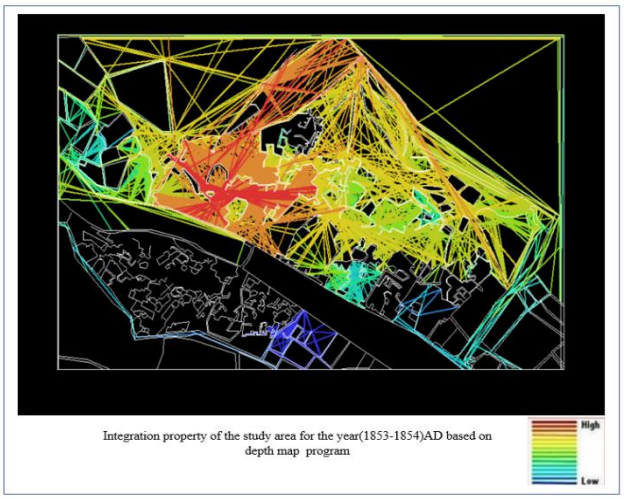

Figure 5. Baghdad street integration 1854- 1853

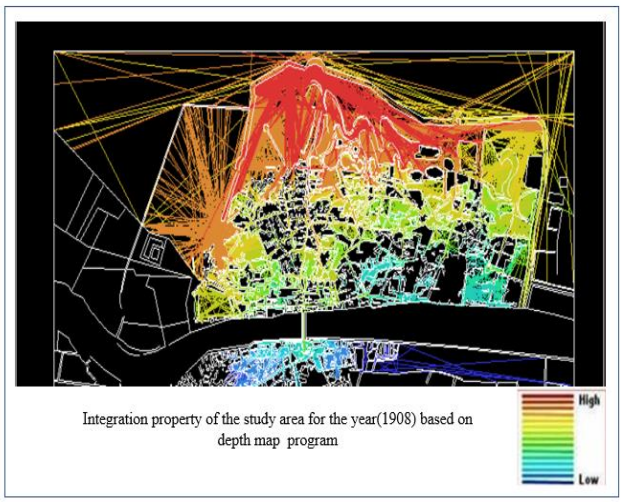

Figure 6. Baghdad street integration 1908

Figure 7. Baghdad street integration (1919)

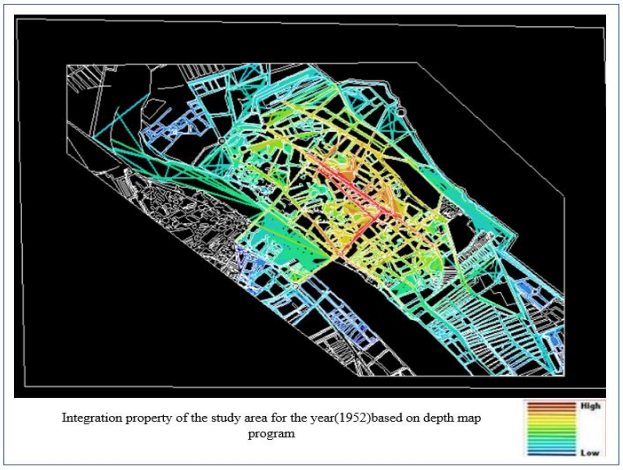

Figure 8. Baghdad street integration 1952

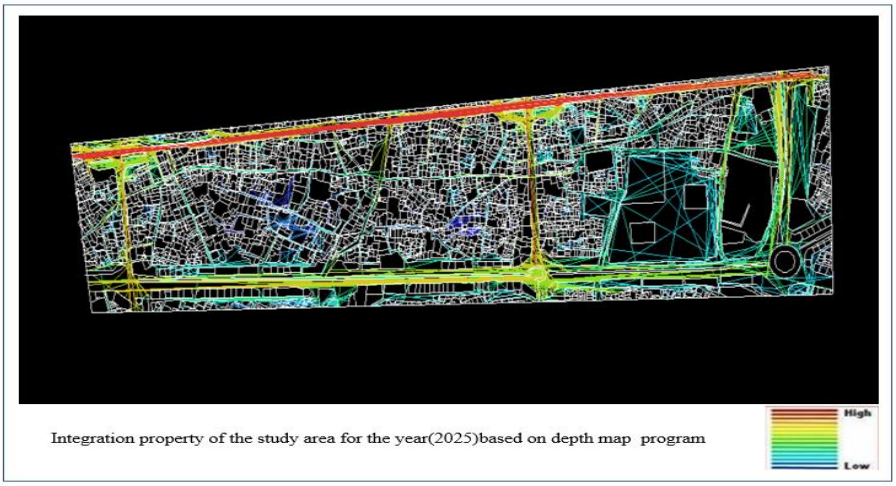

Figure 9. Baghdad street integration 2025

4.3.2. **Connectivity property Values of Al-Rusafa Route Network**

Connectivity measures the number of direct routes linked to each axis, with higher values indicating a more interconnected road network. The results of the connectivity analysis are presented in Table 4, while the corresponding spatial patterns are illustrated in the analysis maps shown in Figures 10–14.

Table 4. Connectivity Values for the Study Area

Step	Method	Purpose
Axial Map Creation	Mapping the minimum possible lines of movement	To represent structural connectivity and main movement paths
Visibility Graph Analysis (VGA)	Generating VGA maps for interconnected organic phases	To analyze visual accessibility and local spatial perception
Data Cleaning	Standardizing networks across all phases	To ensure consistency and comparability between historical and modern route networks

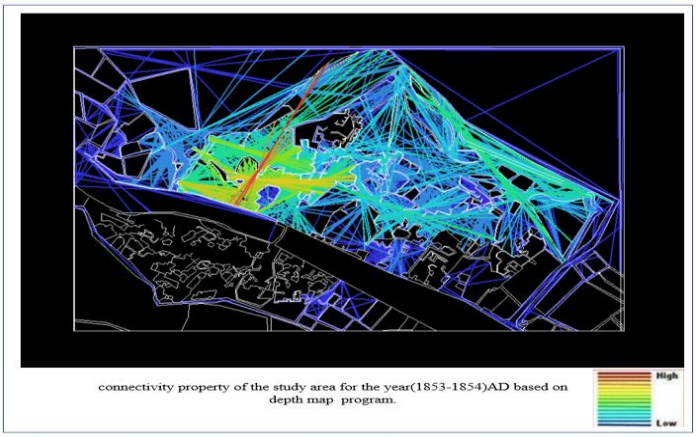

Figure 10. Baghdad street Connectivity1853-1854

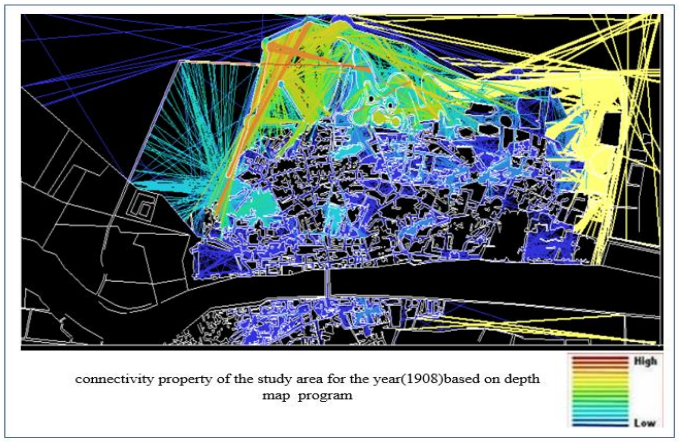

Figure 11. Baghdad street Connectivity 190

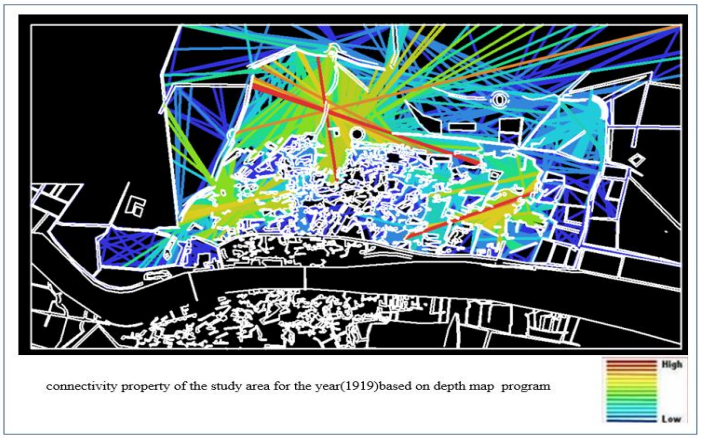

Figure 12. Baghdad street Connectivity 1919

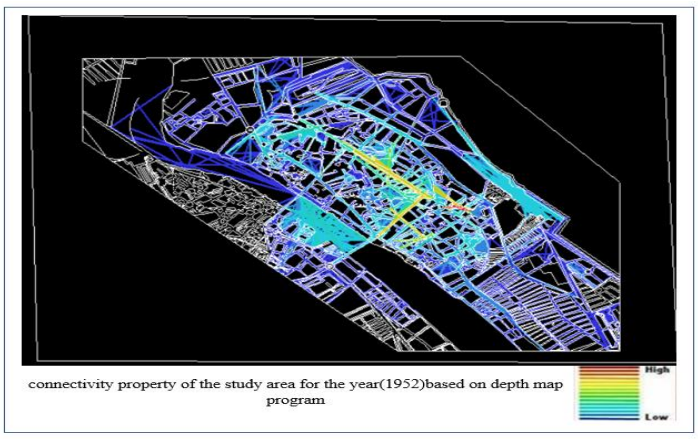

Figure13. Baghdad street Connectivity 1952

Figure 14. Baghdad Street Connectivity (2025)

4.3.3. **Choice property Values of Al-Rusafa Route Network**

Choice measures the likelihood of a route being used for movement, with higher values indicating greater potential for travel between areas due to more efficient connectivity. The results of the choice analysis are summarized in Table 5, and the spatial distribution of choice values is illustrated in Figures 15–19.

Table 5. Choice Values for the Study Area

Year	Min Choice	Max Choice	Interpretation
1853–1854	0	0.130	Low–medium values; limited through movement, highly localized circulation in organic fabric.
1908	0	0.208	Slight increase; emergence of new movement corridors and outward urban growth.
1919	0	0.156	More balanced; clearer hierarchy of movement with stronger connecting axes.
1952	0	Moderate	Moderate values; higher on new streets, traditional alleys lost through-movement due to fragmentation.
2025	0	0.370	Expected increase; improved urban permeability from new roads and increased activity.

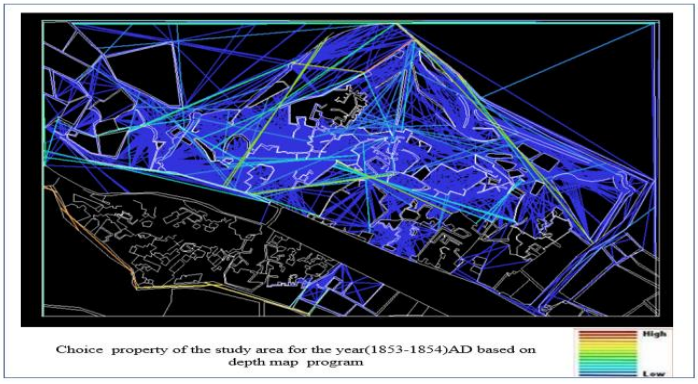

Figure 15. Street network choice, Baghdad 1853–1854

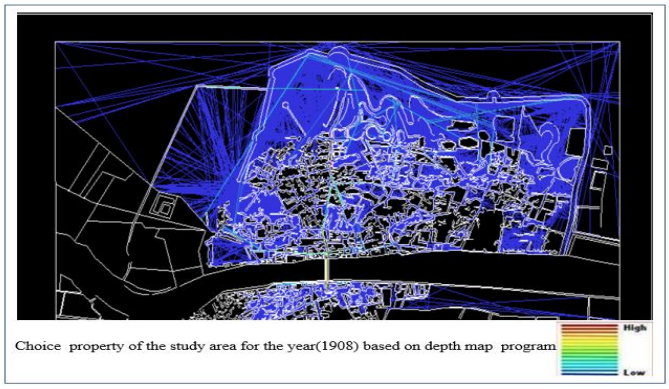

Figure 16. Street network choice, Baghdad 1908

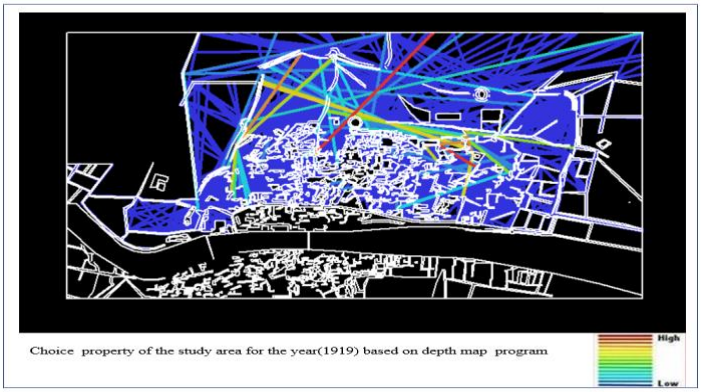

Figure 17. Street network choice, Baghdad 1919

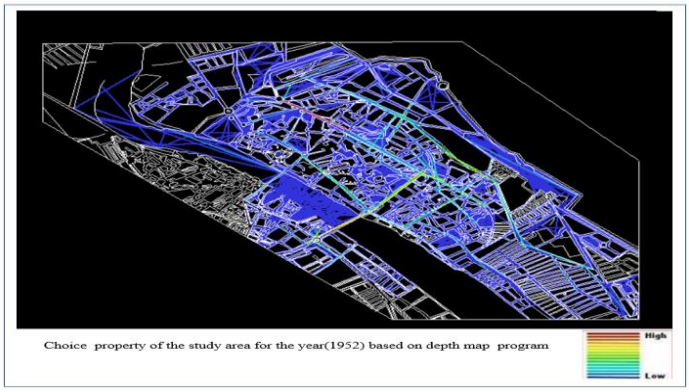

Figure 18. Street network choice, Baghdad 1952

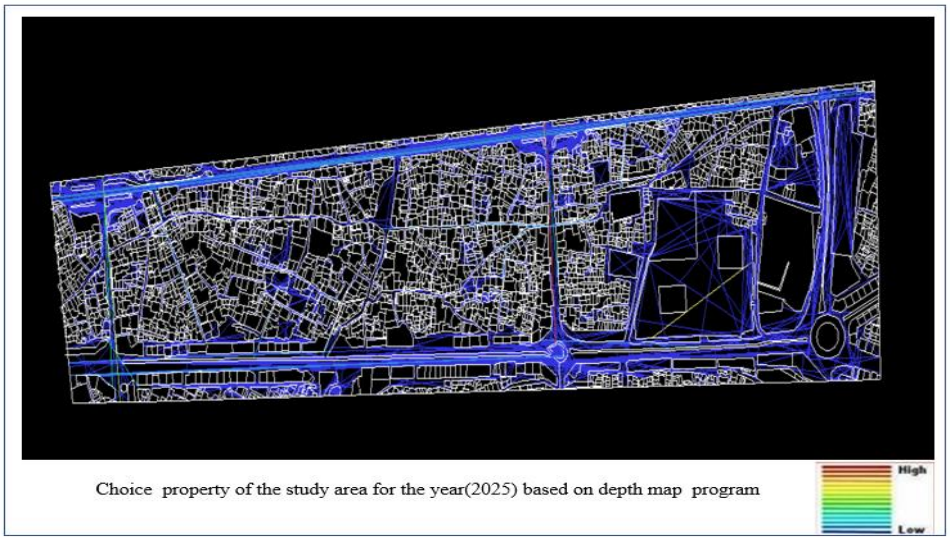

Figure 19. Street network choice, Baghdad (2025)

4.3.4. **Intensity property Values of Al-Rusafa Route Network**

Intensity measures the concentration of socio-economic activity across different areas, where higher values indicate zones of greater urban activity. The results of the intensity analysis are presented in Table 6, and the spatial distribution of intensity values is illustrated in the analysis maps (Figures 20–24).

Table 6. Intensity values for the study area

Year	Min Intensity	Max Intensity	Interpretation
1853–1854	0.130	0.983	Low intensity; reflects minimal urban activity in traditional organic fabric.
1908	0.208	0.839	Slight increase; urban development begins to raise activity levels.
1919	0.240	0.920	Balanced intensity; expansion of network and growth in urban activity within controlled limits.
1952	0.250	0.857	Moderate intensity; limited expansion due to post-war social and economic challenges.
2025	0.268	1.247	High intensity expected; reflects anticipated urban expansion with increased commercial and residential activity.

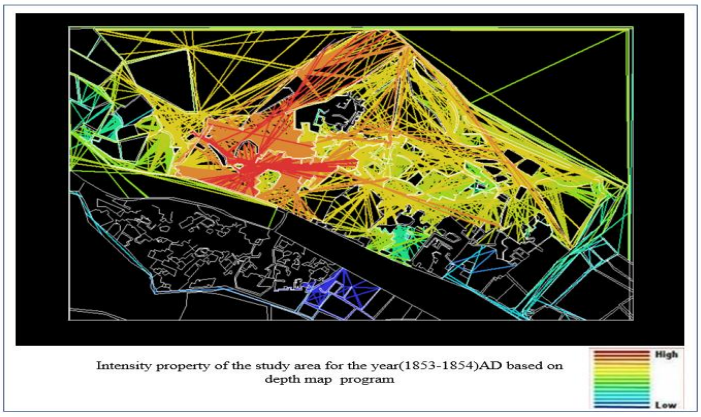

Figure 20. Urban intensity in Baghdad (1853–1854).

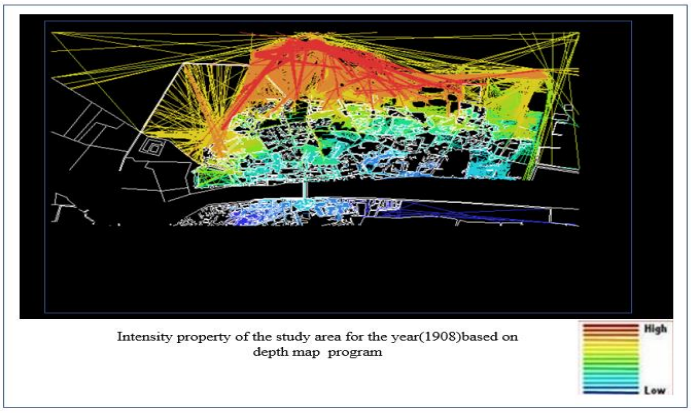

Figure 21. Urban intensity in Baghdad 1908.

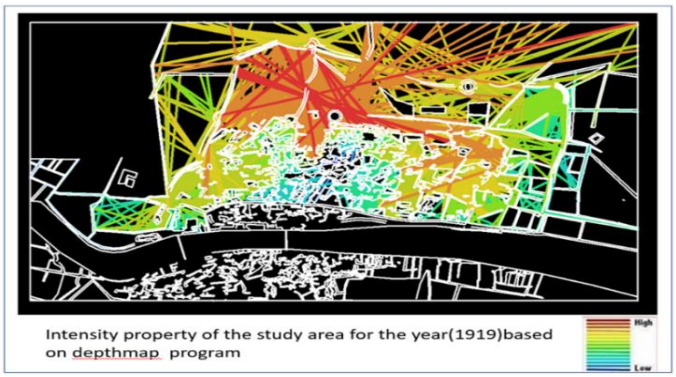

Figure 22. Urban intensity in Baghdad 1919

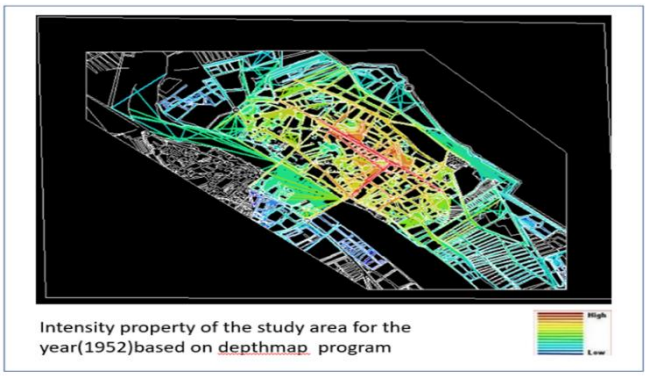

Figure 23. Urban intensity in Baghdad 1952.

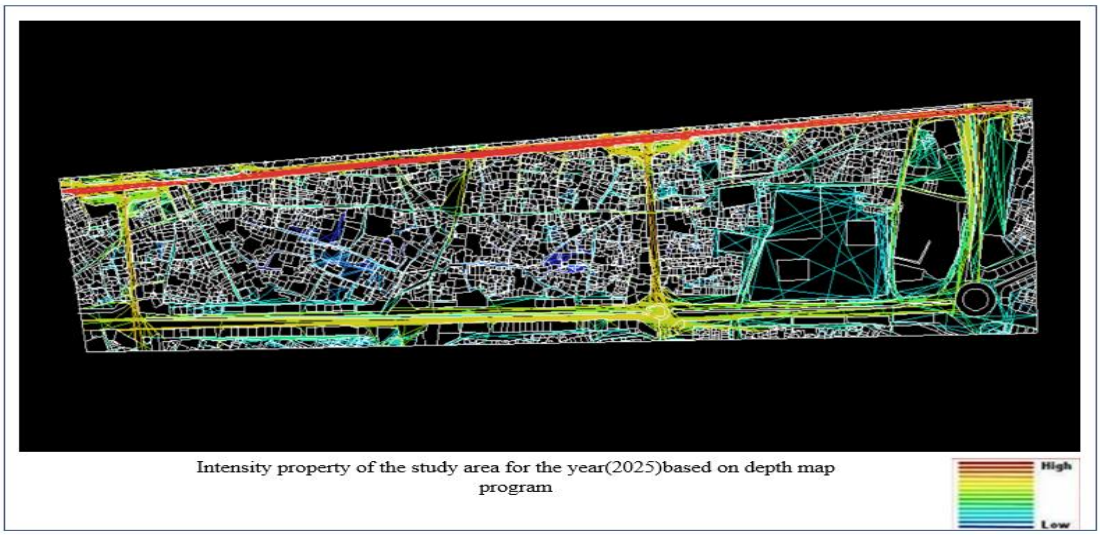

Figure 24. Urban intensity in Baghdad 1919

4.4. Interpreting Morphological Genotype

The study adopted the concept of morphological fingerprinting, which posits the existence of continuous structural roots for paths even after changes in their physical form. This concept was applied according to the framework proposed by Hillier [3],[2].

4.5. Integrating the Results within the Urban Injection Strategy Framework

The translation of spatial analysis results into a practical application framework based on the urban injection strategy—focusing on nodal and linear interventions within historic centres—is presented in Table 7.

Table 7. Types of Urban Injection Based on Spatial Analysis Results

Type of injection	Injection description	Criteria Used
Spinal injections	Improving vital axes that serve as kinetic arteries in the network	Poor Integration. Need to improve Movement and Connectivity.
Intravenous injections	Improving communication pathways between active parts of the network	Highly Used Vital Pathways Functional Deterioration
Cosmetic injection	Improving the overall appearance of visually deteriorated pathways	Visual Deterioration Pathways with Poor Aesthetic Impact
Muscular injection	Improving axes that are vital activity points.	Vital Pathways Increased Commercial or Residential Activity
Green injection	Adding green spaces to improve the urban environment	Environmental Deterioration Pathways Requiring Environmental Regulation

5. Results of Space Syntax Analysis

This section presents the results of the Space Syntax analysis of Old Rusafa's route network across four morphological phases. The analysis focuses on integration, connectivity, choice, and intelligibility to interpret structural shifts in the pathway system and assess the persistence of inherited morphological patterns within the contemporary network.

5.1. Phase One: Traditional Organic Fabric (Until Mid-19th Century)

The spatial configuration of Old Rusafa during this phase exhibits a highly coherent organic structure oriented toward religious and commercial centers. Routes perpendicular to the Tigris River form the primary integration core, reflecting the close relationship between river-based trade, markets, and the mosque-centered urban system. High intelligibility values indicate a strong correlation between local connectivity and global integration, a defining characteristic of traditional Islamic urban fabrics with legible movement structures.

5.2. Phase Two: Wall Removal and the Emergence of Longitudinal Axes (1869–1918)

The demolition of the Rusafa wall and the introduction of Rashid Street marked a structural reorientation of the urban network. Integration and choice values shifted decisively toward the new longitudinal axis parallel to the river, signaling the emergence of a new movement hierarchy. While Rashid Street assumed a dominant configurational role, many historic alleyways experienced reduced global integration due to the partial disruption of their traditional economic and spatial connections. This phase represents a transitional morphology rather than a complete structural rupture.

5.3. Phase Three: Modern Planning Interventions and Network Reorganization (1936–1960)

The implementation of wide, modern streets such as Al-Kifah, Al-Khalifah, and Sheikh Omar Streets reconfigured the integration core of Rusafa. These axes became the most globally integrated routes, restructuring citywide movement patterns. Conversely, the historical alley network suffered a decline in spatial clarity and local-global coherence due to fragmentation. The analysis indicates that modernization redistributed accessibility rather than eliminating earlier structures, embedding new routes within an evolving spatial hierarchy.

5.4. Phase Four: Late Twentieth Century and Post-2003 Transformations

Subsequent urban interventions intensified fragmentation within the historic fabric, weakening the relationship between local alleyways and primary movement axes. Intelligibility values declined, reflecting reduced spatial coherence and disrupted movement logic. Nevertheless, several historic routes retained moderate local integration, indicating latent spatial resilience. Certain modernized streets continued to align structurally with earlier pathways, suggesting that morphological inheritance persisted despite physical alterations.

5.5. Morphological Genotype and Structural Continuity

Comparative analysis across phases reveals a persistent morphological genotype within Old Rusafa's street network. Modern axes such as Al-Khalifa and Sheikh Omar Streets correspond spatially to historical routes identified in nineteenth- and early twentieth-century maps. Their sustained integration performance confirms that urban transformation in Baghdad reshaped, rather than erased, inherited spatial structures. This finding supports the hypothesis that historical pathways continue to influence contemporary movement patterns through embedded configurational logic.

5.6. Spatial Basis for Urban Injection Interventions

By synthesizing integration and intelligibility results, the analysis identifies structurally strategic locations for urban intervention. Highly integrated axes function as primary movement spines suitable for large-scale reinforcement, while historically significant alleyways with weakened connectivity represent critical sites for targeted reconnection. Areas affected by demolition and spatial discontinuity offer opportunities for environmental and spatial remediation. These findings demonstrate how configurational analysis can directly inform an urban injection strategy grounded in the inherited morphology of the historic centre.

6. Discussion

The spatial analysis of morphological transformations in Baghdad's historic center, particularly Old Rusafa, provides a deeper understanding of how pathway orientation, spatial structure, and planning interventions interact over time. Rather than representing isolated episodes of change, these transformations reveal a layered restructuring process that reshaped movement logic while retaining inherited spatial foundations. This discussion addresses five interrelated analytical themes.

6.1. Phased Transformation of Path Orientation

The findings confirm that pathway orientation in Old Rusafa evolved through clearly identifiable morphological phases. The traditional fabric was structured around river-oriented, perpendicular routes that supported market-based economic activity. The removal of the city walls and the introduction of Rashid Street initiated a longitudinal reorientation parallel to the Tigris River, while mid-twentieth-century planning interventions produced a hybrid configuration combining organic alleys with modern grid-based axes. This phased transformation reflects a shift in the logic of natural movement from localized, river-dependent systems to higher-capacity corridors, indicating that changes in orientation were driven by structural reorganization rather than random alteration.

6.2. Morphological Genotype and Structural Resilience

Despite formal modernization, several contemporary streets retain medium to high integration values, demonstrating continuity with historical routes documented in earlier maps. This persistence indicates the presence of a stable morphological genotype embedded within the urban network. From a planning perspective, this finding challenges approaches that treat historic centers as structurally obsolete. It suggests that spatial significance is determined by configurational role rather than physical form, providing a rational basis for prioritizing regeneration along structurally resilient routes instead of pursuing large-scale replacement strategies.

6.3. Spatial Clarity and Network Fragmentation

Later urban transformations correspond with a measurable decline in spatial clarity, reflecting a weakened relationship between local alley systems and global movement structures. This condition is associated with the fragmentation of traditional pathways and the concentration of movement along high-capacity vehicular routes. The marginalization of historically central areas, such as Al-Sarai and Al-Qashl, illustrates how reduced intelligibility can diminish natural movement and economic vitality, reinforcing spatial segregation within the historic center.

6.4. From Spatial Diagnosis to Urban Injection

Interpreting the route network as a vascular system enables the translation of configurational analysis into targeted planning actions. Highly integrated routes operate as urban arteries, locally significant alleys function as connective capillaries, and fragmented spaces act as points of obstruction. Within this framework, urban injection types serve as differentiated interventions: axial reinforcement along major corridors, reconnection of marginalized alleys, visual enhancement of historic markets, and environmental activation of degraded spaces. This demonstrates that Space Syntax can function as a decision-support mechanism rather than a purely descriptive analytical tool.

6.5. Morphological Phases as an Intervention Sequencing Tool

The comparison of morphological phases reveals that different spatial conditions require distinct intervention logics. Organic fabrics benefit from localized connective injections, longitudinal structures support axial reinforcement, and fragmented post-intervention areas require visual, environmental, and connective treatments. This phased reading provides a temporal and spatial sequencing framework that aligns regeneration strategies with the inherited structural condition of each area, enhancing both effectiveness and contextual sensitivity. The translation of Space Syntax indicators into differentiated urban injection types is summarized in Table 8, providing an operational framework that links spatial diagnosis with planning decisions.

Table 8. Translation of Space Syntax Indicators into Urban Injection–Based Planning Decisions

Space Syntax Reading	Spatial Condition	Urban Injection Type	Decision Logic
High integration & high choice	Structurally dominant movement corridors	Spinal Injection	Strengthens primary axes that organize city-wide movement
Moderate local integration, weak global linkage	Locally active but spatially isolated alleys	Venous Injection	Improves local–global connectivity without altering morphology
Moderate integration with low spatial clarity	Historically active but visually degraded streets	Cosmetic Injection	Enhances legibility and functional perception
Low connectivity & low choice	Fragmented or underused spaces	Green Injection	Reduces segregation and activates residual spaces
Phase-specific indicator variation	Differentiated historical layers	Phased Injection Strategy	Aligns interventions with inherited spatial conditions

7. Conclusions

This study examined the morphological transformation of Baghdad's historic center, with particular focus on the Rusafa district, and demonstrated that the evolution of its pathway network was neither random nor detached from its historical context. Instead, it resulted from successive, layered transformations shaped by political decisions, planning interventions, and socio-economic change, which collectively reoriented movement patterns and redefined the spatial hierarchy of routes. The analysis confirms that the pathway system evolved from an organic structure oriented perpendicular to the Tigris River, to a longitudinal configuration parallel to the river following the removal of the city walls and the introduction of Rashid Street, and later into a hybrid grid during mid-twentieth-century modernization. These shifts reflect a gradual reconfiguration of movement logic rather than a complete structural rupture. Spatial analysis further revealed the persistence of a continuous morphological genotype within the contemporary network. Several modern streets retain medium to high spatial integration despite formal restructuring, indicating their alignment with historically embedded routes. This finding demonstrates that urban transformation reshapes inherited structures rather than erasing them, and that configurational significance can persist beyond physical change. The results also indicate a marked decline in spatial intelligibility in the post-2003 period, reflecting the disruption of relationships between local alley systems and dominant movement corridors. This condition contributes to reduced urban performance, weakened economic vitality, and increased spatial fragmentation within the historic center. By integrating Space Syntax results with the urban injection framework, the study confirms the effectiveness of differentiated, spatially informed interventions. Highly integrated routes can function as structural spines for revitalization, while historically significant local paths are suitable for targeted connective interventions. Degraded and vacant spaces, in turn, represent strategic opportunities for environmental and visual enhancement. Overall, the study

demonstrates that the revitalization of Baghdad's historic center depends on a precise understanding of its dynamic spatial structure. Urban expansion does not eliminate historical patterns but reconfigures them through overlapping layers. Accordingly, effective regeneration strategies must be grounded in spatial-structural analysis that recognizes and activates inherited morphological imprints. The proposed analytical–applied framework offers a transferable model for guiding context-sensitive urban regeneration in historic centers across Iraq and the wider region.

8. Recommendations

1. Institutionalizing Spatial Analysis in Historic-Center Planning
Urban regeneration in historic centers should be grounded in spatial analysis by formally integrating Space Syntax indicators (integration, connectivity, intelligibility) into planning and evaluation processes. This includes building institutional capacity to use analytical tools and adopting scenario-based comparisons to ensure interventions respect inherited morphological structures.

2. Targeted Revitalization through the Urban Injection Strategy
Highly integrated streets (Al-Rashid, Al-Khalifa, Al-Kifah) should function as structural spines for revitalization, while historically rooted alleyways and degraded nodes should be addressed through selective urban injections (venous, cosmetic, and green). This targeted approach enables efficient, context-sensitive interventions rather than comprehensive redevelopment.

3. Linking Physical Interventions with Social and Environmental Sustainability
Regeneration strategies should combine visual rehabilitation, green space creation, and pedestrian connectivity with active community participation. Strengthening stakeholder engagement ensures that revitalization enhances spatial performance, preserves social fabric, and avoids displacement or superficial beautification.

Conflict of Interest Declaration
The authors declare that there is no conflict of interest regarding the publication of this manuscript.

Funding Information
No funding was received from any financial institution to conduct this research.

Author Contributions

All authors proposed the research problem, Hawraa Oleiwi Shakeer and Sabeeh Lafta Farhan reviewed the literature, proposed the analysis and discussed the results, Sabeeh discussed the results and Hawraa proposed the conclusion, and all authors discussed the results and the final version of this paper.

Acknowledgments

The authors express their gratitude to the University of Wasit / College of Engineering / Department of Architecture in Wasit - Iraq for supporting this study. In addition, sincere thanks to Ihsan Abbas and Rabee Jameel and Husam Sachit for their advices in the academic writing of this paper.

Notes
Permission was obtained from all authors of the cited articles.

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