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Exploring the Impact of Streets' Syntactic Properties on the Urban Functions and Land Use: Insights from Spatial Network Analysis

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ABSTRACT

This study employs an integrated research model to examine the syntax properties of the historic urban network in older Baghdad, explaining how spatial configurations affect urban functions and land use. The relationship between the street network and land use pattern is again the focus for architects and urban planners trying to revitalize historic urban cores. In this research, a multi-method approach is used, incorporating GIS, space syntax analysis, statistical correlations, and site observations, to systematically analyze the syntactic properties of the street network in Old Rusafa. The examination was conducted within a 400m radius of Old Rusafa's historic urban fabric to analyze the syntactic processes that govern the city's functionality and accessibility despite the multiple morphological changes that have happened in the area. Results show a strong correlation between street network and land use in Old Rusafa, commercial areas positive (ρ=0.175, p<0.01) and residential areas negative (ρ=-0.234, p<0.01). High choice values also correlate with commercial activity (ρ=0.160, p<0.01), so spatial accessibility plays a big role in shaping urban functions and land use. There is a lot to learn from this in other historical urban situations to compare and apply urban design principles based on syntactic properties. Comparative research like this can help architects and urban planners understand the universality of space syntax in urban design.

Keywords: Streets, Space syntax, Urban function, Land use, Accessibility.

1. INTRODUCTION

Urban studies have incorporated space syntax, which offers a set of quantitative and visual instruments for recognizing the link between spatial patterns and urban processes. The development of space syntax was carried out by a team led by Bill Hillier at the Bartlett School of Architecture, University College London **(Hillier and Hanson, 1989; Hillier, 2007; Batty, 2022)**. Graph-based methods in space syntax have highlighted how street configurations determine urban forms, particularly at historic city centers with irregular, centuries-old patterns as opposed to modern grid examples **(Franz et al., 2005; Esposito**

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et al., 2020; Meknac et al., 2024). By objectifying syntactic features like integration and choice, space syntax reveals the underlying structure of movement paths, commerce, and social ties in such enclaves of history **(Hillier, 2007; Xia, 2013; Özbil, 2013; Alobaydi and Rashid, 2015; Safari and Moridani, 2017)**. This informs strategies for heritage conservation and sustainable urban development that respect the unique character and cultural significance of historic urban areas.

In contrast to contemporary cities, which are planned and hierarchical in nature, historical cities tend to grow in an unorganized manner, with serpentine streets emerging from nowhere **(Hakim, 1994; Hakim, 2013; Bianca, 2000; Alsaffar and Alobaydi, 2023)**. The creation of new urban areas primarily depends on zoning and the development of infrastructure projects in the case of contemporary cities, whereas historic urban centers exhibit several centuries' worth of social-economic-cultural influences **(Alobaydi and Rashid, 2024a; Albabely and Alobaydi, 2024)**. Space syntax techniques enable an analysis of these intricate configurations, thereby enlightening how urban life is influenced **(Penn, 2003; Yamu and Van Nes, 2017; Van Nes et al., 2021)**.

The directness of travel in urban streets is measured by a parameter called integration that examines how easily one street segment can be reached from all other parts of the network, global virtuality **(Jiang et al., 2000; Dettlaff, 2014; Hossain et al., 2025)**. Choice counts the number of alternate routes accessible from a specific point along a street, pedestrian flow, and mobility potential. When applied to historical urban grids, these metrics demonstrate how spatial configurations affect pedestrian flow patterns, commercial land use, and the liveliness of places **(Hillier et al., 1976; Hillier and Vaughan, 2007; Van Nes and Yamu, 2021; Khotbehsara et al., 2025)**.

Studies that investigate ancient metropolitan areas like Rome, Istanbul, Cairo, and Fez have found a significant association between high integration values and commercial centers located in preserved quarters. Most time, areas with a low level of integration are used for housing. If we apply space syntax to such bygone periods, we can unearth the underlying patterns of urbanism that sometimes allow us to suggest wise decisions pertaining to heritage preservation and the creation of livable cities that can live with us forever **(Arisha and Abd El-Moneim, 2019)**. With an awareness of the syntactic qualities of old street patterns, modern problems in cities can be solved without compromising their distinctiveness and rich cultural legacy **(Mohammed and Alobaydi, 2020; Alsaffar and Alobaydi, 2025; Alobaydi and Rashid, 2024b)**.

Research has shown that space syntax is a powerful tool for urban analysis. The literature shows how space syntax can be used to inject life into historical areas, understand pedestrian dynamics in mixed-use areas, and optimise retail environments to boost commercial activity. This multifaceted approach gives us valuable knowledge to make more informed and effective urban planning and design decisions **(Lee et al., 2020; Lian and Li, 2023; Fu et al., 2025).**

2. SOCIO-SPATIAL DYNAMICS OF OLD RUSAFA

Rusafa is one of Baghdad's oldest districts and an excellent illustration for studying the connection between form and function within a historic context (see **Fig. 1)**. It is found on the eastern bank of the River Tigris. Ancient Rusafa's history can be traced back to the Abbasid Caliphate era and is the center of religious, commercial, and cultural activities at all times **(Abbas and Al-Dujaili, 2013; Al Hashimi and Alobaydi, 2023)**. In contrast with the new Baghdad expansion, Old Rusafa preserved the traditional city form: the narrow, denser

streets with scattered, irregular, compacted sites among numerous religious buildings, as well as public areas. It is the natural pattern that accompanied the history of the district, characterized by the long history of social as well as economic exchanges.

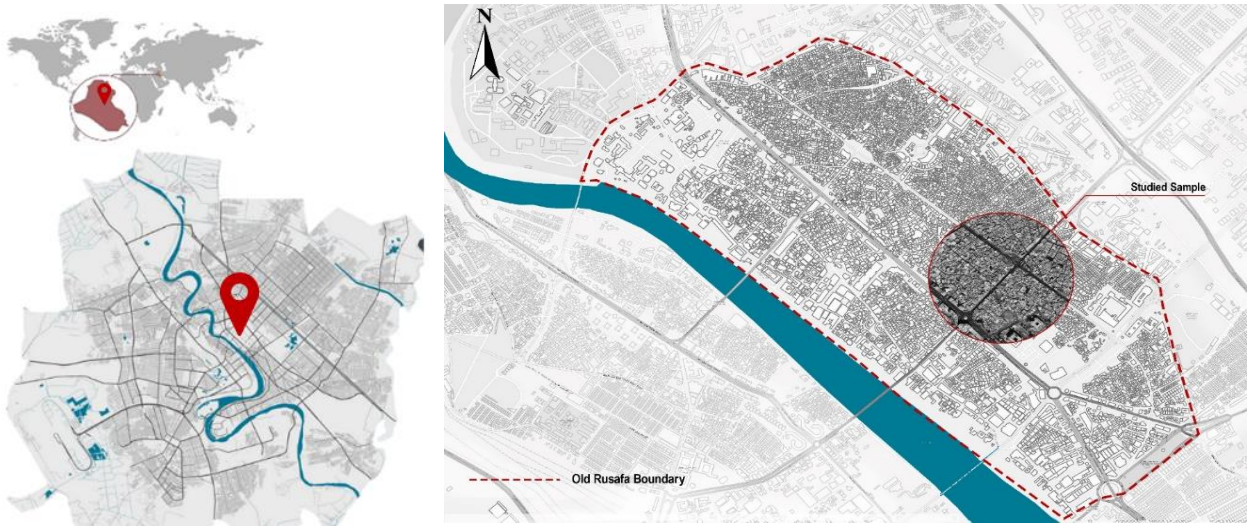

Figure 1. Presents locations of Old Rusafa, Baghdad, and Iraq.

Old Rusafa has changed in response to socio-economic developments while maintaining its essential spatial nature. Significant urban elements and such as Al-Mustansiriya School, Al-Rasheed Street, and Al-Mutanabbi Street, are some of the historical and intellectual landmarks that root the neighborhood's past, culture, and identity. Street-oriented commercial activities have been enhanced through the presence of traditional markets like Souq Al-Sarai and Al-Shorja, which are still vibrant **(Rasheed et al., 2023; Albayati and Alobaydi, 2023)**. The syntactic properties of Old Rusafa's street network play a big role in this. High accessibility within the souqs, for example, facilitates movement and interaction and creates a lively commercial environment. The integration of Al-Rasheed Street connects the district to the larger urban fabric and makes it accessible and economically prominent (see **Fig. 2)**. The alleyways, although less integrated, offer a high degree of choice in navigation and create a sense of exploration and discovery.

However, modern interventions like road expansions and commercial redevelopments have disrupted the historical balance between pedestrian spaces and vehicular access. These changes need to be analyzed spatially to understand their impact on the district's syntactic properties and, consequently, its social and economic dynamics. The introduction of wider roads, for example, may reduce connectivity for pedestrians and prioritize vehicular movement, and impact the traditional commercial areas. Analyzing the changes in integration and choice values resulting from these interventions will be helpful for urban planning and heritage conservation. Old Rusafa's mixed-use urban fabric, high-density residential, specialized commercial, and historical public institutions make it a good case study to apply space syntax. By analyzing spatial accessibility in this heritage context, we can understand how the urban form affects urban life and develop strategies for sustainable urban development that respect the district's historical and cultural heritage.

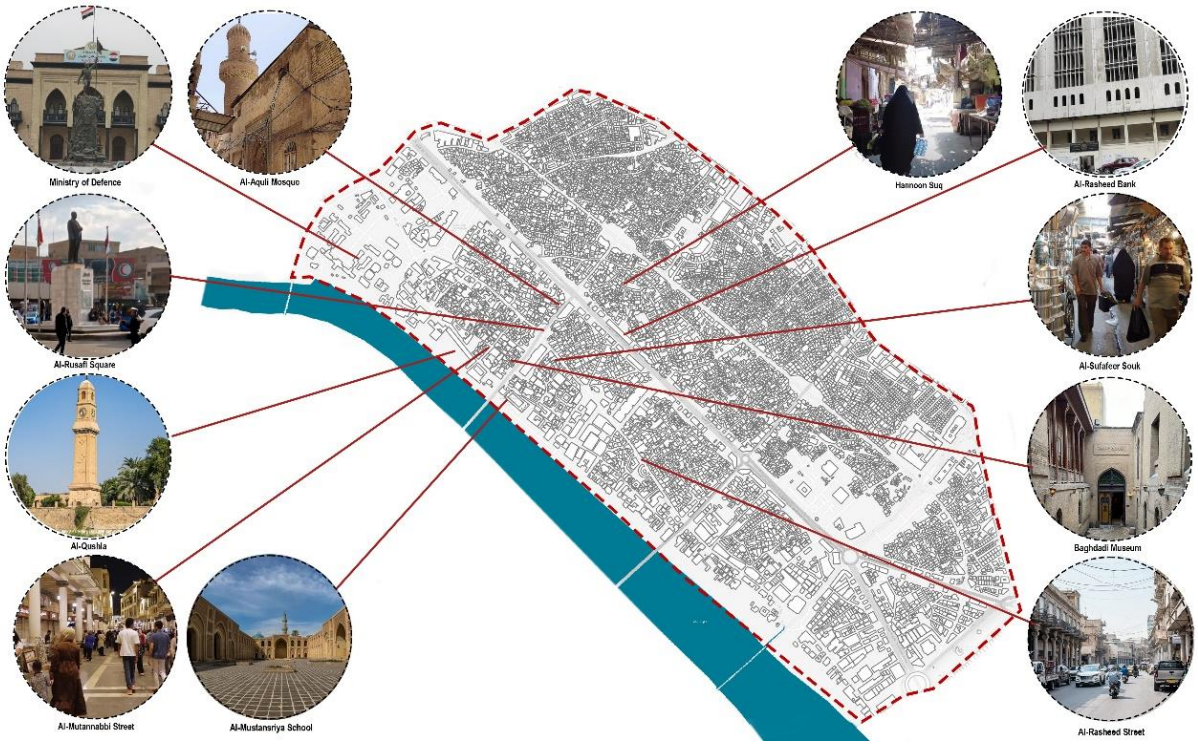

Figure 2. The Old Rusafa's landmarks, Baghdad, Iraq.

3. OLD RUSAFA'S URBAN MORPHOLOGY

Despite the growing interest in the urban morphology of historic cities, Baghdad's urban fabric, especially its oldest districts, remains poorly studied **(Alobaydi and Rashid, 2024a)**. This research aims to fill this gap by using space syntax methodologies to analyze Old Rusafa's street network at multiple scales and provide a quantitative understanding of its spatial configuration and its effect on urban functions. While studies on historic cities like Cairo, Aleppo, and Istanbul have shown the importance of spatial integration in commercial and social hubs, a rigorous space syntax analysis of Baghdad's historic quarters, especially Old Rusafa, is missing **(Hegazi et al., 2022; Özbek et al., 2022; Danilina et al., 2024)**. This study will add to the existing knowledge by applying this framework to Old Rusafa and exploring the relationship between its organic street pattern and history (see **Fig. 3)**.

Research on Baghdad's urban transformation has mostly focused on broad planning challenges, economic shifts, and modernization impacts. However, there is a lack of quantitative analysis on the correlation between space syntax measures and land use patterns in its heritage districts.

This study will address this gap by systematically examining how different scales of spatial integration affect commercial viability, residential cohesion, and accessibility in Old Rusafa. If you quantify the integration values, one will be able to notice how access is straightforwardly made into many regions via the street network; this may have relevance to commercial activities or land prices, too. By the same token, when deciding upon choice values, one will discover patterns nominated for pedestrian movement within areas, as well as likely locations where people can interact together sociably while being located within the same urban area at any point in time. Additionally, knowing about street accessibility unveils the efficiency of the movement of goods and exchange possibilities.

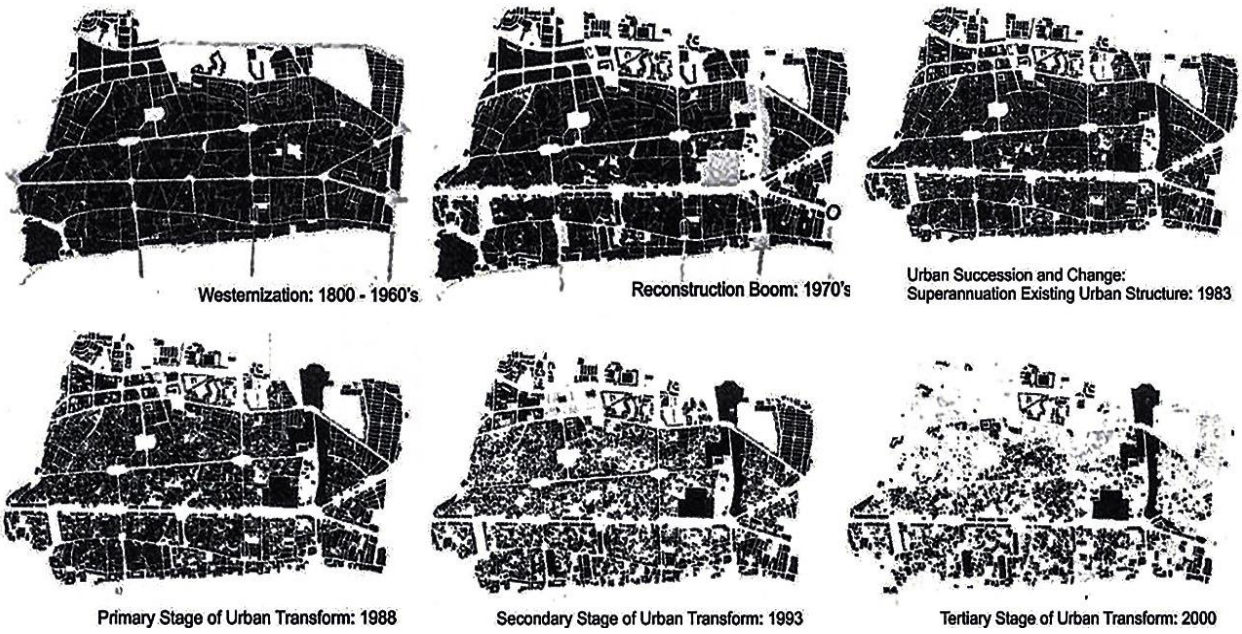

Figure 3. Urban morphological developments of street networks of Old Rusafa **(Bianca et al., 1984).**

Research on Baghdad's urban transformation has mostly focused on broad planning challenges, economic shifts, and modernization impacts. However, there is a lack of quantitative analysis on the correlation between space syntax measures and land use patterns in heritage districts. This study will address this gap by systematically examining how different scales of spatial integration (local and global) affect commercial viability, residential cohesion, and accessibility in Old Rusafa. If you quantify the integration values, one will be able to notice how access is straightforwardly made into many regions via the street network; this may have relevance to commercial activities or land prices, too. By the same token, when deciding upon choice values, one will discover patterns nominated for pedestrian movement within areas, as well as likely locations where people can interact together sociably while being located within the same urban area at any point in time. Additionally, knowing about street accessibility unveils the efficiency of the exchange possibilities.

Hence, by examining both global levels of integration and choice measures, the research will be able to provide an in-depth understanding of how land use patterns in Old Rusafa are affected by spatial structure. To comprehend the intricate connection between the general structure of this district and its particular dynamics in various segments, a multiscale method is necessary. In addition, this research will employ correlation analysis to determine how values are empirically associated with syntactic features, which in turn affect different types of functional land use. In Baghdad, this analytic way of working is aimed at greatly benefiting urban heritage studies, offering a cohesive vision for unravelling connections in a historical view from form to function of urban spaces. Urban planners, researchers keen on historic townscape mechanisms, and heritage conservers are likely to find this research paper usable.

4. METHODOLOGY

With the use of a case study approach, spatial configurations and the patterns of land utilization in Old Rusafa are being examined using a multi-layered methodology through the integration and application of Geographic Information System (GIS), space syntax analysis, and statistical correlation techniques (see **Fig. 4**), in the following manner:

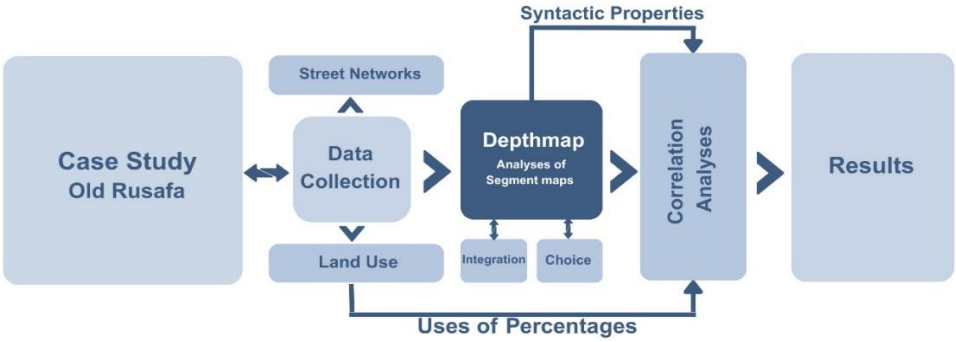

Figure 4. The flowchart of the methodology.

4.1. Study Area Selection and Data Collection

Old Rusafa, which is considered one of the most historically important seen districts in Baghdad, is characterized by a high-density urban structure, low-width streets, and a land use mix. Analysis of spatial properties is made at different levels: (1) This is because such localized urban dynamics can only be captured by a 400 m radius surrounding the local level of the selected area; and then, (2) the area covers a district level when studying the broad spatial interaction. This study has made use of these two scales because they help to evaluate accessibility from a neighbourhood as well as a district point of view, as per **Fig. 1**.

4.2. Space Syntax Analysis

An examination was carried out using DepthmapX to produce Old Rusafa's axial and segment maps for analyzing spatial properties affecting flow and land use; the investigation employs two syntactic measures:

4.2.1 Integration Measure (Global and Local)

Integration values (Rn, R7, R5, R3) quantify how well a space is connected to the whole network. The study looks at global integration (Rn), representing districtwide accessibility, and local integration (R3, R5, and R7, etc.), representing neighborhood-level interactions. This allows for the identification of highly accessible commercial streets and secluded residential areas. The Integration (Rn) value measures how integrated or segregated space is within the entire system **(Hillier and Hanson, 1989; Hillier, 2007)**. It is calculated as:

$$I_{Rn} = \frac{\left(\sum_{j=1}^{N} dij\right) / (N-1)}{D_{MD}} \quad (1)$$

Where:

- I_{Rn} is the global integration value of node i.
- d_{ij} is the shortest path (topological steps) from node i to node j.
- N is the total number of nodes in the system.
- D_{MD} is the mean depth normalization factor, calculated as:

$$D_{MD} = \frac{2\,(N-1)}{N-2} \quad (2)$$

(when N >2; otherwise, the normalizing factor is adjusted).

4.2.2 Choice Measure (Betweenness Centrality)

This measure looks at the likelihood of a street segment being used as a route between other locations, representing its importance in movement networks. The study compares choice values within a 400m radius and across the entire district to see how central pathways facilitate pedestrian and vehicular circulation. Like integration measures, the representations of choice values range from local radii (R3, R5, and R7, etc.) to the global values (Rn). The Choice (Rn) value is equivalent to a betweenness centrality measure and quantifies how often a node is part of the shortest paths between all other nodes **(Hillier and Hanson, 1989; Hillier, 2007)**, as shown in the equation below:

$$C_{Rn}(i) = \sum s \neq i \neq t \; \frac{\sigma_{st}\,(i)}{\sigma_{st}} \quad (3)$$

where:

- $C_{Rn}\,(i)$ is the global choice (betweenness) value of node *i*.
- σ_{st} is the number of shortest paths between nodes *s* and *t*.
- $\sigma_{st}\,(i)$ is the number of those shortest paths that pass-through node *i*.

Using segment analyses, the study gets a more detailed understanding of the street network and can identify subtleties in spatial accessibility that might have been missed when only looking at axial analysis (see **Fig. 5)**. The combination of global and local measures gives insight into how different parts of Old Rusafa work within the broader urban system.

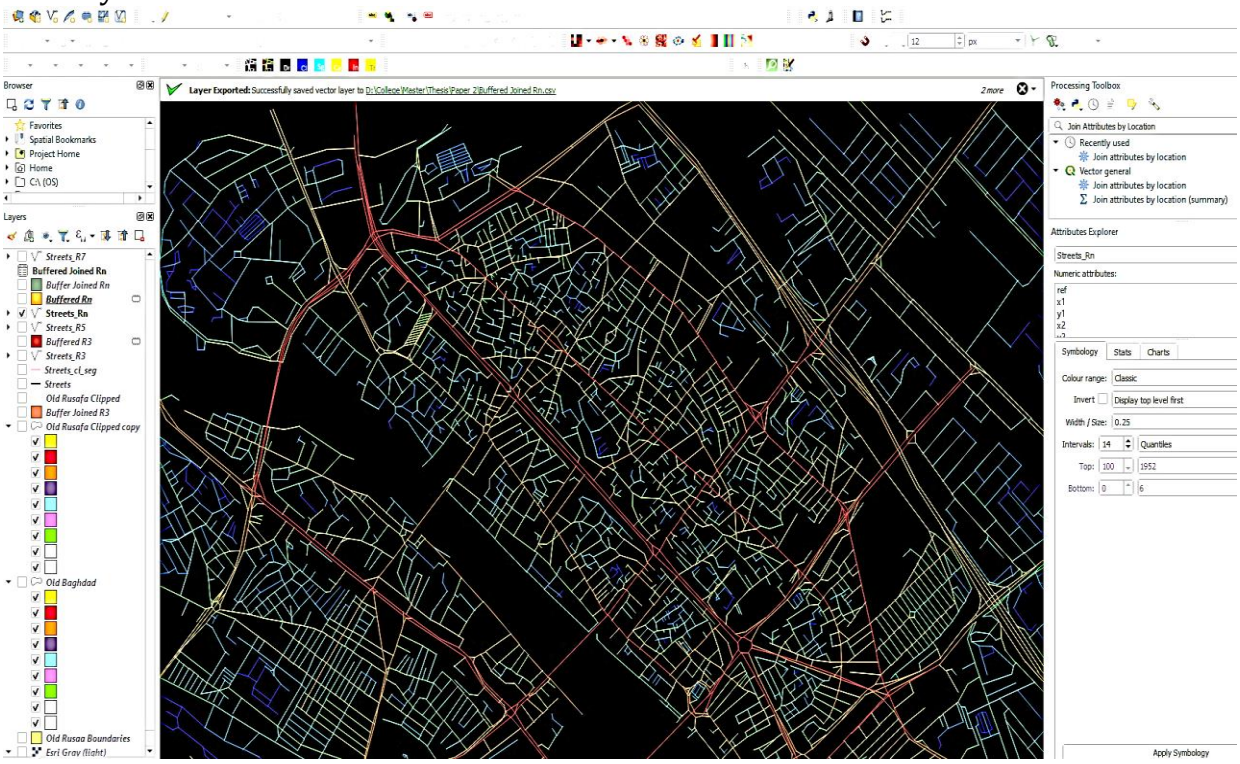

Figure 5. The space syntax analysis in the QGIS software.

4.3. Correlation Analysis of Syntactic Properties

To measure the relationship between spatial configurations and land use in Old Rusafa, a Spearman's Rho correlation analysis is done. This analysis investigates how the syntactic properties – Integration and Choice – correlate with different land use categories: residential, commercial, mixed-use, and public facilities. Higher integration and choice values are expected to correspond to commercial and mixed-use areas, while lower values in residential areas prioritize privacy and reduced traffic. The statistical analysis done using SPSS links each building's land use to its nearest street segment's syntactic values to ensure spatial correlation. By finding out the significant relationship between street network structure and functional land use, the study provides insights into how spatial accessibility affects urban land use patterns and supports data-driven urban planning and heritage conservation.

The methodology used in this study has some limitations. Firstly, while we use space syntax to analyze urban connectivity, other approaches, such as Urban Network Analysis (UNA) and other spatial analysis tools, may give different results and therefore affect the conclusions. Secondly, while this study focuses on the syntactic character of street networks, urban form is a complex interplay of many factors, including socioeconomic dynamics, physical constraints, and building typologies, which may lead to different interpretations. Thirdly, while the case study we used has some similarities with other Iraqi cities and global urban contexts, its unique historical, cultural, and physical characteristics limit the generalizability of the results. Broader generalizability would require more comparative studies across different contexts.

5. RESULTS AND DISCUSSION

The analysis of Old Rusafa's street network through space syntax methodology has produced significant findings that highlight the impact of spatial configurations on urban functions.

5.1. Integration Analysis

The integration analysis of Old Rusafa's street network, in terms of space syntax, identifies significant information about spatial access in different parts of the district—key to understanding urban planning and dynamics.

The district-wide integration map presented in **Fig. 6** reveals high integration areas predominantly in red, indicating that these routes are the most accessible within the broader urban environment. These highly integrated routes facilitate substantial pedestrian and vehicular circulation, stimulating economic activity and enhancing social connectivity across the district. The integration of such arteries is of prime importance to keep urban spaces functionally tied and ease of moving in and out to other areas within it.

Conversely, the blue-colored areas have low levels of integration. Such places are usually formed at the periphery or within residential areas, where there is less connection, hence higher demand for privacy and less traffic. Quiet zones are therefore created within them because they are far from the main busy roads.

A more intricate trend is visible in **Fig. 6** if one focuses on a smaller 400m neighborhood sample. Specifically, lots of red indicate richly mixed-use driven by retail/service activity spaces. This intensified localized integration makes districts more appealing and functional; they therefore become hubs for social activities or trade.

Contrariwise, the sector of the sample in blue colors depicts residential areas that have low integration. They have less congestion as a rule and are meant for residential use rather than business purposes that require much movement of people or goods.

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Figure 6. Shows the streets' integration (Rn) of Old Rusafa.

5.2. Choice Analysis

The choice analysis of Old Rusafa's street network is very important in order to determine the roles some individual streets are playing as they serve as key routes – colored with red lines in the map – through which people and vehicles move within the city. By using this examination, one will be in a position to see which paths are most used by pedestrians or vehicles, and thus these paths can be described as major traffic routes for each area. **Fig. 7** shows an example on a smaller scale, only focusing on one district. They connect major hubs of activity, including commercial districts, public spaces, and key residential areas, making them essential for efficient urban circulation and accessibility.

Streets marked in yellow and green indicate moderate choice values. While it is still significant for local traffic, they are less critical for traffic than the red routes. These streets often facilitate secondary movement, linking smaller neighborhoods or providing alternative routes to the primary red pathways.

Blue lines represent streets with low choice values, typically indicating restricted-access roads that primarily serve local traffic and have minimal impact on broader urban movement. These streets are often found in residential or peripheral areas, where limited through traffic is preferable to maintain tranquility and security for residents.

Within the localized 400m radius sample in **Fig. 7**, the analysis reveals a finer level of street use granularity. Red lines in this sample indicate that even within smaller sections of the urban landscape, certain routes experience significant usage, acting as local spines that support the area's functional needs.

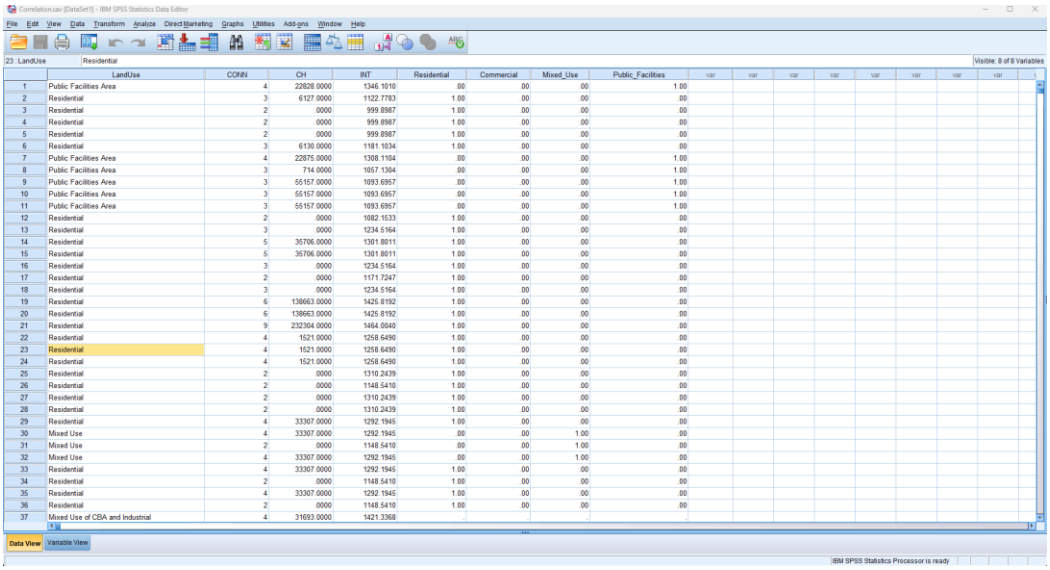
The variation in choice values within this smaller sample highlights the micro-scale complexity of Old Rusafa's urban structure. Some streets emerge as crucial for local

commerce and daily activities, while others remain predominantly residential, reflecting a balance between accessibility and community-specific needs.

Figure 7. Shows the street choice (Rn) of Old Rusafa.

5.3. Correlation Analysis of Syntactic Properties

This section examines the relationship between the syntactic properties of connectivity, integration, and choice with different land use categories in Old Rusafa, utilizing Spearman's Rho in SPSS software to accommodate the ordinal nature of space syntax data and the categorical variables of land use, see **Fig. 8**.



	LandUse	CONN	CH	INT	Residential	Commercial	Mixed_Use	Public_Facilities
1	Public Facilities Area	4	22828.0000	1346.1010	.00	.00	.00	1.00
2	Residential	3	6127.0000	1122.7783	1.00	.00	.00	.00
3	Residential	2	.0000	999.8987	1.00	.00	.00	.00
4	Residential	2	.0000	999.8987	1.00	.00	.00	.00
5	Residential	2	.0000	999.8987	1.00	.00	.00	.00
6	Residential	3	6130.0000	1181.1034	1.00	.00	.00	.00
7	Public Facilities Area	4	22875.0000	1308.1104	.00	.00	.00	1.00
8	Public Facilities Area	3	714.0000	1057.1304	.00	.00	.00	1.00
9	Public Facilities Area	3	55157.0000	1093.6957	.00	.00	.00	1.00
10	Public Facilities Area	3	55157.0000	1093.6957	.00	.00	.00	1.00
11	Public Facilities Area	3	55157.0000	1093.6957	.00	.00	.00	1.00
12	Residential	2	.0000	1082.1533	1.00	.00	.00	.00
13	Residential	3	.0000	1234.5164	1.00	.00	.00	.00
14	Residential	5	35706.0000	1301.8011	1.00	.00	.00	.00
15	Residential	5	35706.0000	1301.8011	1.00	.00	.00	.00
16	Residential	3	.0000	1234.5164	1.00	.00	.00	.00
17	Residential	2	.0000	1171.7247	1.00	.00	.00	.00
18	Residential	3	.0000	1234.5164	1.00	.00	.00	.00
19	Residential	6	138663.0000	1425.8192	1.00	.00	.00	.00
20	Residential	6	138663.0000	1425.8192	1.00	.00	.00	.00
21	Residential	9	232304.0000	1464.0040	1.00	.00	.00	.00
22	Residential	4	1521.0000	1258.6490	1.00	.00	.00	.00
23	Residential	4	1521.0000	1258.6490	1.00	.00	.00	.00
24	Residential	4	1521.0000	1258.6490	1.00	.00	.00	.00
25	Residential	2	.0000	1310.2439	1.00	.00	.00	.00
26	Residential	2	.0000	1148.5410	1.00	.00	.00	.00
27	Residential	2	.0000	1310.2439	1.00	.00	.00	.00
28	Residential	2	.0000	1310.2439	1.00	.00	.00	.00
29	Residential	4	33307.0000	1292.1945	1.00	.00	.00	.00
30	Mixed Use	4	33307.0000	1292.1945	.00	.00	1.00	.00
31	Mixed Use	2	.0000	1148.5410	.00	.00	1.00	.00
32	Mixed Use	4	33307.0000	1292.1945	.00	.00	1.00	.00
33	Residential	4	33307.0000	1292.1945	1.00	.00	.00	.00
34	Residential	2	.0000	1148.5410	1.00	.00	.00	.00
35	Residential	4	33307.0000	1292.1945	1.00	.00	.00	.00
36	Residential	2	.0000	1148.5410	1.00	.00	.00	.00
37	Mixed Use of CBA and Industrial	4	31693.0000	1421.3368				

Figure 8. Shows the SPSS Software Window to perform correlation analysis.

The study establishes correlations between syntactic measures derived from space syntax analysis, specifically connectivity, integration, and choice, and land use categories, including

residential, commercial, mixed-use, and public facilities. Each land use category is represented as a dummy variable to facilitate a quantitative approach, ensuring a structured understanding of these urban relationships.

5.3.1 Correlation Analysis of Street Integration with Land Use Categories

To identify potential relationships between Old Rusafa's street network integration (INT) and land use categories, Spearman's Rho correlation coefficients were calculated as presented in Table 1 and **Fig. 9**. This analysis investigates how integration, a key syntactic measure in space syntax that indicates global accessibility, correlates with the spatial distribution of different land-use types. The findings provide further insights into the relationship between syntactic measures and land uses, as elaborated in the following sections of the study, see **Fig. 10**.

Table 1. Correlation between street integration (Rn) and land uses in Old Rusafa.

Land Use Category	Correlation Coefficient (ρ)	Significance (p-value)
Residential	-0.234	<0.01
Commercial	+0.175	<0.01
Mixed Use	+0.118	<0.01
Public Facilities	+0.026	0.004

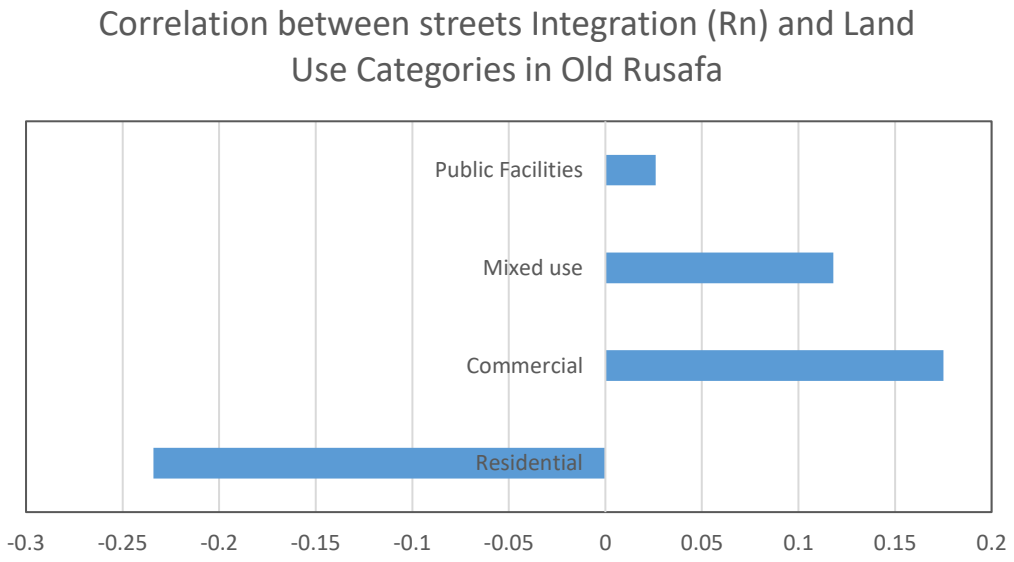


Figure 9. Correlation between streets integration (Rn) and land use categories in Old Rusafa.

Figure 10. Shows the correlation between street integration and land use.

The results of the correlation analysis are summarized below:

5.3.1.1 Residential

Integration and residential land use show a significant negative correlation (ρ=-0.234, $p<0.01$). This suggests that residential areas tend to have lower integration values, possibly due to a preference for more secluded or less accessible locations, which offer greater privacy and reduced traffic flow.

5.3.1.2 Commercial

A positive correlation is observed between integration and commercial land use (ρ=0.175, $p<0.01$). Higher integration values in commercial areas indicate that these zones benefit from better accessibility within the urban fabric, which is crucial for business operations and attracting customers.

5.3.1.3 Mixed Use

Integration also exhibits a notable positive correlation with mixed-use areas (ρ=0.118, $p<0.01$). Mixed-use developments, which combine residential and commercial functions, thrive in well-integrated spaces where accessibility and high pedestrian flow enhance their viability.

5.3.1.4 Public Facilities

There is a weak but significant positive correlation between integration and the presence of public facilities (ρ=0.026, p=0.004). Although the correlation is weaker than in other

categories, it still highlights the importance of accessibility for public facilities, ensuring they are easily reachable by the broader community.

5.3.2 Correlation Analysis of Street Choice with Land Use Categories

This section examines the relationship between the syntactic property of choice (CH) and various land use categories in Old Rusafa using Spearman's Rho correlation coefficients. The choice metric, which estimates the likelihood of a street segment being used as a pathway in urban navigation (betweenness centrality), is correlated with the following land use types: Residential, Commercial, Mixed Use, and Public Facilities, as shown in **Fig. 11**.

Figure 11. Shows the correlation between street choice and land use.

This analysis provides insights into how street-level traffic influences urban land use distribution, see **Table 2** and **Fig. 12**.

5.3.2.1 Residential

There is a strong negative correlation between choice and residential areas (ρ=-0.222, $p<0.01$). This suggests that streets with lower through-traffic are preferred for residential purposes, likely due to reduced noise and congestion, which contribute to a higher quality of life in these areas.

5.3.2.2 Commercial

A significant positive correlation exists between choice and commercial land use (ρ=0.160, $p<0.01$). This highlights the importance of heavily trafficked routes for commercial activities, where greater visibility and accessibility are critical for business viability.

5.3.2.3 Mixed Use

Similarly, mixed-use areas exhibit a positive correlation with choice (ρ=0.115, $p<0.01$). These areas benefit from moderate traffic levels, which support both commercial viability and residential convenience.

5.3.2.4 Public Facilities

The correlation between choice and public facilities is weak but still significant (ρ=0.038, $p<0.01$). Although less evident than in commercial areas, accessibility via frequently traversed routes remains an important factor in ensuring public facilities are reachable by the community.

Table 2. Correlation between street choice (Rn) and land uses in Old Rusafa.

Land Use Category	Correlation Coefficient (ρ)	Significance (p-value)
Residential	-0.222	<0.01
Commercial	+0.160	<0.01
Mixed Use	+0.115	<0.01
Public Facilities	+0.038	<0.01

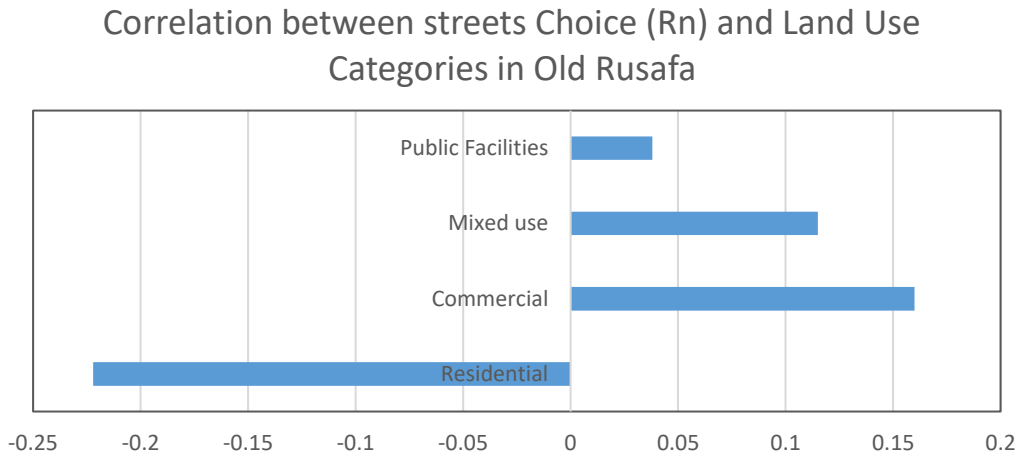


Figure 12. Correlation between street choice (Rn) and land use categories in Old Rusafa.

5.3.3 Correlation between Integration Values, Choice Values, and Land Use Categories

The correlation analysis between street network measures—Integration (INT) and Choice (CH)—and various land use types in Old Rusafa illustrates the primary distinctions in the influence of these spatial attributes on the pattern of urban land use.

Integration values (orange bars) are generally higher than choice values (blue bars) for commercial and mixed-use areas. This shows that global accessibility plays an important role in the spatial distribution of these land uses. Streets with high integration values are more attractive for commercial and mixed-use development because they facilitate movement and expose businesses to greater visibility.

Choice values are slightly lower than integration for the residential areas, reiterating the need for lower traffic exposure in these areas. This policy is in line with urban planning

policies that advocate privacy and lower congestion in residential areas to give residents a more comfortable living space.

Public facilities have a higher degree of urban network dispersion than commercial areas since correlation coefficients are lower for them. Thus, unlike commercial areas with high accessibility, public facilities are usually spread out strategically across cities in order to serve their residents from various parts rather than concentrated in very well-connected areas or places with high congestion, see **Fig. 13**.

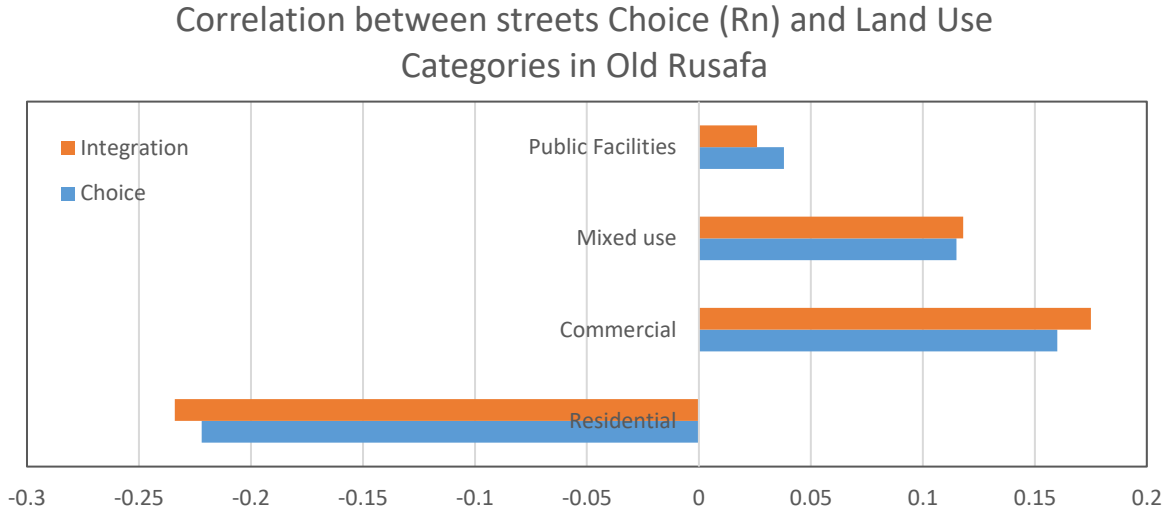


Figure 13. Correlation between street network measures and land use categories in Old Rusafa.

6. CONCLUSIONS

This study shows the relationship between spatial configuration and urban function through the application of Space Syntax on Old Rusafa, Baghdad's historic urban grid. The findings demonstrate how pedestrian and vehicular flows are affected by integration and choice measures and how these measures impact land use over time. The correlation analysis shows that streets with high integration values are commercial or mixed-use areas, benefiting from higher accessibility, which boosts economic vitality through pedestrian movement. The positive correlation between integration and commercial land use ($\rho=0.175$, $p<0.01$ \ rho=0.175, $p<0.01$) means businesses thrive in accessible urban spaces. Mixed-use areas have a notable positive correlation with integration ($\rho=0.118$, $p<0.01$ \ rho=0.118, $p<0.01$), further emphasising the importance of accessibility for multifunctional spaces. Residential areas have a significant negative correlation with integration ($\rho=-0.234$, $p<0.01$ \ rho=-0.234, $p<0.01$), meaning lower integration values. This aligns with urban planning principles that prioritize privacy and reduce traffic in residential zones. Public facilities have a weak but significant positive correlation with integration ($\rho=0.026$, $p=0.004$ \ rho=0.026, $p=0.004$), meaning accessibility but dispersed rather than concentrated in highly integrated zones. Similarly, the choice analysis shows clear trends. Streets with high choice values have a strong positive correlation with commercial land use ($\rho=0.160$, $p<0.01$\rho = 0.160, $p < 0.01$), meaning well-trafficked routes support businesses. Mixed-use areas also have a positive correlation with choice ($\rho=0.115$, $p<0.01$ \ rho=0.115, $p<0.01$), meaning they rely on pedestrian and vehicular movement. Residential areas have a strong negative correlation with choice ($\rho=-0.222$, $p<0.01$\rho=-0.222, $p<0.01$), meaning less trafficked and quieter environments. Commercial and mixed-use areas need global accessibility, and residential

areas need lower choice values to limit traffic exposure. Public facilities weakly correlated are dispersed to maintain accessibility without congestion. These results show that spatial configuration shapes land use. Urban planning must include space syntax to balance business with residential privacy. Spatial configuration is key to urban land use, so we need to integrate space syntax into urban planning and heritage conservation to balance commercial activity with residential living. This will allow planners to make informed and respectful design decisions. Future research should apply and compare this to other historic areas to refine and potentially standardise urban design principles based on syntactic properties.

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Credit Authorship Contribution Statement

Aya Furat Alobaydi: Writing – review and editing, Writing – original draft, Validation, Software, Methodology. Dhirgham Alobaydi: Writing – review and editing, Validation, Software. Sally Fakhri Khalaf: Review and editing, Validation, Software.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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استكشاف تأثير الخصائص التركيبية للشوارع على الوظائف الحضرية واستخدامات الأرض: رؤى من تحليل الشبكة المكانية

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الخلاصة

تعتمد هذه الدراسة نموذجاً بحثياً متكاملاً لتحليل الخصائص التركيبية للشبكة الحضرية التاريخية في بغداد القديمة، موضحةً كيف تؤثر التكوينات المكانية على الوظائف الحضرية وأنماط استخدام الأرض. تُعد العلاقة بين شبكة الشوارع وأنماط استخدام الأراضي محور اهتمام المعماريين والمخططين الحضريين، لا سيما في جهود إعادة إحياء النوى الحضرية التاريخية. تستخدم هذه الدراسة منهجًا متعدد الأدوات يشمل نظم المعلومات الجغرافية (GIS)، وتحليل نحو الفضاء (Space Syntax)، والارتباطات الإحصائية، والملاحظات الميدانية لتحليل الخصائص التركيبية لشبكة الشوارع في منطقة الرصافة القديمة. وقد تم إجراء التحليل ضمن نطاق نصف قطره 400 متر من النسيج الحضري التاريخي للرصافة القديمة، لدراسة العمليات التركيبية التي تحكم وظائف المدينة وإمكانية الوصول إليها، رغم التحولات المورفولوجية العديدة التي شهدتها المنطقة. أظهرت النتائج وجود ارتباط قوي بين شبكة الشوارع وأنماط استخدام الأرض في الرصافة القديمة، حيث سجلت المناطق التجارية ارتباطًا إيجابيًا ($\rho=0.175$, $p<0.01$) بينما أظهرت المناطق السكنية ارتباطًا سلبيًا ($\rho=-0.234$, $p<0.01$). كما أظهرت قيم الاختيار العالية ارتباطًا مع النشاط التجاري ($\rho=0.160$, $p<0.01$)، مما يشير إلى أن إمكانية الوصول المكاني تلعب دورًا كبيرًا في تشكيل الوظائف الحضرية وأنماط استخدام الأرض. تقدم هذه النتائج دروسًا قيمة يمكن تطبيقها على السياقات الحضرية التاريخية الأخرى، مما يسهم في تطوير مبادئ التصميم الحضري المستندة إلى الخصائص التركيبية. يمكن للأبحاث المقارنة مثل هذه أن تساعد المعماريين والمخططين الحضريين على فهم الأبعاد العالمية لنحو الفضاء في التصميم الحضري.

الكلمات المفتاحية: الشوارع، تركيب الفضاء، الوظيفة الحضرية، استخدام الأرض، إمكانية الوصول.