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From Cohesion to Contrast: A Spatial Syntax Comparative Exploration of Jerusalem's Old City Muslim and Christian Quarters

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Abstract

This study examines the underexplored physical disparities within the urban structures of historical cities shaped by religious communities, focusing on the Muslim and Christian quarters of the Old City of Jerusalem. As a city that was both newly developed and transformed during the Islamic period[1], Jerusalem provides a unique perspective for analyzing these distinctions. Employing space syntax, the research investigates the macro- and micro-level spatial configurations of the quarters, uncovering variations in street networks, accessibility, and urban design. The findings reveal how Christian and Muslim communities navigated and shaped their shared environment, offering a deeper understanding of the Islamic contribution to the planning of historical Jerusalem. This study not only advances the discourse on urban morphology in historical cities during the Islamic period but also highlights the relationship between administrative efficiency and Islamic principles of tolerance, as reflected in the physical fabric of the Old City.

1. Introduction

Investigating traditional urban forms across Islamic and pre-Islamic contexts is crucial for understanding Islamic planning, development, and identity. Studies from various Islamic geographic locations analyze old Islamic cities, exploring social, economic, and environmental sustainability [1], classifying neighborhood structures [2], and examining the relationship of quarters to the whole [3]. Since the early Islamic period, caliphs like 'Umar Ibn al-Khattab

1. The majority of scholars contend that the terms *"Islamic design"* and *"Islamic city"* are inapplicable to the Old City of Jerusalem. They argue that Jerusalem does not represent a city founded upon distinctly Islamic urban principles, but rather a medieval urban fabric composed of successive historical strata, to which the Islamic period contributed only marginally. However, evidence from the Madaba Mosaic Map—depicting the pre-Islamic city in the sixth century CE—together with archaeological findings, suggests a significant transformation during the early Islamic era. These sources indicate that the city's pre-Islamic boundaries were expanded eastward, giving rise to a newly established urban core centered around the Al-Aqsa Mosque enclave. This new nucleus profoundly influenced Jerusalem's spatial morphology and stimulated the development of new public and private architectural structures [5].

established laws for non-Muslims to coexist peacefully. Examining these historical conditions played a role in shaping city structures, neighborhoods, and development, evident in manuscripts like [4].

Traditional Islamic cities reveal a hierarchical social structure through their physical design, where local citizen involvement in city planning, especially at the neighborhood level, often outweighs the influence of rulers' broader decisions [5-13]. Islamic law and neighborhood building practices emphasize this community-driven influence, particularly through the roles of 'neighborhoods'—smaller, cohesive units—and 'quarters,' which are larger sections. These residential clusters, typically enclosed and occasionally gated, encouraged the privatization of public space, with adjacent homeowners transforming shared areas into extensions of private domains [14,6]. This dynamic integration helped unify individual houses into coherent clusters that shaped the city's distinctive identity.

This research explores how layered historical influences, including Islamic principles, shaped the spatial and social organization of traditional Islamic cities, focusing on the Old City of Jerusalem to explore contrasts between Islamic and non-Muslim quarters. Building on perspectives like Abu Lughod [15] on Islam's role in social cohesion, this study investigates whether Islamic planning principles shape both Muslim and non-Muslim areas, assessing distinctions in street networks, relationships, and accessibility [15]. It further evaluates the degree to which these physical separations align with social needs, as reflected in historical regulations and their evolution to the present day.

Technology, particularly space syntax, serves as a powerful analytical tool, revolutionizing the study of old cities and historical areas through its quantitative and visual approach to understanding spatial configurations. This method enables a detailed analysis of urban networks, uncovering patterns of accessibility, connectivity, and movement that have shaped the social and functional dynamics of the Old City of Jerusalem [16][17][18][19]. By mapping and quantifying spatial relationships, space syntax reveals how Christian and Muslim communities structured their environments to support trade, social interactions, and religious or cultural practices. In historically diverse cities, such as Jerusalem with its distinct religious and cultural quarters, space syntax proves invaluable in identifying unique spatial strategies [20]. It provides critical insights into how urban forms mirrored social hierarchies, fostered community interactions, and facilitated the coexistence of different groups across time [21].

The integration of space syntax and GIS has long been recognized as a powerful approach to analyzing spatial patterns [22-23]. Space syntax contributes quantitative methods for describing spatial structures from a cognitive standpoint, while GIS offers advanced capabilities in data analysis and geographic modeling [24]. The value of this integration was highlighted as early as 25 years ago, when [25] introduced a methodological framework that incorporated space syntax's connectivity graph modeling within GIS to improve the study of urban spatial configurations and human behavior. Since then, numerous applications have continued to demonstrate the potential of this combined approach in urban research [26-28]. Building on this foundation, [29] proposed a comprehensive framework that unites space syntax, GIS, and urban morphology, establishing an evidence-based design model that quantitatively connects spatial configuration with socio-economic factors to support predictive urban analysis and planning.

Increasingly, research highlights the value of integrating GIS and space syntax in examining historic sites and traditional urban areas, particularly in relation to heritage conservation and spatial accessibility [30-33] Employed a socio-spatial vulnerability framework that uses space syntax to assess how human activities worsen risks to heritage buildings in historic Cairo. Similarly, in the context of old town evolution, [34] applied multisource data integration with GIS and space syntax to analyse Wuxi's old urban area, revealing how modernization and vehicular traffic altered spatial patterns, threatening the preservation of regional characteristics. These studies confirm the capabilities of the space syntax GIS integration approach in providing a better understanding and insights into historical areas.

The Old City of Jerusalem, a revered site for Judaism, Christianity, and Islam, holds a rich historical and religious legacy within its ancient walls. Its structure, initially shaped during Hadrian's time as *Aelia Capitolina*, continues to influence the layout of the Islamic, Christian, Armenian, and Jewish quarters [35-36]. Under Islamic rule, the city expanded to accommodate diverse communities, with Caliph 'Umar guaranteeing safety for Christian sites, embodying religious tolerance. Unlike other Islamic cities, where mosques are central, the Al-Aqsa Mosque in Jerusalem is surrounded by Islamic social functions and separated from residential areas, creating a unique spatial organization [37].

Today, while the Old City preserves its distinct quarters, boundaries between them blend due to the interconnected street network and overlapping architectural features, like terracotta-tiled buildings. The Islamic Quarter is the largest, but the quarters share similarities in building types, despite specific landmarks such as churches in the Christian Quarter. Although demographic shifts since 1967 have changed the population makeup [38-40], the Muslim and Christian quarters largely retain their historical layout, illustrating the enduring social and spatial complexity of Jerusalem's Old City "Figure 1".

This research investigates the complexities shaping the urban fabric of Jerusalem's Old City, specifically the Muslim and Christian quarters, which evolved in response to varied social, topographical, and structural challenges from the early Islamic period to today. Key issues include how public and private spaces, street layouts, and the integration of new thoroughfares impact neighborhood morphology, identity, and social cohesion. The study questions traditional assumptions about Islamic city structure—whether distinct areas form isolated social groups or if a more interconnected, holistic urban system is at play. A spatial syntax and morphological analysis will clarify these socio-spatial

relationships, exploring if and how local neighborhood identities contribute to the overall coherence of Jerusalem's urban form.
While Space Syntax provides valuable configurational insights, it represents one analytical dimension among many. Integrating morphological, typological, and socio-spatial documentation would yield a more holistic understanding, especially in a dense, historically complex context such as Jerusalem. The central research question guiding this study is: How do Islamic and non-Islamic planning principles manifest spatially within the Muslim and Christian quarters of the Old City of Jerusalem? It is hypothesized that the Muslim Quarter demonstrates higher integration and connectivity due to Islamic urban planning traditions emphasizing communal interaction and accessibility, whereas the Christian Quarter reflects enclosed spatial characteristics shaped by religious and social constraints.

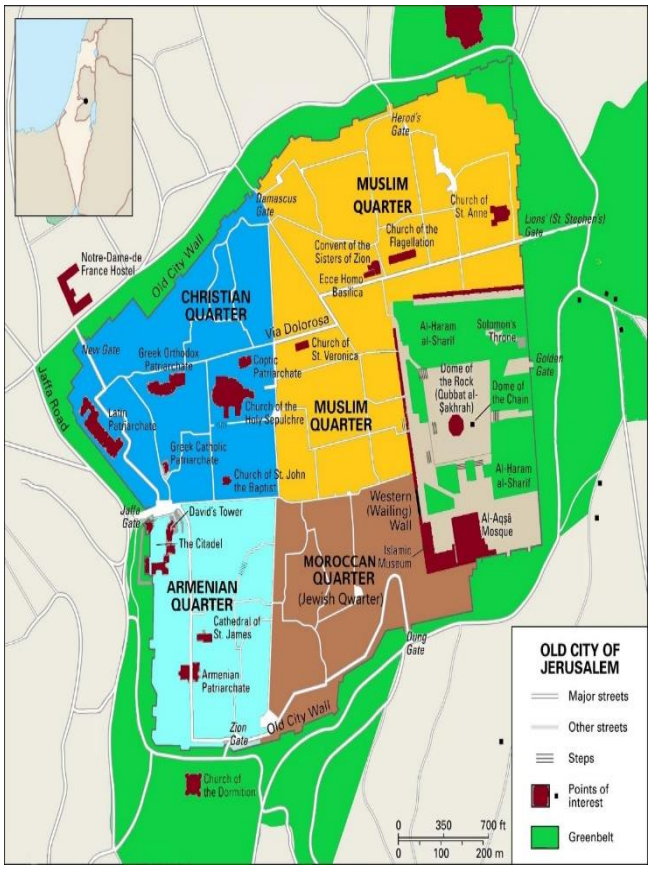

Figure 1. Spatial Layout and Quarters of the Old City of Jerusalem.

2. Method

This study adopts a space syntax methodology to critically examine the spatial configuration of the Muslim and Christian quarters in Jerusalem's Old City, emphasizing the role of movement patterns in shaping urban morphology and facilitating social interactions.2 By interrogating the socio-cultural contexts underpinning the development and expansion of these quarters over centuries, the research seeks to uncover nuanced distinctions that have influenced the transformation of the historical urban fabric of the Old City. Using GIS and syntactic methods like axial map analysis, the study examines street connectivity, integration, and choice to understand the relationship between the urban layout and social life. This configurational technique allows insights into the historical evolution of the Old City's Muslim and Christian quarters, offering a model for analyzing functional relationships and spatial patterns across diverse cultural contexts "Figure 2".

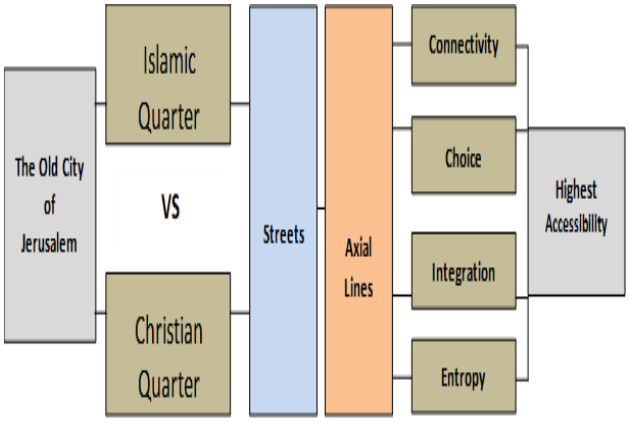

Figure 2. Research Methodology Diagram for Physical and Spatial Exploration.

The research methodology integrates comprehensive data collection and advanced spatial analysis to explore the Muslim and Christian Quarters of Jerusalem's Old City. Data collection involved detailed mapping of the urban fabric, including street networks, pathways, and spatial hierarchies, using historical and recent maps, and on-site and field observations. A comparative evaluation of non-invasive measurement methods (laser scanning, UAV photogrammetry) in the architectural documentation of historic structures shows that combining methods often yields richer results (62). The analysis employs space syntax, a robust method for examining spatial configurations and their influence on social and functional dynamics. Yakar investigates the 3D reconstruction of residential areas using UAV-based Structure from Motion (SfM) photogrammetry by comparing three different methods in terms of their advantages and limitations for city modelling. (63). Through this framework, key metrics such as integration, connectivity, and accessibility are quantified to reveal patterns and variations within the quarters. The study utilizes specialized software, including DepthmapX and QGIS, to process spatial data, construct axial maps, and generate visual and numerical outputs. These tools

2 Previous research on Jerusalem has employed various analytical frameworks beyond space syntax. Socio-political and urban planning studies have examined governance, policy, and spatial segregation [51-54], while geopolitical and historical analyses have traced territorial change and urban transformation [55-56]. Other works have focused on heritage preservation and typological aspects of the Old City's built fabric [57-59]. In contrast, Lerman and Lebendiger and Rokem, Weiss, and Miodownik applied space syntax to demonstrate how Jerusalem's street configuration shapes accessibility and social interaction, providing the analytical basis for the present study [60-61].

enable precise modelling and interpretation of the spatial properties of the Old City's urban network, providing insights into the relationship between spatial structure and the historical, cultural, and social organization of its Muslim and Christian communities.

To contextualize the syntactic results, complementary datasets—including building ages, height profiles, and morphological typologies—will be incorporated in future stages to visualize the historical continuity and vertical layering of the Old City. This integration strengthens the interpretive depth of Space Syntax outcomes by linking them to the city's stratified architectural history. The base maps used in this analysis were derived from the Jerusalem Municipality GIS database and historical cadastral maps dated between 1880 and 2020, projected in the Palestine Grid (EPSG:28191) coordinate system. Fieldwork was conducted between May and September 2024, involving on-site verification of street alignments, visual observation of movement patterns, and photographic documentation of spatial features to validate digital models. Recent research employing photogrammetry for cultural heritage areas demonstrates rapid, cost-effective surface modelling and high spatial accuracy, making it a suitable approach for many aplications (64,65,66).

3. Results and Discussion

This section presents the findings from the applied methodology on the spatial axial network of the Old City of Jerusalem. It critically analyses the aspects of connectivity, choice, integration, mean depth, and entropy, considering both qualitative and quantitative outcomes. Furthermore, these findings facilitate a comparative analysis between the Muslim and Christian quarters, focusing on building accessibility, socio-spatial dynamics, and physical factors.

3.1. Connectivity

Connectivity, as understood within spatial syntax theory, quantifies the number of direct connections a street segment maintains with its immediate neighbors. This metric is instrumental in understanding the structural integration of urban networks and their impact on movement patterns, economic activities, and social interactions. In Jerusalem's Old City, connectivity plays a crucial role in shaping the dynamics of movement, commerce, and cultural exchange, with notable distinctions between the Muslim and Christian Quarters.

3.1.1. High Connectivity and Urban Hubs

Streets with high connectivity values, represented in yellow and orange on the connectivity map "Figure 3", signify segments with extensive direct links to surrounding streets. These areas often act as primary thoroughfares, supporting significant urban integration.

A prominent example is the southern section of the Roman Cardo Street, which historically delineates the Islamic and Christian Quarters. This segment links key Islamic administrative institutions near the Al-Aqsa Mosque enclave and vital commercial markets, such as *Sūq al-Qattānīn*, emphasizing its centrality in movement and activity networks "Figure 4".

The strategic role of high-connectivity streets extends beyond movement facilitation; they also bolster economic vitality. Markets along these streets, in accordance with Islamic urban traditions, often cluster near mosques to serve as social and economic hubs. This spatial relationship highlights the integration of functional and cultural priorities in urban planning [6].

3.1.2. Moderate Connectivity: Secondary Connectors

Streets with moderate connectivity, marked in light green, function as secondary connectors that link highly integrated segments to less accessible or peripheral zones. For instance, the northern section of the Roman Cardo Street, extending southward from *Bāb al-ʻĀmoūd* (Damascus Gate), connects to smaller streets leading to residential neighborhoods in both the Muslim and Christian Quarters. While these streets lack the extensive direct connections of their high-connectivity counterparts, they play a pivotal role in sustaining urban cohesion and accessibility.

Figure 3. Connectivity Map (The connectivity values in the streets of the Old city of Jerusalem). The figure illustrates how connectivity values correspond to socio-economic intensity, emphasizing the relationship between commercial corridors and public movement.

Figure 4. VGA Connectivity Map generated through Visibility Graph Analysis (VGA) highlighting the visibility patterns across different segments.

3.1.3. Low Connectivity: Peripheral and Residential Streets

Low-connectivity streets, illustrated in blue, are characterized by limited direct links and are typically found in peripheral areas or residential zones. These include smaller alleys and cul-de-sacs, common in the Old City's Muslim and Christian Quarters. The spatial organization of low-connectivity streets reflects traditional Islamic urban morphology, where privacy is a key design consideration. This principle aligns with patterns observed in other Islamic cities, such as Damascus and Cairo, where architectural and spatial strategies—such as controlled access points and setbacks—preserve the sanctity of residential spaces while integrating commercial activities.

3.1.4. Comparative Connectivity: Muslim and Christian Quarters

The connectivity analysis reveals that while the number of directly connected streets in the Muslim and Christian Quarters is comparable, the Muslim Quarter features a greater absolute number of streets due to its larger spatial extent. This abundance naturally enhances connectivity, particularly in areas near public institutions and markets surrounding the Al-Aqsa Mosque enclave.

However, the fragmentation of connectivity within both quarters is influenced by variations in street types, surrounding activities, and physical configurations. For example, major streets like the southern Roman *Cardo* Street and the ancient *Decumanus* (east-west street) branch into lower-connectivity alleys, illustrating the interplay between central and peripheral urban spaces.

3.1.5. Roman *Cardo* Street: A Central Axis

The Roman Cardo Street, extending along a north-south axis, demonstrates the highest connectivity in the Old City. This historic street bisects the city, serving as a critical boundary between the Islamic and Christian Quarters. Its southern section, in particular, exhibits significant connectivity due to its proximity to major religious and commercial landmarks, including the Al-Aqsa Mosque enclave and the Church of the Holy Sepulchre. Surrounding public buildings, such as schools, hospices, and baths, further enhance the integration of this street into the city's broader urban network, reinforcing its function as a central artery of movement and interaction.

3.1.6. Markets and Connectivity

The connectivity map highlights the strategic placement of markets, particularly in the Islamic Quarter. Markets like *Sūq al-Qattānīn*, located near the Al-Aqsa Mosque enclave, exemplify the role of economic activity in shaping urban morphology. These markets not only facilitate commerce but also act as cultural and social focal points, aligning with historical Islamic urban practices.

The relationship between markets and connectivity highlights their dual role: as functional economic spaces and as integral elements of cultural and religious identity within the urban fabric.

To sum up, connectivity in the Old City of Jerusalem is a multifaceted construct that encapsulates historical, cultural, and functional dimensions of urban design. High-connectivity streets function as essential connectors and activity hubs, while low-connectivity streets safeguard privacy and residential character. The enduring relevance of streets like the Roman Cardo illustrates the interplay between historical significance and contemporary functionality, emphasizing the importance of connectivity in shaping urban life.

3.2. Choice

Choice (Betweenness Centrality) in spatial syntax analysis measures the frequency with which a network segment is traversed while traveling between all pairs of locations. This metric identifies critical pathways or "shortcuts" that facilitate movement within an urban system. In the Old City of Jerusalem, the majority of streets are marked with low choice values (depicted in dark blue on the map), indicating dispersed movement patterns. This distribution minimizes reliance on any single street as a dominant connector, promoting a network where movement is distributed across multiple routes "Figure 5".

Figure 5. Choice Map: The choice values in the streets of the Old city of Jerusalem. The figure demonstrates the decentralized movement patterns across the quarters, with Via Dolorosa as an exception due to its dual religious function.

3.2.1. Observations on Movement and User Patterns

Fieldwork data revealed nuanced movement patterns influenced by user familiarity with the Old City. Individuals were categorized into three groups:

1. Residents with extensive local knowledge,
2. Residents with limited familiarity, and
3. Strangers unfamiliar with the area.

This categorization highlights the interplay between familiarity and various factors, including time spent on specific streets, visit frequency, purpose, demographics, and the types of activities occurring. Movement patterns reflect not only accessibility but also the informal and transitional nature of urban spaces, which influence the quality and frequency of use [41-42]. Choice analysis thus considers not only primary thoroughfares but also secondary and transitional routes that contribute to the overall urban accessibility.

3.2.2. *Via Dolorosa*: A Unique Case of Moderate Choice

While most streets in the Old City exhibit low choice values, *Via Dolorosa* (*Tarīq al-ʿĀlām*) stands out as an exception. Located in the Islamic Quarter near the northwestern corner of the Al-Aqsa Mosque enclave, this street shows moderate choice values. Its significance arises from its dual role: serving as a Christian pilgrimage route and a tourist path, while also providing Muslim visitors with direct access to Al-Aqsa Mosque [43]. The street's unique function reflects the intersection of religious symbolism and strategic connectivity, making it a preferred route for diverse groups of users.

3.2.3. Urban Gateways and the Role of Choice

The analysis reveals that streets connected to the city's gates—key entry points to the Old City—play a vital role in shaping spatial choice. Residents and visitors alike rely on these access points, which influence their mental maps of the city. Streets radiating from gates tend to penetrate deeper into the quarters [39], increasing exposure and interaction. This effect is particularly evident in streets leading to landmarks such as Al-Aqsa Mosque in the Muslim Quarter and the Church of the Holy Sepulchre in the Christian Quarter [44-45]. However, this increased exposure often disrupts the sense of privacy and control within adjacent residential areas, especially near primary thoroughfares.

3.2.4. Comparative Analysis: Muslim and Christian Quarters

When comparing spatial choice across the Muslim and Christian Quarters, the map shows a uniform low-choice pattern across both areas (depicted in blue). This equilibrium suggests a lack of dominant streets that naturally attract movement or serve as central connectors. Instead, the urban fabric reflects a decentralized structure, where movement is influenced by subjective human intentions and the contextual significance of specific destinations.

The Roman *Cardo*, a historically significant street, illustrates this dynamic. While historically central to the city's spatial organization, the modern *Cardo* (marked in blue) now exhibits low choice values, reflecting its diminished role in contemporary connectivity. Instead, it functions within a polygonal network of intersecting streets that define specific plots of land, such as the Christian Quarter surrounding the Church of the Holy Sepulchre.

3.2.5. Privacy, Exposure, and Urban Dynamics

The relationship between spatial choice and privacy stresses a critical tension within the Old City's urban fabric. Streets extending from gates into the residential cores of the quarters increase exposure and reduce residents' control over their immediate environment. This dynamic contrasts with traditional urban design principles, particularly in the Islamic Quarter, where privacy is a central consideration [46] .

To sum up, the spatial choice analysis of Jerusalem's Old City highlights the absence of dominant, high-choice streets and the decentralized nature of its urban layout. Movement patterns are shaped by a combination of physical network characteristics and users' subjective perceptions, influenced by destinations and cultural landmarks. *Via Dolorosa* emerges as a unique exception, reflecting the complex interplay of religious significance, accessibility, and movement. Overall, the low choice values across the Muslim and Christian Quarters reveal a balanced yet nuanced spatial structure, where connectivity and privacy coexist within a historically and culturally significant urban framework.

3.3. Integration

Integration, a core concept in spatial syntax analysis, evaluates the accessibility and centrality of streets or spatial segments within an urban network. It measures how connected a space is by assessing the steps required to reach other areas in the network. This metric is particularly valuable in analyzing the spatial dynamics of Jerusalem's Old City, especially within the Muslim and Christian Quarters. By examining integration on both local and global scales, the analysis offers a nuanced understanding of connectivity, movement, and spatial coherence, revealing the interplay between individual spaces and the broader urban structure "Figure 6".

3.3.1. Integration Values: High and Low

High Integration (Red and Yellow)

Streets with high integration, marked in red and yellow, are the most accessible and well-connected segments of the network. These streets, including the historic Cardo and Decumanus, form the backbone of the city's movement and interaction, minimizing the steps or turns needed to reach other locations. High-integration streets are often key thoroughfares or commercial zones that attract significant pedestrian and vehicular traffic. In the Old City, they also connect major religious sites, underscoring their dual role in facilitating movement and supporting socio-economic activities.

Low Integration (Blue and Green)

Streets with low integration, marked in blue and green, are less accessible and typically located on the network's periphery. These areas often correspond to residential neighborhoods or quieter zones with fewer connections, requiring more steps or turns to access. Such streets experience lower traffic levels and serve as private, less-frequented spaces, aligning with traditional urban design principles that prioritize privacy.

Figure 6. Integration Map. The Global Integration of connectivity in the Old city of Jerusalem, considering movement and access between different areas. This figure visualizes the integration hierarchy of the Old City's street network, where high-integration axes correspond to historically active commercial and religious routes.

3.3.2. Integration in the Spatial Patterns in the Old City

The global integration analysis reveals a high degree of connectivity between the Muslim and Christian Quarters, a result of the spatial configuration of the city's main streets "Figure 7". Roads with the highest integration values act as bridges between these distinct neighborhoods, linking the primary religious cores of both communities. However, this high connectivity raises concerns about privacy and security, particularly in areas where residential spaces intersect with highly integrated commercial streets.

In contrast, cul-de-sacs and secondary streets show lower integration values, emphasizing their reduced role in urban connectivity compared to main thoroughfares. On a local scale, streets at the periphery of the Muslim and Christian Quarters exhibit slightly lower integration values but remain essential access routes, ensuring consistent accessibility across neighborhoods. This pattern suggests that the Old City's urban fabric is designed to balance movement and interaction with the need for coherence and functionality "Figure 6".

3.3.3. Integration in the Muslim Quarter

A key feature of the Muslim Quarter is a highly integrated urban space located between the Al-Aqsa Mosque enclave and the city's north-south Roman *Cardo*. This area demonstrates high integration values, underscoring its strategic role in connecting religious,

social, and economic activities within the quarter. Despite the predominance of residential neighborhoods in this region, human activity and movement remain remarkably high due to the Al-Aqsa Mosque's pivotal location on the city's eastern edge and its integration into the broader urban framework.

Figure 7. VGA Integration Map generated through Visibility Graph Analysis (VGA) highlighting visibility patterns across various segments.

The primary commercial streets leading to Al-Aqsa enclave intersect with adjacent residential areas. While this overlap might initially appear to compromise privacy, urban planning interventions have been implemented to maintain and enhance the privacy of these neighborhoods. This balance highlights the interplay between urban connectivity and cultural values, ensuring the functionality of the urban fabric without undermining traditional design principles.

The integration analysis of Jerusalem's Old City highlights a deliberate and strategic balance between connectivity, privacy, and functionality within its urban structure. High-integration streets enable movement and socio-economic activity, while low-integration areas preserve the privacy and tranquility of residential neighborhoods. The interconnected patterns of the Muslim and Christian Quarters reflect a historically evolved urban design aimed at accommodating both religious and communal needs. At the center of this dynamic lies Al-Aqsa Mosque enclave, a focal point of spatial and cultural significance, anchoring the urban fabric of the Old City.

3.4. Entropy

In DepthMapX, entropy serves as a metric to evaluate the complexity or "disorder" within spatial networks, particularly in the distribution of connectivity, integration, and visibility. This measure is widely applied in architectural and urban planning analyses to understand spatial configurations.

Entropy quantifies uncertainty or unpredictability within a spatial layout. When applied in DepthMapX, it offers a quantitative assessment of the uniformity or variability in the distribution of spatial properties. Essentially, entropy indicates the degree of order or disorder in a spatial network, such as streets, rooms, or other interconnected entities. Higher entropy reflects greater complexity or variability, while lower entropy suggests a more regular and predictable spatial structure.

The entropy map provides a visual representation of the distribution of entropy values across different routes and spaces in an urban layout. It uses a color-coding system ranging from blue and green (indicating lower entropy) to yellow, orange, and red (indicating higher entropy) "Figure 8".

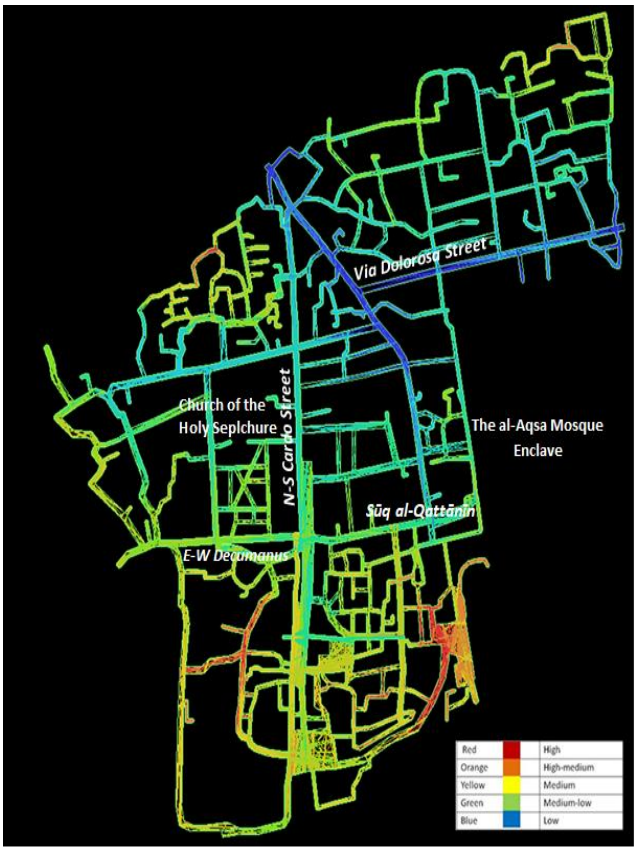

Figure 8. Entropy Map. The entropy distribution indicates contrasts between the ordered Islamic Quarter and the complex spatial fabric of the Christian Quarter.

3.4.1. Blue and Green (Low Entropy)

These areas exhibit low entropy, reflecting more uniform or regular spatial connectivity. Streets or spaces shown in blue or green are characterized by straightforward and predictable spatial relationships.

Within the Muslim Quarter, low-entropy areas are associated with simpler layouts that facilitate easier navigation, providing efficient access to the Al-Aqsa Mosque, which serves as the new urban core of Islamic Jerusalem [47-48].

3.4.2. Yellow to Red (High Entropy)

Areas marked in yellow, orange, or red indicate higher entropy, representing greater spatial complexity. These regions are characterized by irregular intersections, dead ends, or diverse routing options, making them **less predictable** and more challenging to navigate. Such areas often correspond to neighborhoods with intricate street networks or limited visibility.

In the context of Jerusalem, entropy analysis reveals that the main street surrounding the northern area of Al-Aqsa Mosque enclave, along with another street near its northeastern side—referred to as the Secondary *Cardo* within the Muslim Quarter—demonstrates greater regularity, spatial clarity, and significantly lower entropy. These streets contrast sharply with the city's primary *Cardo*, which separates the Muslim and Christian Quarters and exhibits higher entropy values.

The streets within the Muslim Quarter function as crucial connectors, linking the city's primary eastern and western gates while providing direct access to Al-Aqsa Mosque enclave. Their low-entropy configuration highlights their role in facilitating navigation for both visitors and residents, underscoring the functional simplicity of their spatial layout.

This pattern reflects the historical evolution of Jerusalem during the Islamic period, during which urban expansion was intentionally directed toward Al-Aqsa Mosque enclave. This deliberate strategy positioned the mosque as a central and vibrant focal point within the city's urban fabric.

4. Conclusion

This study presents a comprehensive spatial analysis of Jerusalem's Old City, focusing on the distinct characteristics of the Muslim and Christian Quarters. Through the application of space syntax metrics—connectivity, choice, integration, and entropy—the paper contributes valuable insights into the dynamic interaction between historical, cultural, and functional elements that shape the urban fabric of these two quarters.

The analysis reveals how spatial organization reflects a complex relationship between accessibility, socio-economic activity, and the preservation of privacy. High-connectivity streets, such as the Roman Cardo and markets like *Sūq al-Qattānīn*, are identified as critical urban arteries, facilitating movement, commerce, and cultural exchange while anchoring religious and communal hubs. In contrast, low-connectivity streets, often peripheral or residential, prioritize privacy and seclusion, reflecting traditional urban design principles. The deliberate hierarchy in the street network, balancing open interaction and residential privacy, underscores the nuanced approach to urban planning in Jerusalem.

Further, the analysis of choice illustrates a decentralized movement pattern across the city, with distributed accessibility rather than the dominance of a single pathway. Streets like the *Via Dolorosa*, which hold both religious and cultural significance, highlight the role of spatial choice in accommodating diverse user groups. Integration metrics reveal the strategic placement of main thoroughfares, particularly within the Muslim Quarter, where high-integration streets bridge residential and commercial zones, reinforcing socio-spatial coherence.

Entropy analysis adds another layer of understanding, distinguishing between areas of predictable navigation and regions characterized by greater complexity. The low-entropy configuration of streets surrounding the Al-Aqsa Mosque enclave reflects intentional urban planning that balances accessibility with religious and cultural significance, contributing to the Old City's distinct spatial organization.

A key contribution of this paper is its analysis of the spatial distinctions between the Muslim and Christian Quarters. The Muslim Quarter, with its higher connectivity and vibrancy, also exhibits a certain level of local ambiguity in its street network. In contrast, the Christian Quarter is characterized by fewer but more visible and connected streets and squares. This divergence stems from two primary factors: first, the architectural traditions of each community, with Islamic spaces favoring a gradual transition between streets and buildings [9], while Christian spaces emphasize shared squares that integrate buildings; and second, the minority status of Christian denominations in the city, which influenced the spatial layout, particularly through the use of courtyards to foster a sense of community and security [49].

The spatial organization of the Muslim Quarter, particularly its road network and proximity to the Al-Aqsa Mosque enclave and surrounding commercial areas, highlights the strong influence of religious and commercial functions on its development. This is contrasted with the Christian Quarter, where the street network, shaped by earlier planning, connects the main horizontal and vertical axes, suggesting a more enclosed, less connected structure.

Despite these differences, the study reveals that both quarters share key characteristics reflective of broader Islamic urban planning traditions. Both quarters adhere to the principles of local connectivity, communal interaction, and privacy, which have shaped the urban character of Jerusalem across cultural and historical contexts. This observation underscores the deep historical, cultural, and functional interconnections that define the Old City.

While this research has advanced our understanding of the spatial organization of Jerusalem's Old City, particularly in distinguishing the Muslim and Christian Quarters, it also highlights the need for further study. The focus on macro and micro-scale street patterns and building configurations provides a valuable framework, but a more nuanced analysis at the micro-scale—examining dimensions, usage categories, and functional distributions—could yield additional insights.

Future research should expand on these aspects to develop a more holistic understanding of the intricate urban dynamics of Jerusalem's Old City and its role as a living testament to the intersection of space, culture, and society. In summary, the study highlights that despite their distinct religious affiliations, both quarters reflect the enduring principles of Islamic urbanism—community-centered spatial order, privacy, and balanced accessibility. The integration of space syntax and GIS provides a replicable methodological framework for analyzing other multi-faith historical cities. Future research should incorporate dynamic simulation of pedestrian flows and 3D morphological modeling to assess temporal changes in accessibility and social interaction.

Author contributions

Haithem Ratrout, Khalid Qamhieh, and Ihab Hijazi: Conceptualization, Methodology, Software, Field study **Mohammed Itair:** Data curation **Diana Enab, Mona Qamhieh:** Writing-Original draft preparation **Ihab Hijazi, Mohammed Itair:** Software, Validation, Field study **Ihab Hijazi, Diana Enab, Haithem Ratrout, Mohammed Itair:** Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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