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Connectivity, Integration, and Entropy measurements to assess: Visual perception of city users, urban quality, and growth

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ABSTRACT

BACKGROUND AND OBJECTIVES: Batna city's road network has evolved due to various factors, particularly residents' practices and movements, which have shaped the city's routes and spatial hierarchies. However, the logic of urban production has been unexplored through the prism of user experience. This study aimed to analyze the spatial configuration of the city's road network, to identify the mechanisms driving the city's evolution, highlighting the users' contribution, providing guidelines for future, thoughtful urban planning, and enhancing the quality of urban space by reconciling city users' perception with different approaches to planning.

METHODS: The study applied space syntax Analysis, using depthmap 10 software. It calculated the following parameters: Connectivity, integration, and entropy, and analyzed 25753 axes of Batna's road network. These measures allowed understanding users' perception of accessibility, movement, and route choices. This analysis was complemented by a sociological study and field observations. To assess the robustness of the relationship between these parameters, statistical tests were performed, including Pearson and Spearman correlations, as well as a linear regression test analyzed through the ANOVA table, to examine the relationships between two dualities: connectivity/ integration and connectivity/ entropy.

FINDINGS: Connectivity values in Batna city ranged from 0 to 7, with higher values (4-7) found in formal districts. The average integration value was 1.17, peaking at 2.63. Pearson and Spearman confirmed strong correlations between these attributes (p-value less than 0.001), while the ANOVA table from linear regression predicted 14% of the variance in Integration. These values revealed areas with high centrality and accessibility, aligning with the questionnaire responses on urban dynamics and frequency. The analysis also recorded high spatial choice and complexity, revealed by a maximum entropy value of 1.057, observed in more than 25753 spatial units analyzed in this study.

CONCLUSION: The study was distinguished by the inclusive approach, based on the exhaustive analysis of the road structure of Batna city. It highlighted that urban quality and perception, although immaterial and subjective concepts, can be objectified and analyzed rigorously. It advocated for urban planning that is more sensitive to spatial configuration. This study was unique in that it analyzed the entire road network of the city, thus providing a solid basis for testing, in future research, other parameters derived from the Space Syntax method.

NUMBER OF REFERENCES	NUMBER OF FIGURES	NUMBER OF TABLES
99	16	6

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INTRODUCTION

In the current context of urban development, interactions between urban users, communities, and the changing environments are emerging as a central issue, highlighting the importance of integrating lived experiences into urban transformation processes. Regardless of scale, each intervention, whether large or small, contributes actively to the ongoing Production of the Urban Space (PUS) (Gu, 2019). In Algeria, the recent transformations and the rapid Urban Growth (UG) impacted the resources and lifestyles of the inhabitants, leading to a review of urban policy, actions, and behaviors within the city. The Quality of the Urban Space (QUS) is now seen as a crucial driver of development, but continues to elude consistent large-scale measurement due to persistent ambiguities for assessing how it is perceived by urban dwellers (Olorunfemi and Adeniran, 2020). Recent studies call for innovative methods to deepen the understanding of these interrelations (Han *et al.*, 2023; Lei *et al.*, 2024), particularly in addressing challenges related to Urban Configuration (UC) (Yadav and Gupta, 2021). The link between the QUS and the physical components of the urban space remains largely underexplored. Architects and urban planners must analyze and foresee the evolution of these components, integrating the perceptive experiences of urban users. The Urban Reality (UR) shaped by the actions of inhabitants and visitors in appropriating urban spaces deserves attention (Khainnar, 2021; Lübcke *et al.*, 2011). Spatial configuration plays a decisive role in the PUS and QUS. By avoiding restricting the analysis to perceptual experiences alone, this study focuses on objectively Measurable and Quantifiable Indicators (MQI), such as connectivity, integration, and entropy of Space Syntax Theory (SST), which directly influence the functioning and navigation of urban spaces. Road Networks (RN), in particular, structure these dynamics. In Batna city, both planned and unplanned RN shape accessibility and mobility; planned urban structure reflects formal design principles, while unplanned networks emerge from users' practices. The city of Batna has been chosen, within the diverse urban contexts of Algeria, for several reasons. Located in the eastern Highlands, it plays a strategic position linking the northern coastal zones and the Saharan territories. Unlike coastal metropolises, Batna exemplifies the challenges faced by interior cities that are experiencing rapid and uneven urban expansion. Consequently, an investigation yields valuable insights into the broader processes influencing medium-sized cities in Algeria. Therefore, the main questions asked in this study are as follows: What is the spatial configuration of Batna city? Where are the main areas of the city likely to attract people, both residents and visitors? How do these urban dynamics influence urban production, spatial quality, and urban experiences, including the perception of users and urban flows? Knowing that inquiries regarding the QUS are connected to how humans visually perceive it, which in turn influences pedestrian movement, especially since this category encompasses all types of urban users. This study investigates how UC is linked to PUS, UG, QUS, human visual perception, and movement by combining Space Syntax Analysis (SSA) with statistical tests, including Pearson and Spearman correlations and Analysis of Variance ANOVA from linear regression tests. Complemented by a social survey, this study explores various urban environments, particularly the entrances of the city, dominated by an organic urban fabric and the planned city's core. Based on these reflections, the study relies in particular on the following hypotheses:

-The visual perception of city users is influenced by several factors, including the spatial configuration. Therefore, both can be analyzed, predicted, and measured.

- Batna city's core, a highly connected central space, generating a higher potential for pedestrian flow, as well as a visually appealing and well-structured urban space, can influence the overall perception and interaction within the city, and these urban dynamics define the quality of the whole city.

-The neighborhoods, including those of an informal nature or located in the outskirts, that have successfully coordinated internal mobility effectively have met the expectations of urban users, and they are often referred to as quality urban spaces.

This study aims to precisely analyze how the UC of the city of Batna influences the urban dynamics within current residential districts, in particular through the parameters of connectivity, integration, and entropy. The research also seeks to predict potential transformations in Batna's urban morphology by studying the logic of the spatial presence and movement of users within the city. Additionally, this study aims to provide a comprehensive analysis of all the neighborhoods in the city of Batna, without separating the spaces, and considering them as fragmented entities. The objective is thus to build an integrated understanding of the urban structure of the city. The proposed methodological approach provided an objective analysis of accessibility, legibility, and spatial hierarchy, supporting a rigorous study of the Batna case, conducted in 2024.

Literature review

Indicators of urban structure about scale of analysis: human dimension and street-level dynamics:

The processes of PUS have been mainly studied by different researchers, highlighting the complexity of contemporary urban dynamics (Hersous *et al.,* 2023; Robertson and Neuhaus, 2024; Yu *et al.*, 2023). Over the last few decades, UG has been shaped by intense competition between cities (Hoornweg *et al.,* 2007; B. Huang *et al.,* 2020; Talukder *et al.,* 2025), with urbanization emerging as the structuring force of modern society (Huang *et al.,* 2025; Lakjaa, 2016). Successful UG has always required structured physical planning, an effective system of public spaces, and well-connected RN (Karssenberg, 2016). These elements affect the overall image of the city (Danese *et al.*, 2009). However, Le Corbusier advocates an organic and decentralized approach in the creation of urban structures, warning against the rigid designs of architects that ignore the complexity of social interactions. Because as long as there are dynamics of daily life in urban spaces, visions about urban planning differ, and the criteria of QUS are constantly evolving (Alexander *et al.,* 1977; Lakjaa, 2016).Pedro Gomes (2017) emphasizes the central role of urban public spaces, in particular RN, in the PUS in Western Europe, also constituting a dimension of public action. Similar to the majority of Mediterranean cities, the main hub for socializing is the street, it structured around public services, local shops, and the multitude of restaurants and cafes, along with the various events taking place there (Barakat and Chamussy, 2002). As a system of alternative routes, it contributes to the readability of the city, facilitating the overall understanding of the urban fabric. Consequently, this dimension must maintain reasonable flexibility, allowing great latitude in the development of space planning solutions. This urbanization also does not cancel the roles of city users. Investigating users' visual perception preferences concerning urban public space contributes to an understanding of the interplay between the structural dynamics of the PUS and everyday practices that contribute to urban reconfigurations. This improvement encourages social interactions while promoting balanced and sustainable UG, rooted in community well-being and the attractiveness of the living space (Jalaladdini and Oktay, 2012; Peng *et al.,* 2025). These alterations throughout the years have reshaped the idea of what constitutes QUS, in light of social dynamics (Chen *et al.*, 2016; El Sharnouby, 2019; Hall and Pfeiffer, 2013; Huang *et al.,* 2020; Mebirouk, 2019; Rolland, 2022). Acknowledging the active participation of urban users within the context of extensive urbanization serves as a crucial foundation for adopting a more inclusive and participatory framework in urban planning. From this perspective, the RN constitutes a fundamental element of mediation between planning and use, since it structures not only mobility but also the forms of appropriation of space by users. Over the past decades, the city of Batna has experienced significant changes on a major scale in the layout structure, redefining the urban landscape. The central area of the city evolved, often with a concentration of economic and cultural functions, while the urban periphery developed rapidly, leading to forms of urban sprawl and uncontrolled densification, also leading the city toward an uncertain and chaotic future (Mammri, 2011). Regarding the consequent urban visual attributes, they are influenced by the spatial disposition of urban sprawl indicators, noticeable fragmentation, and uneven urban landscapes (Osman *et al.*, 2016). Previous studies on the city of Batna have primarily addressed specific aspects of the urban fabric, such as morphological analyses or investigations at the neighborhood scale (Bendib and Naceur, 2018; Touati and Arrouf, 2024). In contrast, the present study adopts a more integrated perspective, examining the city as a whole. Within this comprehensive approach, particular attention is given to urban RN in particular, Pedestrian-friendly streets (Ayman AbdelAziz *et al.,* 2020). These networks constitute essential and widespread components of the cityscape, manifesting through diverse visual configurations, embodying the fundamental principles of planning (Biljecki and Chow, 2022; Chen *et al.,* 2024). The usage of these spaces by individuals shapes the trajectory of the UG.

Moreover, the issue of human interaction cannot be discussed without discussing pedestrian movement and experience (Wang *et al.,* 2023; Yassin, 2019). Furthermore, the dual role of the street, both unifying and segmenting (Sutcliffe and Cipkar, 2022), illustrates the capacity of Mediterranean cities to encourage social interactions and cultural exchanges through accessible public spaces, while revealing the vulnerability to social fragmentation and spatial segregation in the event of unbalanced urban development. For several decades, they have constituted a privileged tool in the production of cities. Extending from streets to neighborhoods, the QUS experienced by these urban dwellers at this level will determine the future of the PUS. The Sinjar city study (Omar *et al.,* 2022) makes a relevant contribution to sustainable urban planning in the southern Mediterranean context, mobilizing GIS capabilities to guide the city's UG (Shojaeivand, 2019). However, integrating the structure of the RN would have strengthened the approach, taking into account mobility dynamics and spatial connectivity. A hierarchical and thoughtful RN is indeed an essential lever in a long-term sustainable development vision, facilitating accessibility, limiting uncontrolled sprawl, and structuring centralities. In another perspective oriented mainly on technological performances in generic urban environments, the study of (Al-Neami *et al.,* 2025) addressed reflections on connectivity without explicit analysis of spatial organization or UC. The adopted approach in this paper makes it possible to understand the PUS in relation to the QUS and the road structure, providing a relevant spatial framework for the implementation of technological solutions such as the intelligent reflecting surfaces, by integrating the physical and morphological constraints of urban space into these reflections. In his article, (Adio *et al.,* 2024) discussed current trends in digital urban planning by referencing various international case studies, such as Singapore, Songdo, Toronto. This analysis facilitated an understanding of the factors contributing to the successful implementation of smart cities across diverse contexts. The article provided specific examples of how technology is integrated into urban planning, particularly at the RN scale. However, it did not offer a structural reading of urban space. The study of (Kaled and Maysoon, 2024) proposed a descriptive and analytical methodology aimed at exploring the visual and aesthetic determinants in the design of public spaces in Arab cities. Unlike this study, where space syntax is used to support a visual and symbolic reading, this paper's approach focuses on the topological structure of the urban RN, measuring accessibility, connectivity, depth, and integration of axes. It is based on rigorous mathematical modeling and provides quantifiable results. Several other studies have contributed to objectifying elements that were previously difficult to measure, such as atmosphere, movement, and perception of urban space, by extending beyond classic qualitative methodologies; in line with the studies conducted by Li (2024),Ma *et al. (*2021), and Zhang *et al.* (2018, 2019). Whereas these studies emphasized perceived formal QUS through street images. In comparison, this paper proposes a functional and dynamic approach by analyzing the structural performance of the spatial network, using space syntax measures. The two approaches are thus complementary; one sheds light on the visible and sensitive QUS, the other on the underlying structure and the potential for use. To plan for the future, the current production of cities must be rethought through analyzing the UR. The spatial layout of the Algerian cities reflects the human experiences, different indicators about the uniqueness, and it can also talk about the future of the city. Certainly, it can indicate whether the city is developing qualitatively or not (IPHS, 2016).

QUS through road network analysis

Cities have a rich tradition of aiming for perfection, but they fail to achieve this goal (Oliveira, 2022; Robertson and Neuhaus, 2024). When talking about the UG and the production of a QUS, this concept should be defined. (ISO) Standards define it as the capability to meet stated or implicit requirements (El Sharnouby, 2019)**.** QUS is a frequently used but it is vague term in the urban context. It is a fundamental component of political and societal issues (Castel *et al.,* 2019; Golshan *et al.,* 2021). This concept has progressed alongside inhabitant life, for this reason, researchers suggested examining the urban environment primarily in terms of people, the human senses and bodily movement, since individuals interact with the living environment and travel through it through senses and actions (Daniel and Vining, 1983; Gehl and Svarre, 2013; Kanelli *et al.*, 2021; Krzeptowska-Moszkowicz *et* *al.*, 2023; Monteiro and Pinho, 2022; Stahl, 2009). Due to the omnipresent subjectivity in this field (Adams, 2013; CAUE *et al.,* 2014; MERAD, 2017), it remains multidimensional and complex to assess, and requires several criteria for comprehensive assessment. Hence, this work is important as it aims to present these various theoretical notions for interpreting the topics of quality and spatial development, utilizing MQI. Gehl defined twelve criteria of quality, serving as guidelines for designing urban spaces, organized into three main categories: « Protection, Comfort, and Enjoyment » (Gehl and Svarre, 2013), which align the different measures of SST, because the perception of these criteria is influenced by the accessibility, visibility and centrality of spaces, and also, a fundamental aspect of the SST is to examine the visual perception of city users through these dimensions (accessibility, centrality and connectivity). Therefore, these categories are influenced by the parameters of space syntax. Within urban life, quality is experienced through the living conditions and the urban landscape, while in society, it is related to aesthetics and the symbolic charge of buildings (Ben mehni and Amokrane, 2020; CAUE *et al.*, 2014; islami *et al.*, 2017). A city's quality depends fundamentally on both physical and social elements. They share a dependency relationship, where one affects the other and vice versa (Attig, 2019). Although people may recognize urban quality when they see the output of a city, sense ambient environmental quality, prompting planning tools to prioritize visual impact (Ervin and Steinitz, 2003), because visibility plays a crucial factor in influencing movement and choice of trajectories of city users (Varoudis, 2014), and because visual satisfaction is the most common need among human beings (Mebirouk, 2002). This fact brings up the question of consultation with residents and the move from top-down to bottom-up approaches and strategies (Musango *et al.*, 2017). Enhancing the image of the city cannot be achieved without the continual contribution of the population (Ben mehni and Amokrane, 2020; Hunziker *et al.*, 2007; Weitkamp *et al*., 2007).

Understanding the UC through Space Syntax Analysis: Indicators provided by Depthmap

The study used Depthmap, which is a piece of software, as defined by Bill Hillier. In the late 1970s and early 1980s, Bill Hillier and his colleagues at the Bartlett School of Architecture at University College London introduced SST for studying, examining, and analyzing spatial relationships (Van Nes and Yamu, 2021).It is one of the tools which offers a concise definition of urban space, able to detect subtle local structures that seem almost non-existent (Hillier *et al*., 2012), able to capture the urban structure's skeleton (Porta *et al.*, 2006) and it provides the synergy between number of properties in a syntactical way within the space, without analyzing the place character (Van Nes, 2014). According to Bill Hillier's theory, the city consists of two sub-systems; the first is the physical one made up of buildings connected by the street pattern, and the second sub-system apprehends human movements, interactions, and activities (Attig, 2019; Xia, 2013). The two interact over time, this space-society paradigm has direct implications for PUS and QUS in the broader sense (Karimi, 2018). SSA presents MQI (Han, 2009). This topological mode abstracts urban space by discarding geometric properties such as location, length, and orientation; thereby simplifying patterns and relationships in urban space into a mathematical model (Attig, 2019; Ma *et al.*, 2019). It captures the diversity of urban forms, even if they are part of a complex relationship system, highlighting that the way UG is structured has a direct impact on the QUS (Al_Sayed *et al.,* 2014). Several space syntax techniques allow analyzing the visibility and perception of urban space at different scales, combining several complementary approaches (Askarizad *et al.,* 2024). One example is isovist analysis, which measures fields of vision from a given point, revealing what an individual can see from a fixed position. Visual Graph Analysis (VGA) extends this logic to an entire space by mapping the continuity of visual fields across a network. Axial Analysis traces all possible lines of visibility and movement in space, allowing for to assessment of the overall connectivity and accessibility of the urban fabric. Finally, agent-based modeling simulates the movements of pedestrians or users in this space, integrating visual and behavioral biases. Together, these methods offer a detailed reading of urban visibility, ranging from the local perspective to large-scale spatial organization (Van Nes and Yamu, 2021).In this research, axial analysis was favored because it allows a global reading of the spatial structure of the city. Applied to the entire city of Batna, this method highlights the structuring axes, the zones of centrality, as well as the

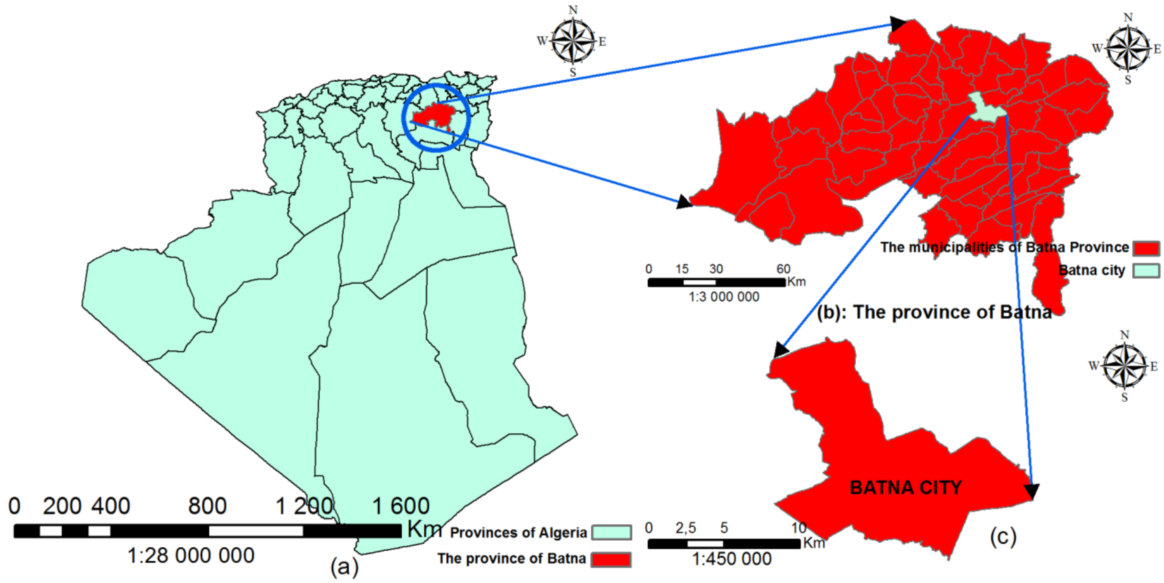

Fig. 1: Geographic location of the study area:(a) The location of the province of BATNA in Algeria, (b)The province of Batna, (c) Batna City. Source: The authors

enclosed spaces, thus providing a solid basis for the interpretation of urban users' perception, UG and the QUS of Batna city.

MATERIALS AND METHODS

Research area

The commune of Batna is the administrative center of the wilaya that has the same name, located in the North-East of Algeria Fig. 1. The urban area of Batna is characterized by a flat landscape, surrounded by mountains. These constraints deliberately limit the spread of urbanization. Therefore, topography has always played a key role in choosing city locations and shaping the UG for several purposes. Due to the geographical location and the rich historical background, Batna city attracts visitors from the surrounding communes and regions. It includes a large industrial zone, a major university center, and two major hospitals. This grants it a strategic location and a social hub for the development of several sectors. Additionally, it stands out as an economic center. This attractiveness led to a demographic growth, generated also an accelerated urbanization and the emergence of new residential areas (Hamla 1, 2, and 3), shown in Fig. 2. Simultaneously, the demand for urban mobility is also rapidly increasing, resulting an urban development pattern that deviated from the original European model to a city in transition toward modernity with limited availability of public spaces.

Data collection and approach methodology

To understand the urban complexity, the logic of the production, and the evolution of this city. The study proposed a methodology that combined «the empirical and theoretical orientations» (Swaffield, 1991). The theoretical sections have explained the concepts related to urban form, growth, inhabitants' perception, and the scale of intervention. Empirically, to collect quantitative and qualitative data, this methodological approach combined a spatial analysis based on the main parameters of space syntax and the questionnaire survey. Site observation, OpenStreetMap (OSM) files, the PDAU (Master Plan for Development and Urban Planning; an urban planning instrument known in Algeria by the French name 'Plan Directeur d'Aménagement et d'Urbanisme'), and, in particular, the POS (Land Use Plan) (Bendib and Naceur, 2018) of Batna city have been used to provide reliable and relevant spatial inputs Fig. 3. The DXF file was processed to eliminate irrelevant details, preserving only the crucial existing spatial features like roads, pedestrian paths. Once again, it

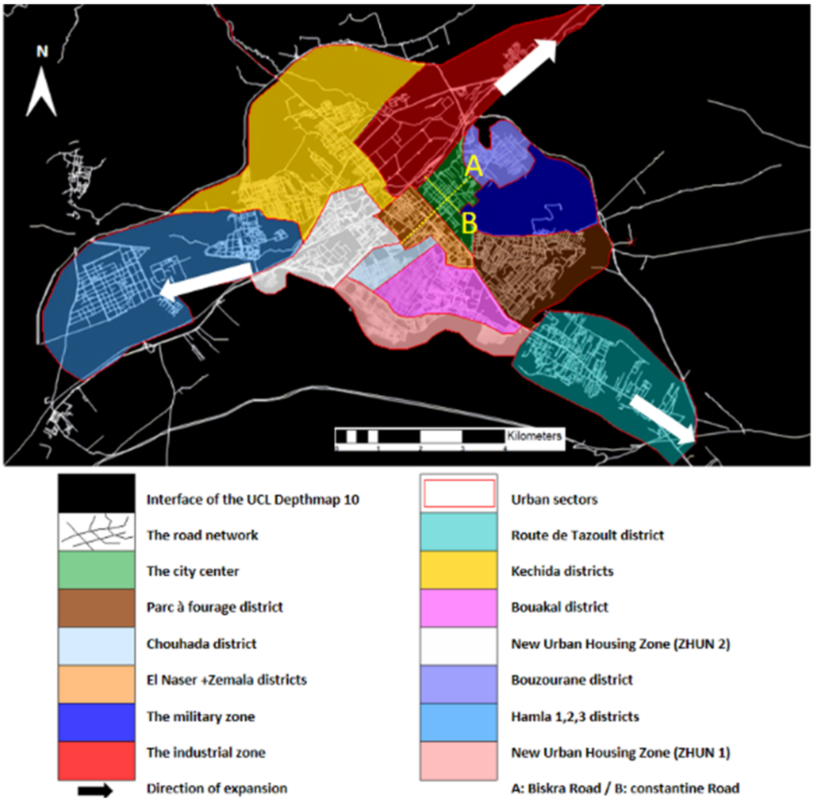

Fig. 2: Urban sectors of Batna City. Source: The authors

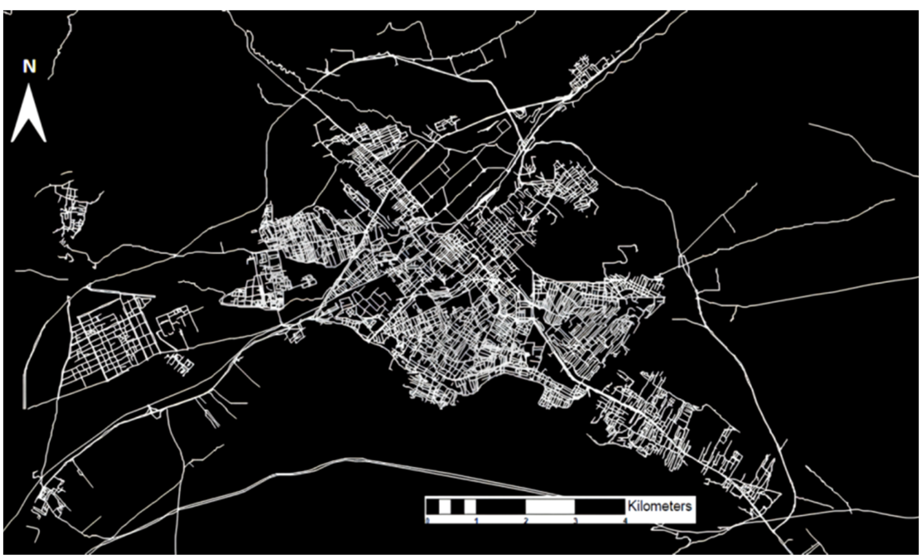

Fig. 3: Batna natural city, the unanalyzed spatial configuration (Dxf file opened on UCL Depthmap 10 -input). Source: The authors

was validated using satellite imagery (such as OSM) and field observations to ensure the spatial accuracy and completeness. The analysis extracted three key parameters (Connectivity, Integration, and Entropy); subsequently, the results were obtained by the analysis of several maps and the perfect knowledge of the study area. As residents and users of this city, this research relied on direct personal observations of the urban space under study. These observations, derived from daily experience and fieldwork, enriched the analysis and constituted a starting point for in-depth reflection on the spatial dynamics that characterize the city, enabling a more accurate and realistic understanding of the transformations taking place within the city. Research conducted in previous studies has uncovered a substantial variety of viewpoints and perspectives regarding the relationship between spatial configuration and social dynamics in urban spaces (Askarizad *et al.,* 2024). Several of these studies (Baiz and Atakara, 2023; Mojaveri *et al*., 2022; Zhang *et al*., 2023)have advocated for the implementation of a questionnaire, as external data to explore other dimensions of cities (such as societal processes, human behavior, socioeconomic and environmental factors).The researchers used the questionnaire and observations to interpret the topological results obtained by space syntax, to study the contexts of different cities in Iraq, Iran, and China. And this constituted a limitation to the use of the Space Syntax tool. Consequently, this study employed a social survey, through the questionnaire, which had been administered to 390 persons who had often lived or visited the city of Batna in 2024, including questions on the interaction with the urban space and the transition from a low to a high urban density. It was designed as a complementary tool to examine forms of public space appropriation and Road network usage, to evaluate the perception of urban dwellers about the living space, and to allow the comparison between different areas, specifically, through questions related to the frequency of users' movement. Three selected questions were included to complement SSA findings. To enhance analytical rigor, the study incorporated statistical methods, executed using SPSS software. It examined the relationships between key spatial parameters through Pearson and Spearman correlation tests, as well as ANOVA derived from a linear regression test. Two dualities were analyzed: connectivity/ integration and connectivity/ entropy. These statistical tests aimed to reveal the strength and nature of correlations, thus providing a thorough understanding of spatial dynamics and their perceptual implications.

The city of Batna shows irregular urban networks Fig. 3, where the districts have spontaneously evolved. Neighborhoods have undergone multiple additions, modifications, and redevelopments based on various elements: Social interactions, economic issues, cultural influences, and political contexts. The observation that the informal sector predominates despite large-scale urban expansion in the city of Batna raises fundamental questions about urban dynamics, development mechanisms, and the resulting city image. An accelerated decomposition of urban morphology has been observed, generating small centralities in the process of being constituted, creating complementary relationships that do not exclude the individuality of each urban entity, and without diluting the structural and functional importance of the city (Kumps *et al.*, 1984). The map (Fig. 3) shows a "**connected matrix"** (UN-Habitat, 2018) of streets that are public spaces, which form the basic framework and public space infrastructure of Batna city, upon which the built environment rests and urban dwellers execute various activities.

Analytical framework

a. The axial map

It is the primary representation to analyze urban forms as a spatial configuration, the key element of the modeling technique, and the main model produced by Space Syntax software (Hillier and Chiaradia, 2004). It consists of the representation of the urban road network (where the smallest possible number of straight lines are drawn that cross the accessible spaces of a city). It was initially formulated based on visibility and accessibility's perspective (Han, 2009); the original design of the axial map is based on the principle that urban spaces are arranged according to what people can observe and easily access. In other words, the more visible and easily accessible a space is, the more likely it is that that space will be frequented. This links visual perception to how the space is used and occupied. Therefore, these axial lines are interconnected and accessible (Hillier and Chiaradia, 2004), represent directions of unblocked movement and visibility (Han, 2009). It is then analyzed using topology and mathematical graph theory. Topological analysis examines how different axial lines are connected. The aim is to understand the structure of the network abstractly, without considering exact distances or angles, but focusing on the relationships of connection and continuity between spaces. Graph theory then makes it possible to determine several essential quantitative measures. Based on the above, the axial map of Batna city's urban grid was presented and analyzed configurationally.

b. Axial analysis

This research has calculated space syntax attributes numerically and graphically by utilizing UCL Depthmap 10 software, generating an axial map for the whole of Batna city. This map, Fig.3, is built based on an accurate, scaled, and updated electronic cadastral plan. The axial map is created for the study area, covering an area of 116.41 km².The input data (the map imported into UCL Depthmap) must be in DXF format Fig.3, which consists of lines representing the road network across the entire Batna city. Overlaying the resulting graphs with the input map (Fig.3) then allows for verification of the validity and accuracy of the generated graphs. The base map imported (the DXF file) was converted into an axial map using "Map" options in the software, generating a network of the longest and shortest straight lines covering all accessible and visible spaces of Batna City. After constructing the axial map, a graph analysis was performed, which calculates the three syntactic measures. To achieve significant results, the study configured the analysis to include multiple Radii, betweenness measurement, local and length-weighted measurements of the lines (This is a programming of the parameters that appear in the command window), which indicate an analysis focused on both local measurement and the importance of the lines in the global network. To run the graph analysis, local and global topological radius (R) (n, 2, 3, 5, 7) have been selcted: This means that the analysis has considered elements located from two "steps" away from each element analyzed up to a larger scale, to cover greater distances and capture a more global perspective of the urban network. Therefore, these radii are used to analyze local depth within walkable urban areas and to observe vehicle movements across the city of Batna. This technique takes into consideration the visual perception of pedestrians and people in vehicles. After running the graph analysis, the software generates a range of spatial metrics. Among these, the selected three parameters. Connectivity, Integration, and Entropy are spatial attributes that explain functional patterns of land utilization, the vehicle and pedestrian movement flows, aspects of social welfare, and discontent within Batna city. In conducting the SSA, the study reveals methodological limitations inherent in this research. The Axial Analysis is limited to modeling the road network in the form of straight lines representing the longest visual axes, which reduces the spatial complexity of the city by neglecting buildings, height variations, and the three-dimensional dimensions of the urban environment. This is the case of several studies which have used the same software, either for an architectural or urban analysis (Chen, 2022; Ravari *et al.*, 2024)

RESULTS AND DISCUSSION

Initially, Maps generated by space syntax confirm the idea that geometric order is difficult to identify because urban spaces have adapted to local needs, natural features (such as landforms), and particular historical developments, instead of conforming to the PDAU. In terms of the line length distributions, across all scales ranging from the neighborhood to the whole city, the axial map is made up of a minimal quantity of long lines alongside a vast multitude of shorter ones (Hillier, 2009). Significant differences have been found between sub-areas (The city center and the adjacent neighborhoods); the city core and the new contemporary sub-area (Hamla neighborhood + La route de Tazoult) (Refer to Fig.2 which contains the names of the city's districts), exhibited higher levels of spatial connectivity, Integration, Mean depth, Node count, choice and the lowest level of Entropy, as shown in the figures Figs. 4, 5, 6, 7, and 8. These space syntax attributes have been linked to several aspects of people's behavior and perception in space. An example, the most integrated spaces are places of intense urban life. Furthermore, it was observed that the regular road network has the strongest influence on pedestrian movement. Whereas, in the recently created and evolving sub-systems, the physical dimension has the strongest influence on pedestrian movement. Also, the level of road network integration influences the location of commercial activities; there is a significant correlation between topological

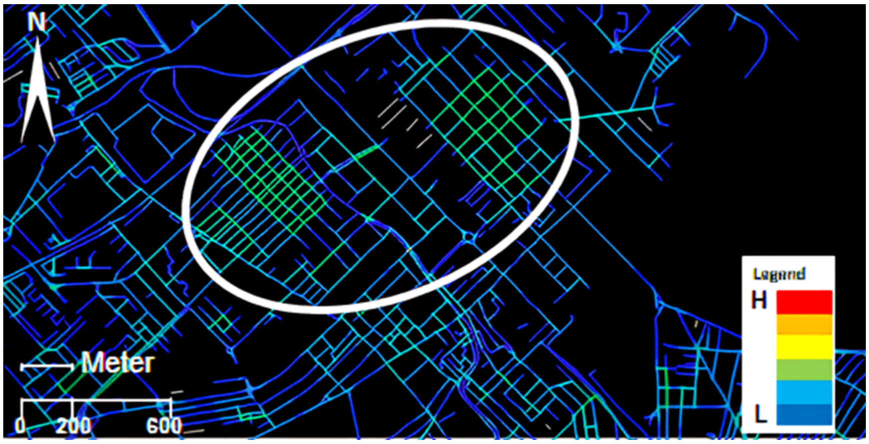

Fig. 4: Arbitrary section of the Axial map of Batna_ Choice. Source: The authors

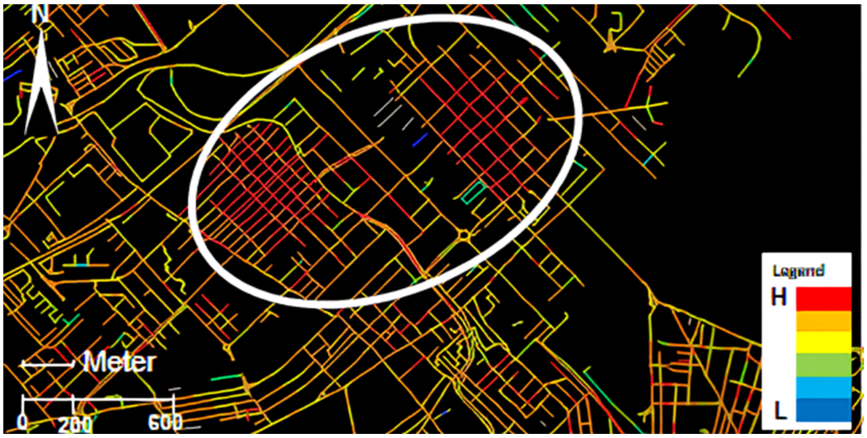

Fig. 5: Arbitrary section of the Axial map of Batna_ Mean depth-R2. Source: The authors

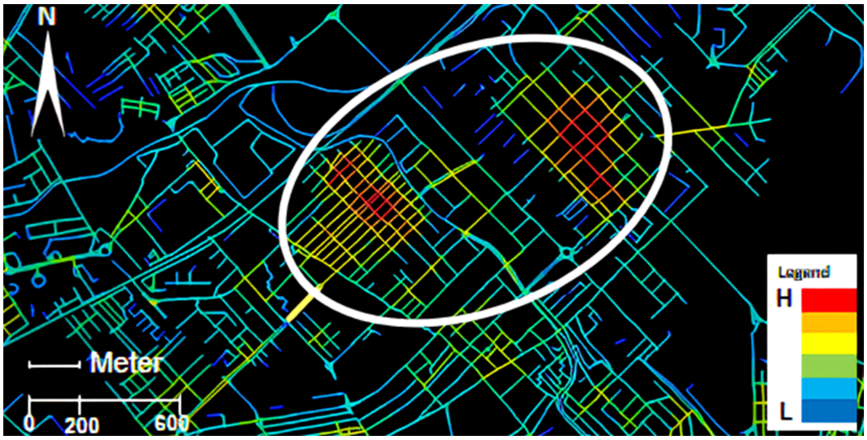

Fig. 6: Arbitrary section of the Axial map of Batna_ Node count-R2. Source: The authors

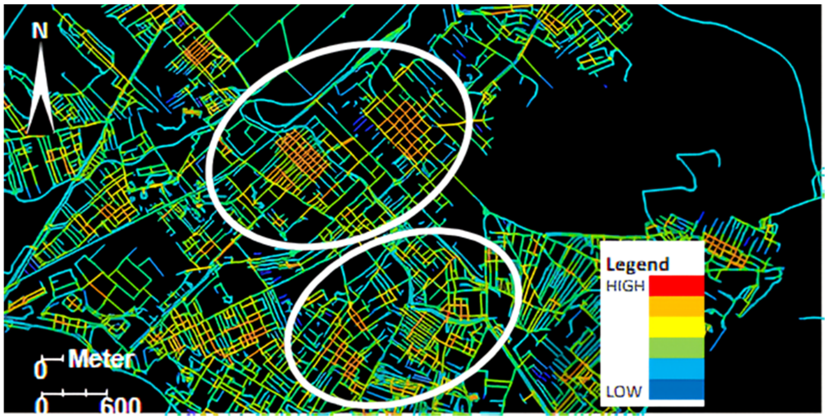

Fig. 7: Arbitrary sections of the Axial map of Batna_Connectivity-R2. Source: The authors

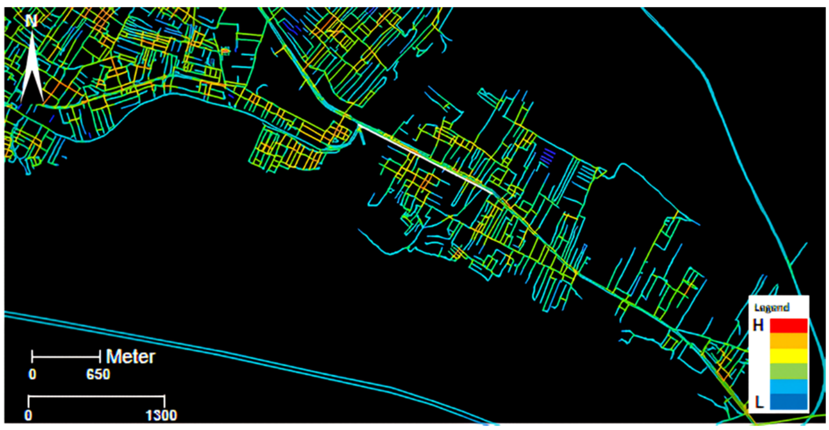

Fig. 8: Route de Tazoult district_ Connectivity. Source: The authors

metrics and human movement rates, and individual spaces can be ranked based on these metrics to predict urban users' movement (Jiang, 2009). The great veins of our cities (the road to Biskra and the road to Constantine) extended from the core to the sub-areas. These wide streets that constitute the main traffic network are highly integrated, with high connectivity value. These roads are central spaces in this spatial network, which were once designed to promote a balance between the different modes of transport. However, over time, these urban arteries have become spaces dominated by automobiles. The priority given to motor vehicles has often led to the neglect of pedestrians and other forms of transport. Sidewalks are reduced, pedestrian crossings are insufficient, and public spaces are transformed into simple passageways for cars. This preeminence of the automobile over Batnian's old urban infrastructures profoundly changes the character and functionality of these once lively and accessible spaces, especially at the side of the city entrances, although this does not change the characteristics of these streets in the heart of the city. Detectable by Batna city's users, these characteristics deliberately help to neutralize urbanization expansion and determine its direction and shape through concentration or dispersion. The social value of streets makes them significant within the whole city.

The higher levels are graphically expressed through the continuity of lines, meaning lines connected by almost straight lines. This occurs at different scales, and at each scale, the lines are locally longer. The absence of a regular and geometric pattern, with the presence of long lines, is actually due to the presence of fallow lands and undeveloped plots. Batna city undergoes linear urbanization along the two main roads that constitute the principal transport axes, and acquires a dual structure through the geometry and scaling of the street networks: a dominant organic layout in the foreground, characterized by shorter lines and less linear continuity, and another more regular network, especially in the city center.

Connectivity

It is a static local measurement and the most obvious parameter for topological analysis. The connectivity graph is composed of axial lines that represent continuous visual axes and circulation axes. This local metric considers all direct links each street has with nearby and adjacent streets. A street that connects to numerous side streets exhibits a high level of connectivity, while a street with limited connections shows a low level of connectivity. These values are illustrated using a range of colours. The linear spaces or the street structure are considered as a spatial configuration, which describes human behavior and activities. The colorful representation facilitates the analysis of local dynamics and allows urban planners to quickly identify the most interconnected roads within an axial map. This definition aligns with the findings of(Dong *et al.*, 2022) about urban vitality, which is seen as a key component of the QUS and PUS, and it is reflected through external spatial features, functional characteristics, accessibility, and location, activity, and diversity experienced within a given urban space, and visitors' perceptions. This view is supported by Mohamad and Said (2014), who have recognized that the quality of street connectivity is a key element in enhancing the QUS. Unlike global metrics such as integration that examine the whole urban network, connectivity is referred to as a local metric since it focuses solely on interactions within a limited area of a street. It is also static, because it does not change depending on other parts of the urban network. It focuses only on the number of immediate intersections of a street with its neighbors (Attig, 2019; Van Nes and Yamu, 2021). The degree of connectivity for each street in the city of Batna is visualised on a map in Fig.9.

The most connected segments (5-7) are rare; less than 10%. Segments with connectivity 2 constitute the majority, 53.8%, reflecting a fragmented urban structure (see Fig.10). As a static local metric, connectivity subtly indicates how close the urban blocks are along axial lines. The layout of the main roads influences the directions of the plots, which tend to bend in response to the influence of these highly connected axes. The high connectivity is registered in several districts, whether formal or informal, but especially in formal ones, such as the city centre (centre ville, stand). Here, streets have many connections to the side streets and have a high

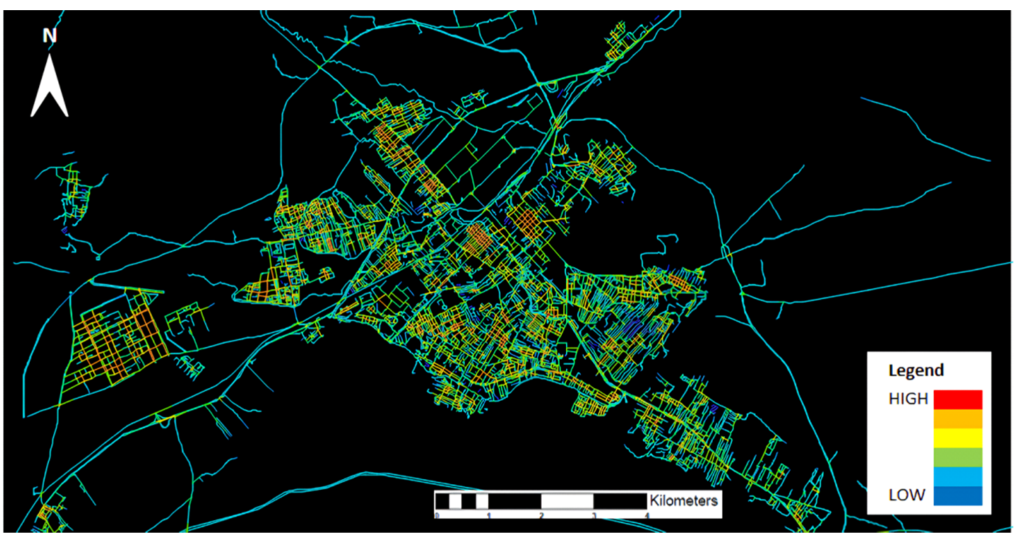

Fig. 9: Axial map_ Connectivity (Generated using UCL Depthmap 10 -Output). Source: The authors

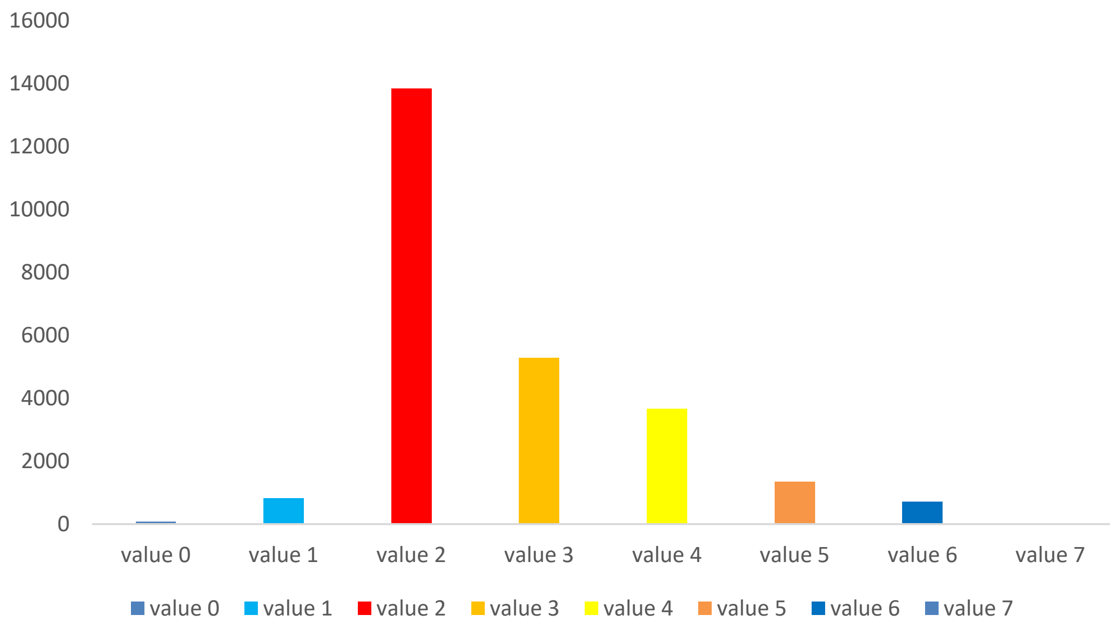

Fig. 10: Histogram explaining the measurement of connectivity in Batna city. Source: The authors

connectivity value, as visualized in the colour range (the red and yellow (on maps) are roads with the most connections to adjacent roads). Whereas, the value goes down heading to the extension areas of the city, to large arborescent systems (Route de Tazoult, Kéchida). Consequently, streets in these districts with a few connections have a low connectivity value, displaying also the range from public to private spaces in the Batna Road network. The extension areas of the city have sizably reduced allocations of land for public spaces. Some people may be excluded from informal spaces if they feel unsafe. The UC of Batna city and the street atmospheres, at this scale, highlight the growing importance given to interactions between humans and the urban setting, notably by the need for the strong return of pedestrian spaces, to enhance the QUS. This desired transformation towards more accessible agglomerations, especially at the entrances and exits of the city of Batna, underlines the importance of rethinking the PUS to better meet the expectations of users. The urban atmosphere is perceived as something tangible of the UR that materializes through space and users, shaping sensations, behaviors, and interactions, as reflected in the layout of roads and dwellings.

Integration

As defined by Hillier and Hanson (1984), within a configuration, Integration represents a normalized form of the typological distance between a particular space and all other spaces in the system (Hillier *et al.,* 2012). This measure assesses the potential of a segment as a destination for movement (Hillier, 2009). It symbolizes the level of depth and shallowness within an urban system, in which highly integrated regions have been shown to attract movement and activity *(*Alalouch *et al.,* 2019). Up to the specified radius and specified distance definition, configurational measures R2 to R3 are considered local measurements, while measurements R5 to R7 are global measurements. Integration is often associated with a linear increase in mobility and movement, and is also called accessibility in this context (Hillier and Chiaradia, 2004).

The graphical interface highlights Batna's urban spaces through 25753 axial lines analyzed, colored uniformly according to the level of local spatial integration, allowing a detailed assessment of spatial integration across the city. The red segments represent the areas that are the most easily accessible topologically, while the blue symbolizes the most distant lines, Figs. 11 and 12. Fig.11 shows the same analysis with the analytical radius limited to a depth of two. The calculation considers immediate and localized structure, calculating for each line of the axial map all the directly connected lines, as well as those subsequently connected to them. This measure is called the “local” spatial integration map R2 or “local” spatial accessibility, identifying the development of secondary urban centralities in Batna. Fig.12 shows the spatial integration map R7. The results obtained when using a local radius R2 in the integration calculations are the most significant. The majority of axial lines have a relatively moderate degree of integration, with an average value of 1.17. This indicates that, in general, the city has a certain level of accessibility, but no place is perfectly integrated. The maximum value is 2.63, shown on the map by the red dispersed areas. The dispersion of these areas on

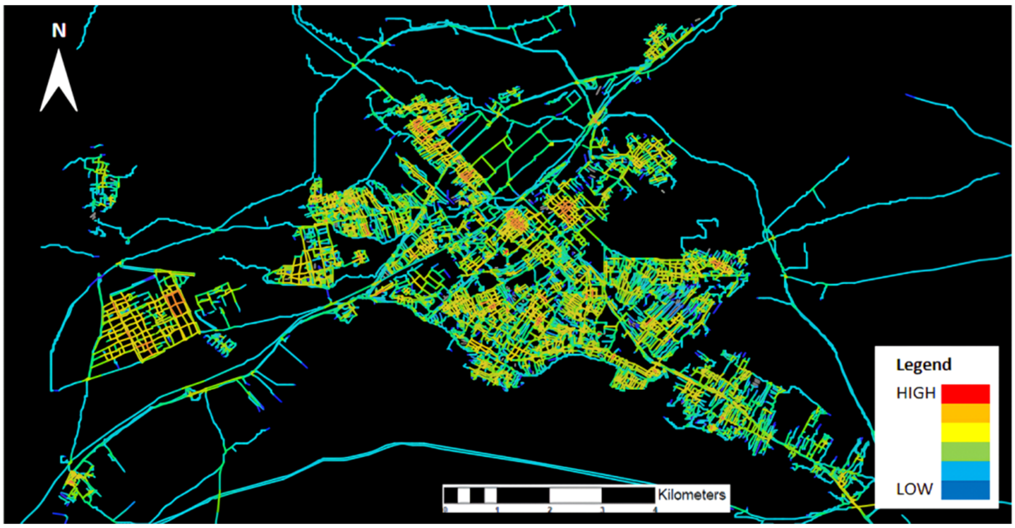

Fig. 11: Axial Analysis_ Integration Radius 2, (UCL Depthmap 10 Output)- Source: The authors

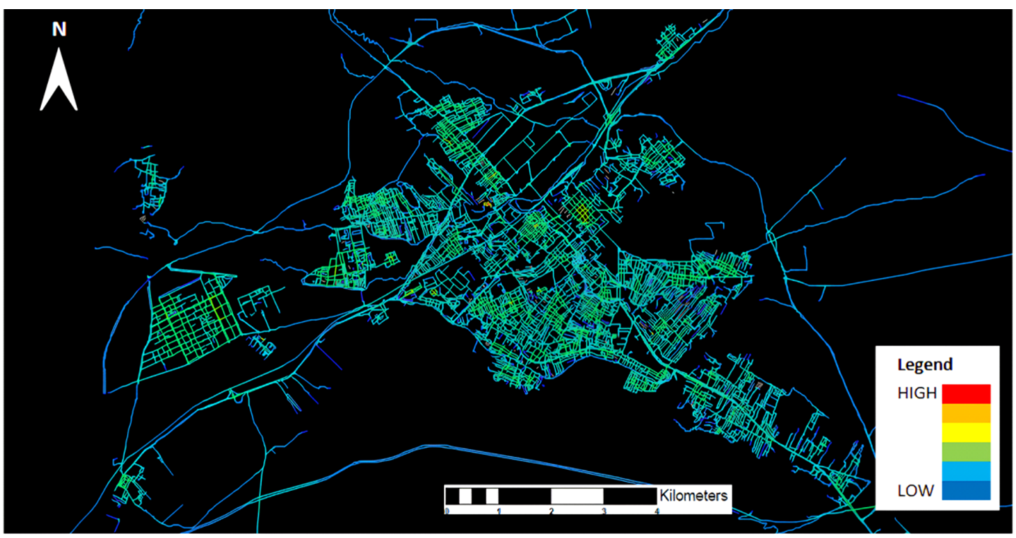

Fig. 12: Axial Analysis_ Integration Radius 7, (UCL Depthmap 10 Output)- Source: The authors

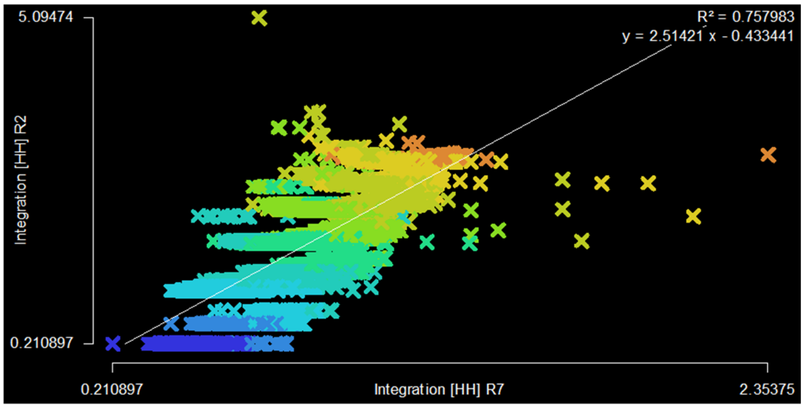

Fig. 13: A graph representing the correlation between Integration R7 (X axis) and Integration R2 (Y axis). Source: The authors

the map, rather than being concentrated in a single space, indicates a heterogeneous distribution of accessibility in the city. Some points of the city have an efficient spatial integration, but being far from each other indicates a polycentric urban structure. This result indicates that there are several centers of activity in the city (the city center, the industrial zone of Kechida, the new urban pole of Hamla), and each space is well connected to the immediate surroundings. Extremely isolated areas or streets in the urban network are presented by a minimum value of 0.21, indicating poorly integrated axial lines. The axial lines demonstrate considerable diversity in terms of accessibility and integration within Batna's urban network; this is evidenced by a standard deviation value of 0.39, reflecting significant variation in the spatial characteristics. To further explore the relationship between these two topological integration scales, a scatter plot was generated using UCL Depthmap software Fig.13, integration R7 (x-axis), representing a global scale, and integration R2 (y-axis), associated with a local scale. The resulting graph highlights a strong positive correlation, illustrated by a coefficient of determination R^2= 0.75. This means that 75% of the variance of the integration values R2 can be explained by the variance of the integration values R7, according to a linear relationship. In other words, the most integrated segments at large scale (R7) are also, to a large extent, at a smaller scale (R2), suggesting a structural synergy between the two levels of topological analysis.

These radii, R2 and R7, allowed for analyzing localized areas in an urban network to understand the immediate accessibility and the local centrality. This matches the findings of prior research by Liu *et al.,* (2021), who proposed examining the quality and vitality of the city through internal indicators, specifically "small-scale urban public street area". Also, they helped to identify proximity centers or sub-spaces within a larger network. This allowed revealing which neighborhoods have good connectivity with the immediate surroundings, taking into account the entire city network. Highly integrated areas are key points of centrality and connection, facilitating movement and concentrating traffic flows. The absence of uniformly red sections implies that there is potential for the city to improve connectivity and accessibility within various parts of the urban framework. The notable variations in integration values indicate considerable disparities in the connections between various districts and streets of Batna city, which may influence mobility and access to services throughout Batna. Results of the survey about the most frequented areas support (Hillier and Hanson, 1984) findings and the findings of the present study regarding spatial integration and connectivity as attributes defining the QUS. It confirms that the PUS, in particular public spaces, influences social behaviors and interactions. This dynamic contributes to the improvement of the QUS and is important for planning UG. The spaces identified as the most frequented in the questionnaire are also those that have a strong interconnection with other spaces. These spaces are accessible and welcoming to all city

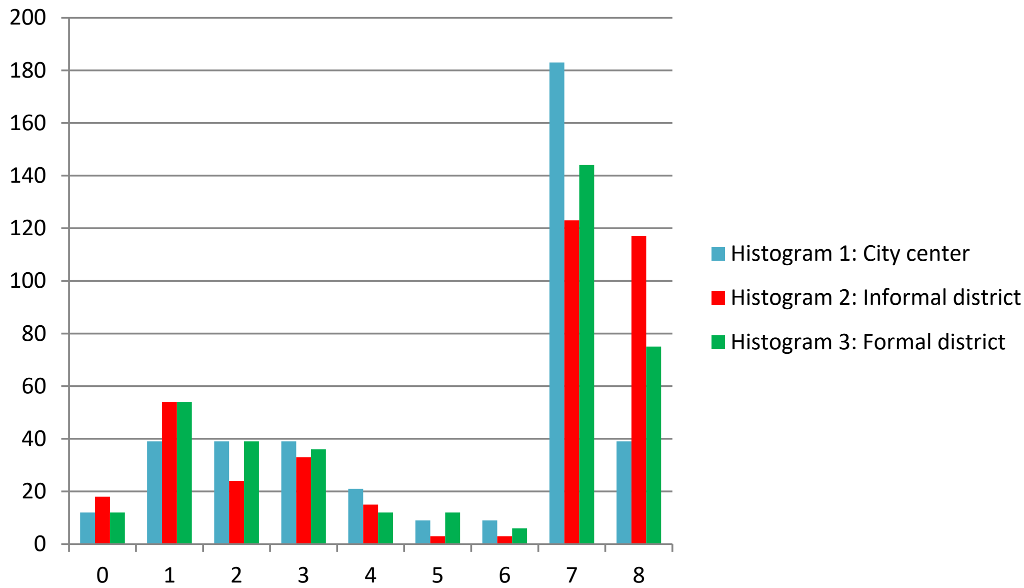

Fig. 14: A combination chart of histograms representing the frequency of visits to Batna city's center, to an informal neighborhood, and to a formal neighborhood. Source: The authors

users, also defining safe spaces. Spatial connectivity and integration play a critical role in attracting movement and activity in a given urban environment.

The new centralities are better represented by local measurements. While the spatial configuration R7 exhibits some homogeneity. This measurement provides more detailed information than the overall view. It gives an image of all the winding, often radial roads that every Batnian knows, which are often the best roads for most destinations. The city center districts, certain informal neighborhoods (Kéchida), and the new urban extension Hamla remain dominant. The city center, stand, chikhi, and Hamla districts are integrated at the level of a global measure and also present very powerful local integrators. Histogram (1) Fig.14: represents the frequency of visits to the city center of Batna city by 378/390 respondents. The horizontal x-axis shows the number of visits to the city center per week, ranging from 0 to 8. The number 0 represents the fact that the person the questioned has never visited the city center. The number 8 corresponds to answers indicating that the person lives in the same neighbourhood or works there every day. The number 7 represents a reference, taking into account the number of days of the week, and setting the number 7 times/week as the response, indicating the maximum attendance in the city center of Batna. The vertical y-axis represents the number of respondents corresponding to each frequency of visits. The same principle is used to analyze the other two histograms. The majority of respondents (46.9%) visit the city center daily (7 visits per week (7/7)), represented by the largest bar (about 183 respondents). 0 to 3 visits per week represents a rate of 30%. About 5% of respondents visit between 5 and 6 times a week, and the other respondents chose answer 8 (representing a rate of 10%). The analysis revealed that the city center is a central location for respondents, with almost half visiting it every day. The remaining visitors come mainly 1-3 times a week. The histogram (2), Fig.14, represents the frequency of visits to an informal neighborhood. The analysis is based on a sample of 390 respondents, and the study received 372 responses to this question. The histogram shows 3 types of attendance: 1- despite the informal nature of the neighborhood, 123 of respondents (31.5 %) frequent the informal settlement every day of the week. It remains a place frequented daily by a third of respondents, due to professional and residential activities. Response case (8) represents 30% of respondents, or 117 people, who selected this answer. These respondents

Table 1: Correlation Analysis Between Connectivity and global Integration in Batna city

		Connectivity	Integration [HH] R2
Connectivity	Pearson Correlation	1	0.375**
	Sig. (2-tailed)		0.000
	N	25753	25753
Integration [HH] R2	Pearson Correlation	0.375**	1
	Sig. (2-tailed)	0.000	
	N	25753	25753

**. Correlation is significant at the 0.01 level (2-tailed).

probably live or work in the informal neighborhood and go there daily. These high percentages show that the informal settlement is a living space for a significant part of the population, and it is not just a place of passage. Moderate frequency, which is represented by a percentage of 13.8% (1/7), 6.2% (2/7), 8.5% (3/7), and 3.8% (4/7): these percentages are relatively significant, often linked to semi-regular activities and do not require daily presence on this type of urban fabric. The low percentages represent frequencies of (5/7 and 6/7), indicating that this type of organic urban fabric is a place of passage. The histogram (3), Fig.14, represents the frequency of visits to a formal neighborhood. The analysis is based on a sample of 390 respondents, but the study received 378 responses to this question. 144 Respondents frequent a formal neighborhood daily (7/7), or 36.9%. This indicates that a large percentage of the questioned people are in contact with the formal neighborhood every day. This has resulted from the strong presence of important activities and residences in this urban area. 13.8% of respondents only visit the area once a week. This suggests that some urban users only need to go there for specific reasons. 10% and 9.2% representing respectively 2/7 and 3/7 frequency, indicate that the presence in this type of neighborhood varies according to individual needs. Two low percentages, 1.6% and 3.1% representing respectively (6/7, 4 and 5/7) frequencies. 19.2% of respondents chose index 8; in the case of the formal neighborhood, these respondents live or work in the formal districts of Batna city. These results reveal a difference in the use of formal neighborhoods. This daily or occasional visit depends on people's needs. The city center is the most regularly visited zone, with 46.9% of respondents visiting it every day of the week. In formal residential areas, 36.9% of surveyed people attend daily, indicating a considerable amount, yet it is still lower compared to the city center. Among respondents in informal neighborhoods, 31.5% report visiting daily, highlighting that these spaces are active living areas. These results confirm that Batna's urban core influences perceptions of the entire urban space.

Relational forces in spatial configuration: the case of connectivity and integration

In order to evaluate the strength and characteristics of the relationship between Connectivity and spatial Integration R2, both Pearson's correlation coefficient and Spearman's rank correlation coefficient were calculated (De Lotto *et al.,* 2024). Pearson's test assesses linear dependence based on the assumption of normality, whereas Spearman's test identifies monotonic relationships without the necessity of a normal distribution. The agreement of findings from both statistical methods reinforces the reliability of the observed correlation.

-The correlation analysis (Table 1) conducted in SPSS between Connectivity and Integration R2 aims to understand the extent to which local structure (immediate connectivity) influences and it is associated with global structure (street integration). It made it possible to quantify these spatial interactions. This test assesses the structural coherence of Batna's road network and the capacity of the urban fabric to produce spaces that are legible, accessible, and conducive to social and functional use. The Pearson correlation coefficient (r), measuring the strength and direction of the linear relationship between these two variables, is equivalent to 0.375, which means that there is a moderate positive correlation between the two indicators, the more a street segment is well connected locally, the more it tends to be accessible globally, however this relationship is not strong (it is moderate), which suggests that there are other factors that influence global integration. The obtained p-value (Sig. = 0.000) indicates a highly significant

Table 2:Spearman’s rho correlation analysis between connectivity and global integration in Batna city

			Connectivity	Integration [HH] R2
Spearman's rho	Connectivity	Correlation Coefficient	1.000	0.993**
		Sig. (2-tailed)	.	0.000
		N	25753	25753
	Integration [HH] R2	Correlation Coefficient	0.993**	1.000
		Sig. (2-tailed)	0.000	.
		N	25753	25753

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3: ANOVA table of linear regression between connectivity and integration R2

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	33949.335	1	33949.335	4221.261	0.000[b]
	Residual	207101.442	25751	8.042		
	Total	241050.777	25752			

a. Dependent Variable: Integration [HH] R2
b. Predictors : (Constant), Connectivity

correlation between the two variables. Being less than 0.05, it allows us to reject the null hypothesis and confirms that there is a real relationship, with less than 0.1% probability that it is due to chance. The analyzed sample includes 25753 street segments, which is a very large size. Such a large size guarantees the robustness and reliability of the results obtained, thus strengthening the statistical validity and ensuring better representativeness of the spatial phenomena studied.

The Spearman correlation coefficient (ρ) obtained is 0.993 (Table 2), indicating a strong and positive relationship between connectivity and integration R2 in the spatial network of Batna city. It also means that the two variables increase together. Concretely, the more a street segment is well connected locally, the more it tends to be well integrated into the entire road network. This strong correlation reveals a great coherence between the local and global logics of the spatial system in Batna. The two-tailed significance value (Sig. 2-tailed) obtained is 0.000, which corresponds to a p-value less than 0.001. This outcome confirms with high statistical confidence that the observed relationship reflects a genuine structural pattern rather than a random occurrence. This statistical robustness is further reinforced by the considerable size of the sample analyzed (N = 25753 street segments), which gives the test strong analytical power, ensures increased reliability of the results, and confers solid empirical legitimacy to the interpretation of the spatial dynamics observed in the city of Batna.

Predictive dynamics in UC: Linear regression test between Connectivity and Integration

This linear regression seeks to evaluate how spatial connectivity influences the level of integration R2 as measured by Depthmap.

The regression test produced a High F statistic (F=4221.261), calculated from data from UCL Depthmap software for Batna city, indicating a high level of variability explained by the model (Table 3). The associated Significance value (p-value=0.000), less than 0.001, indicates an extremely strong statistical significance. Therefore, these findings validate that the model demonstrates a robust linear correlation between the two variables. The explanatory variable (Connectivity) contributes substantially to the variation in the dependent variable, Integration R2. The ANOVA table from the regression test reveals that the sum of squares attributed to the regression is (33949.335), out of a total (241050.777). This allows us to calculate R^2 =0.140. The Coefficient of determination R^2 is relatively modest, and it indicates that 14% of the variance in Integration R2 is explained by Connectivity. This result is logical within the context of spatial analysis, where other factors typically influence the Integration and mobility within the streets. Furthermore, the model is based on a very large sample size (25753), which increases the reliability of the results.The coefficient table (Table 4) provides more insights into the nature of the link between the two variables. The Unstandardized Coefficient (B = 1.543) indicates that a one unit increase in connectivity leads to an increase of 1.543

Table 4: Coefficients table from linear regression test between connectivity and integration

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	(Constant)	-1.161	0.057		-20.200	0.000	-1.274	-1.049
	Connectivity	1.543	0.024	0.375	64.971	0.000	1.497	1.590

a. Dependent Variable: Integration [HH] R2

units in Integration R2. This effect is statistically robust, as evidenced by the low standard error (0.024), a high t-value (64.971), and a very high significance level (p-value= 0.000). Moreover, the standardized beta coefficient of (0.375) reflects a moderate but significant effect, confirming that connectivity significantly influences the spatial integration of the urban fabric. The 95% confidence interval for B [1.497 – 1.590], excluding the zero value, reinforces the precision and reliability of this estimate (Table 4). This result reinforces the idea that well-connected street segments are more likely to function as movement attractors within Batna's urban fabric. Moreover, these findings support the hypothesis that districts, including informal zones or those located in peripheral areas, that have successfully organized internal mobility tend to attract visitors and to meet urban users' expectations about the safety of those streets. Consequently, these urban entities are often perceived as high-quality urban spaces, where spatial configuration plays an important role in enhancing mobility, usability, and social performance. This also confirms the hypothesis that Batna city's center is the most attractive place within the urban fabric. The correlation also suggests that configuration potentially influences how urban users navigate and experience Batna city. Therefore, the relationship between spatial form and perception is measurable.

Entropy: "degree of spatial disorder and complexity of route choices"

This parameter simulated distributions according to visual constraints. Visual blockage plays a role in urban dynamics, which can encourage exploration of urban space or cause feelings of confusion and discomfort; excessive segmentation of the field of vision impairs the ability of city users to choose the trajectories. It measures the disorder and randomness applied to the way a city is developed and structured. The law of entropy states that the costs of human activity are irrevocable and non-negotiable. The entropic aspects in the extraction, processing, and use of raw materials required for industrial production cannot be eliminated; this law suggests that natural processes generally progress toward a condition of increased disorder (Barbier, 2021).

The colors present on the entropy map are governed by the same law used in SSA, meaning that red often represents the highest values, medium to high values are represented in yellow or orange, while blue represents low values. The axial map, generated using UCL Depthmap 10 software, calculating the entropy parameter R2 Fig.15, highlights the spatial complexity of the city of Batna and the urban extension of Hamla. The level of disorder is high; this is revealed by the predominance of the color red at about 90% on the map, indicating a very complex urban network, composed of many connections and variations in the layout of the streets. Therefore, the entropy is high. The neighborhoods have developed organically and randomly, with streets added or modified over time without following an orderly pattern. The graph shown in Fig.16 shows the relationship between entropy (X-axis) and total line length (Y-axis), and the linear correlation coefficient (represented by a regression line) shows the decreasing relationship between these two variables. The points on the left side of the graph are relatively scattered, indicating low entropy values, specifically ranging from 0.31 to approximately 0.4. In this area, the line lengths vary little. On the right, points with higher entropy values (up to about 1.05) are denser and more spread out, but the line lengths also vary considerably. This indicates that systems with higher entropy have greater diversity and spatial complexity. In this logic, Zachary and Dobson (2021) used entropy to explore how urban space in Sheffield (UK) grows and functions. Also, the study of (Tang *et al.,* 2024)

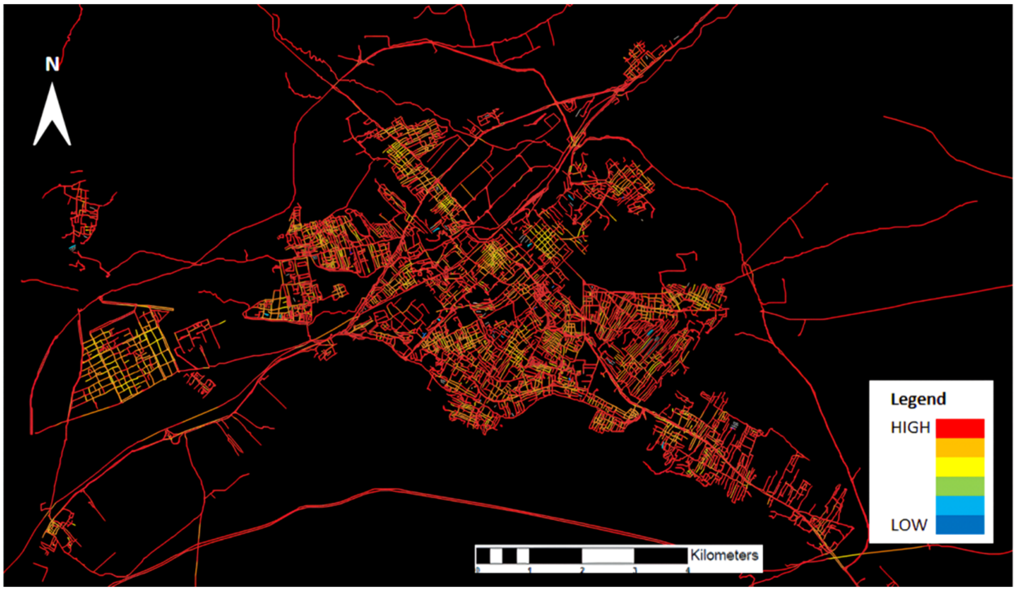

Fig. 15: Axial map_ Entropy R2 (Generated using UCL Depthmap 10- Output). Source: The authors

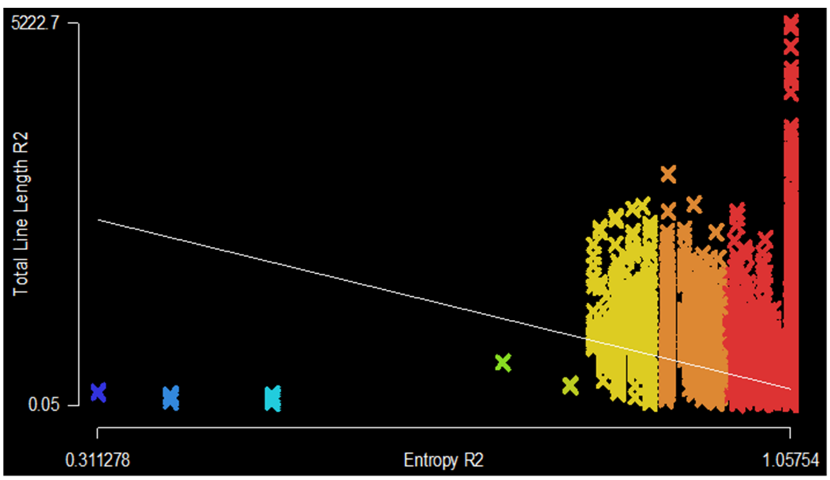

Fig. 16: A graph representing the relationship between entropy (X axis) and total line length (Y axis). Source: The authors

illustrated a localized use of entropy, where spaces with high entropic value, identified using space syntax, corresponded to the main centers of activity, thus reinforcing the interest of this measure for the intelligent management of flows in public spaces. The complexity recorded in Fig.15 may stem from dense connectivity of short segments of streets, mixed-use functions as highlighted by previous studies. Although the presence of structured districts, high values suggested intense activity and user flows across the whole city. This urban complexity goes beyond geometric characteristics. In this context, the road network of Batna city presents corridors of movement and social interaction nodes, influencing permanently the visual perception of users and may increase or reduce the attractiveness of the city. Accordingly, QUS depends on the results of this parameter.

Table 5: Correlation analysis between Connectivity and Entropy in Batna City

		Entropy R2	Connectivity
Pearson Correlation	Entropy R2	1.000	0.288
	Connectivity	0.288	1.000
Sig. (1-tailed)	Entropy R2	.	0.000
	Connectivity	0.000	.
N	Entropy R2	25753	25753
	Connectivity	25753	25753

Table 6: ANOVA table of linear regression between Connectivity and Entropy R2

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	447.138	1	447.138	2327.894	0.000[b]
	Residual	4946.206	25751	0.192		
	Total	5393.344	25752			

a. Dependent Variable: Entropy R2

b. Predictors: (Constant), Connectivity

Predictive dynamics in UC: Linear regression test between Connectivity and entropy

To assess the existence of a statistical link between street connectivity and spatial complexity, a linear regression test was performed on data from the UCL Depthmap software. Pearson correlation analysis reveals a low to moderate positive and significant relation between Connectivity and Entropy (r = 0.288, p-value = 0.000 <0.001)Table 5, suggesting that the more connected a space is, the more entropy tends to increase, resulting a visual complexity and a potentially more fragmented field of vision Fig.15, but the connection is not very strong 0.1< r < 0,3. The linear regression performed took connectivity as the independent variable and entropy as the dependent variable. The obtained model is statistically significant (F= 2327.894; p-value = 0.000 <0.001), from ANOVA Table 6. The Mean Square of the Error (MSE) =0.192, compared to the total variance of entropy 5393.344, meaning that the model only explains about 8.3% of the variance, explaining only a limited proportion of the variations. The MSE, therefore, confirms that connectivity alone is not sufficient to account for the entropic complexity of urban forms. Thus, Entropy is affected by other factors, such as economic and population factors (Papadimitriou, 2022). High connectivity is aimed at improving accessibility, flow of movement, and mobility. However, the positive correlation with entropy shows that a highly connected space can also be more visually complex, and therefore less readable for the users. This attribute is not a guarantee of QUS. In a context of a fast UG, these effects are accentuated, underscoring the need for a balance between spatial intelligibility and accessibility to maintain sustainable QUS.

Recommendations

Finally, as only three space syntax parameters were analyzed, it is recommended that future research should study other metrics, such as choice, control, and controllability, to enrich spatial analysis. Particular attention should be given to vernacular and local urban planning, refocusing on pedestrian movement, the connectivity of public spaces, and the enhancement of city entrances, which reflect the UR of the lived urban atmosphere often created by the inhabitants. These dynamics foster a strong sense of local identity and contribute to the city's vitality. Prioritizing Human experience in urban planning is a fundamental strategy to strengthen the QUS, improving spatial interactions, and increasing urban attractiveness in a context of competition between Algerian cities. Results of this study allowed proposing a structured approach to rethink the PUS, based on MQI from SSA and SST. This process brings with it an in-depth local spatial diagnosis, aiming to identify levels of connectivity, integration, and spatial complexity. It proceeds by focusing on districts with weak spatial performance, including marginalized or unplanned neighborhoods subject to social fragmentation. Areas with strong integration should be designated as strategic hubs that can drive UG. In addition, access streets to major urban attractors must be improved. The reconfiguration of

RN then becomes a priority, involving establishing open, readable, and accessible spaces in central and intermediate areas. Finally, the integration of spatial indicators from SST into urban planning studies and policies is important to frame coherently the UG, to improve the QUS, and guarantee sustainable PUS.

CONCLUSION

By mobilizing spatial configuration indicators such as Connectivity, Integration, and Entropy from axial line analysis of SSA. This analysis aimed to clarify how the configuration of the street system influences circulation patterns, social dynamics, and the trajectories of the evolution of the city. The UC analysis of Batna city revealed the direct impact of UC on QUS, PUS, and users' perception, validating the idea that the urban experience is shaped by the topological organization of space. By using data from UCL Depthmap and processing it via linear regression in SPSS, it was demonstrated that the "connectivity" variable exerts a significant effect on the level of integration ($F=4221.261$, $R^2 = 0.140$), and it also exerts a significant effect on urban complexity or entropy. These results confirmed the hypothesis that visual perception and urban interaction can be measured and explained objectively by UC. However, predictability rates 14% and 8.3% derived from linear regression tests indicated that other factors contribute to enhancing users' perception, PUS, and the QUS. The study highlighted that the best-integrated residential neighborhoods, whether located in central or peripheral areas, Figs. 11 and 12, display greater fluidity for both pedestrian and car traffic, despite the complexity of both the urban structure and the route's choice. In this perspective, these parameters can be used to anticipate potential changes in urban morphology by identifying areas where low connectivity and high entropy, Figs. 9 and 15 could hinder the development of quality urbanity. On the local scale, this study agrees on the fact that the city's RN constitutes an essential element for achieving spatial quality. A good layout of public spaces thus modifies the behavior of the people who frequent them and encourages greater participation in activities. The main contribution of this study lies in the comprehensive and integrated approach: neighborhoods were not analyzed in isolation, but each spatial entity was interpreted as an interconnected fragment of a larger urban whole. This approach enabled a holistic reading of urban processes, transcending administrative boundaries and the oppositions between Batna's center and periphery. Batna must be transformed from a locality that people pass through for basic needs into a multitude of interactive spaces, where various activities can flourish in each area.

AUTHOR CONTRIBUTIONS

The first author conceived the presented study, performed the literature review and developed it, performed the analysis, interpreted the data, and prepared the manuscript text. The second and third authors verified the analytical methods, helped in the literature review, and supervised the findings of this work. All authors discussed the results and contributed to the final manuscript.

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CONFLICT OF INTEREST

The authors declare no potential conflict of interest regarding the publication of this work. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy, have been completely witnessed by the authors.

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ABBREVIATIONS (NOMENCLATURE)

ANOVA	Analysis Of Variance
B	Unstandardized Coefficient; from the Coefficients Table from the linear regression test
Beta (Standardized Coefficient)	Coefficient from the coefficients Table from the linear regression test indicates the strength and direction of the relationship between variables
F (F statistic)	Fisher's statistic is used in ANOVA
ISO	International Organization for Standardization
MQI	Measurable and Quantifiable Indicators
MSE	The Mean Squared Error
ρ	Spearman's rank correlation coefficient
PDAU **(in French)**	Plan Directeur d'Aménagement et d'Urbanisme (Master Plan for Development and Urban Planning)
POS **(in French)**	Plan d'Occupation des Sols (Land Use Plan)
PUS	Production of Urban Spaces
QUS	Quality of the Urban Space
r	Pearson Correlation coefficient
R (n, 2, 3, 5, 7)	local and global topological radius
R^2	Coefficient of determination (proportion of explained variance)
RN	The Road Network
Sig. (2-tailed)	Significance level (p-value) for a two-tailed statistical test
SPSS	Statistical Package of the Social Sciences
SSA	Space Syntax Analysis
SST	Space Syntax Theory
Std. error	Standard error, from the Coefficients Table from the linear regression test
t	from the Coefficients Table from the linear regression test; the test statistic is calculated as B divided by Std. error
UC	Urban Configuration
UCL	University College London
UG	Urban Growth
UR	Urban Reality
X axis	Horizontal axis
Y axis	Vertical axis

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