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The Role of Synergy Index on the People Interaction Inside the City of Djelfa by Using Space Syntax Technique

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K E Y W O R D S

Local Spatial, Global Spatial, Space Syntax, Djelfa, Integration (Rn, R3, R5), Synergy.

A B S T R A C T

Algerian cities in general, and the city of Djelfa in particular, are witnessing significant demographic growth and rapid spatial expansion, which has resulted in the emergence of new neighborhoods somewhat far from the historical city center, which is saturated with commercial and service activities. The research aims to identify whether visitors can meet residents outside the old city center, the level of interaction between them, and the most appealing areas for this interaction, which could develop into secondary commercial zones that alleviate pressure on the city center. We utilized the spatial syntax technique to measure these interactions by modeling the maps of the city of Djelfa into axial maps and measuring indicators such as global integration (Rn), local integration (R3 and R5), and synergy. The research confirmed the effectiveness of the adopted methodology, revealing a weak synergy index, i.e., weak interaction between visitors and locals at the city level. While the historic city center has maintained its centrality, it has expanded beyond its borders, and the Boutrifis district has emerged as a secondary local commercial hub. Some neighborhoods appear isolated according to the global integration index, but they witness significant internal movement based on local integration, such as the Al-Fusha, Al-Shawa, Bin Saeed, and Al-Zaria neighborhoods.

الكلمات المفتاحية

البنية الداخلية، البنية الشاملة، بناء الجملة الفراغية، الجلفة، التكامل (Rn, R3, R5)، التآزر.

الملخص

تشهد المدن الجزائرية عمومًا، ومدينة الجلفة خصوصًا، نموًا سكانياً ملحوظاً وتوسعاً مجالياً متسارعاً، مما أدى إلى ظهور أحياء جديدة بعيدة نسبياً عن مركز المدينة التاريخي المكتظ بالأنشطة التجارية والخدمية. يهدف البحث إلى تحديد مدى إمكانية لقاء الزوار بالسكان المحليين خارج مركز المدينة القديمة، ومستوى التفاعل بينهم، والمناطق الأكثر جاذبية لهذا التفاعل، والتي يمكن أن تتطور إلى مناطق تجارية ثانوية تخفف الضغط على مركز المدينة. وقد تم استخدام تقنية بناء الجملة الفراغية في قياس هذه التفاعلات من خلال نمذجة خرائط مدينة الجلفة على شكل خرائط محورية، وقياس بعض المؤشرات مثل التكامل العالمي (Rn)، والتكامل المحلي (R3 وR5)، والتآزر. أكد البحث فعالية المنهجية المتبعة، كاشفاً عن ضعف مؤشر التآزر، أي ضعف التفاعل بين الزوار والسكان على مستوى المدينة ككل، في حين حافظ مركز المدينة التاريخي على مركزيته، فقد توسع خارج حدوده وبرز حي بوتريفيس كمركز تجاري محلي ثانوي. تبدو بعض الأحياء معزولة وفقاً لمؤشر التكامل العالمي، إلا أنها تشهد حركة داخلية ملحوظة قائمة على التكامل المحلي، مثل أحياء الفصحى والشعوا وبن سعيد والزريعة.

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1. Introduction

The city is two things: "a large collection of buildings linked by space, and a complex system of human activity linked by interaction" (Hillier and Vaughan, 2007, p. 205). Cities are successful when they maximize contact and interaction, facilitating the generation of ideas and the dissemination of knowledge while providing an environment that conserves energy and resources and minimizes environmental impact (Rubiera-Morollón and Garrido-Yserte, 2020). Understanding the relationship between urban streets and land use distribution is especially important in historic urban cores where culture and modern urban demands coexist. (Alobaydi et al., 2025).

Recent academic research has increasingly focused on the synergy index as a key metric within space syntax analyses to understand the complex interactions between local and global spatial structures in urban environments. Hillier (1996) laid the theoretical groundwork by demonstrating how spatial configurations influence social behavior and movement patterns, highlighting integration as a core concept. Building on this, Abuhayya et al. (2024) examined how the design features of urban green spaces contribute to attracting visitors. Penn et al. (2004) and Turner (2007) showed that axes with high global and local integration values tend to exhibit strong synergistic effects, attracting both pedestrian flows and economic activities. Gil et al. (2014) advanced this field by integrating space syntax with GIS tools, enabling more precise measurement of spatial synergy and its implications for urban planning. Froy (2021) empirically confirmed that spatial synergy fosters agglomeration economies by enhancing connectivity among urban functions, supply chains, and labor markets. Shen (2017) further elaborated on the socio-economic impacts of spatio-functional synergy, demonstrating its role in shaping urban functional regions and housing market dynamics. Hillier and Hanson (1984) originally emphasized the social logic of space, which underpins the synergy concept by linking spatial form to social interaction patterns. Dalton et al. (2012) and subsequent studies have highlighted that while some urban areas may appear isolated on a global scale, local integration and synergy indices reveal vibrant internal dynamics crucial for sustainable urban development. Moreover, recent ecological and urban studies (e.g., Zhang et al., 2023; Chen et al., 2023) have expanded the synergy concept to include environmental and economic growth factors, showing that synergy indices can capture multi-dimensional urban resilience and coordinated development. Collectively, these studies confirm that the synergy index, as measured through space syntax indicators, is a robust theoretical and empirical tool for analyzing the interplay between spatial structure and urban socio-economic processes.

In this research, we aim to study the extent of the relationship between the internal spatial structure and the global spatial system of the city of Djelfa, referred to in the methodology of spatial syntax as the synergy index. Through this, we aim to understand the possibility of visitors meeting with local residents within the city, the degree of interaction between them, and the axes that most attract this interaction by working on the axial map. According to Hillier and Hanson (1984, p. 91), the axial map "is constructed by taking an accurate map and drawing a set of intersecting lines through all the spaces of the urban grid so that the grid is covered and all rings of circulation are completed", a methodological approach further refined by Turner et al. (2005) and Vaughan and Geddes (2009).

The Synergy index in Space Syntax is a metric used to analyze the relationship between local integration and global integration within urban networks or built environment systems. It is scientifically defined as the correlation coefficient between the local integration values and the global integration values for a set of spaces or axes under study (Abou El Seoud, 2014; Fang, 2021; Lyu et al., 2023).

This index aims to:

- Evaluate the strength of the linkage between local parts and the overall system: It measures the extent to which spaces of local importance (or locally pivotal spaces) represent similar importance at the system-wide level (Abou El Seoud, 2014).
- Support understanding of the relationship between spatial components (such as corridors or streets) and the overall structure of the city or neighborhood, thereby helping to identify areas that form the dynamic or pivotal "heart" of the place (Fang, 2021).
- Clarify the functional role of spaces: A high Synergy value indicates a strong alignment between how space is connected locally and globally, which enhances the clarity and legibility of the system for its users (Lyu et al., 2023).

- Assist in interpreting economic and social dynamics within study areas, such as the correlation between a local area's economy and the broader urban economy (Abou El Seoud, 2014).

The measurement typically involves plotting a linear relationship between local integration (usually based on a short radius such as R3) and global integration (usually based on a larger radius, e.g., Rn or the whole system), then calculating the correlation coefficient. The closer the index value is to 1, the stronger the integration; lower values indicate a growing disconnection between local and global levels (Fang, 2021). Urban synergy is a complex and comprehensive system that integrates various subsystems to achieve broader objectives related to the overall development characteristics of the city (Ahmed and Rasheed, 2020).

The space syntax methodology views the global integration index (Rn) as an indicator that makes it evident how integrated a particular axis is with respect to the city's axes overall (i.e., moving to it from any axis in the city has the fewest depths or deviations) or how isolated and challenging it is to reach from every other axis in the city (i.e., moving to it from any axis in the city has the greatest number of depths or deviations). The axes of spaces, whether integrated or isolated, are displayed in relation to the city as a whole by the integration index (Rn), a global measure. As a result, areas with high levels of movement are the integrated spaces for this index. These spaces are commercial locations with a comprehensive impact, meaning that their visitors come from many city neighborhoods. While the index (R3) in the space syntax is local because it does not exceed three depths or deviations when calculated, it targets axes with a local influence, i.e., residents of a single neighborhood. The most prominent axes in this index are those that allow for local movement among neighborhood people. We find few commercial activities, and we do not find hotels or major shopping malls because they are not useful to their owners.

In the space syntax methodology, the relationship between the global integration variable (Rn) and the local integration variable (R3) identifies axes with high current or future mobility and commercial activity. The stronger the link, i.e., the synergy, the more likely visitors are to meet locals, resulting in the formation of other commercial hubs that relieve pressure on the old center. This is what we worked on in the study, and we corroborated our findings by examining the (R5) indicator, which shows secondary urban centers.

Algerian cities in general, and the city of Djelfa in particular, are witnessing significant demographic growth and rapid spatial expansion, which has resulted in the emergence of new neighborhoods somewhat far from the historical city center, which is saturated with commercial and service activities. In addition to the functional and historical dimensions of the city center of Djelfa, it is a center of human interaction between users of the urban area (visitors and residents). Our goal was to answer the following question: Can the synergy index play a role in measuring the degree of human interaction within the city of Djelfa using the space syntax technique?

To answer the question, we relied on two hypotheses: The old city center of Djelfa still represents the area of highest interaction between city users (visitors and residents). The spaces where visitors meet and interact with residents can be predicted by measuring the synergy index; these areas could be considered as secondary commercial zones in the future.

2. Materials and Methods

2.1. Space Syntax

Space syntax's popularity has grown rapidly in recent years as an approach that connects the fields of urban spatial analysis and urban design in the arena of transport, land use, and people's behavior. An ever-growing number of international scholars and practitioners are applying space syntax at various scales, from buildings and neighborhoods to metropolitan areas and entire regions (Van Nes & Yamu, 2021). As a method for describing and analyzing the relationships between spaces in urban areas and buildings, space syntax understands spaces as voids (streets, squares, rooms, fields, etc.) between walls, fences, and other obstructions that restrain movement or the visual field (Klarqvist, 2015). Originally pioneered in the 1970s by Hillier and his colleagues at University College London, based on topological ideas (Van Nes & Yamu, 2021a), the concept was formally introduced by Hillier and Hanson (1984). This enabled the analysis of built environments through spatial descriptors (Van Nes & Yamu, 2021b). They contend that the relationship between form and function travels through spaces in both structures and cities, asserting their

interdependence. As Hillier (1996, p. 42) observed, “At the most elementary level, people move in lines, and tend to approximate lines in more complex routes. Then, if an individual stops to talk to a group of people, the group will collectively define a space in which all the people that the first people can see can see each other.”

Space syntax models spatial configurations using connectivity graphs, identifying patterns to study urban structures and human behaviors (Jiang et al., 2000). It conceptualizes space not through Euclidean geometry but through topological relationships represented by configurations (Filomena et al., 2019; Thaler, 2020). As a quantitative language, it explores interrelationships between spatial configuration and human society by analyzing structural characteristics of habitats (Bafna, 2003; Karimi, 2017). Incorporating concepts of spatial scaling and partitioning, it provides a novel language for describing urban patterns (Dawes & Ostwald, 2020) and quantifies urban form logic through spatial organization analysis, forming unique analytical methods (Bafna, 2003). These models are utilized to assess spatial planning schemes, enabling researchers to refine proposals based on evaluation outcomes (Derya Arslan and Ergener, 2022; Mahmoud & Omar, 2015).

Therefore, this research utilizes space syntax analysis to examine the interaction areas between local residents and visitors, as well as their spatial characteristics, by measuring global integration (Rn), local integration (R3), and ultimately the synergy index.

2.2. Study Area

The Djelfa province, established by the 1974 administrative division, is situated in the central northern part of Algeria, south of Algiers, between latitudes 33°35' and 36°12' north and longitudes 2° and 5° east. It lies in the heart of the steppe highlands, covering a vast area of 32,362 km², which is about 1.36% of Algeria’s total area. The province extends over 300 km from north to south and up to 150 km in width from east to west. It shares borders with nine other provinces: Medea and Tissemsilt to the north; M’sila and Biskra to the east; Ouargla and El-Oued to the southeast; Laghouat and Ghardaia to the southwest; and Tiaret to the west. Djelfa city itself features multiple important roads developed through various urban growth phases, as shown in Figure (1), including bypass roads to reduce city center congestion and streets connecting different neighborhoods within the city.

2.3. Digital Modeling of Djelfa City

After completing the urban scheme for Djelfa city with the XDF extension, we converted it into an axial map. Let us perform an axial analysis with DepthmapX of the latest version, 0.8.0, examining the most important metrics in this type of analysis (global and local indexes) to accurately identify the transformations that have affected the spatial structure and their effects. DepthmapX is a multi-platform software developed to perform multiple spatial network analyses in order to explore the complexity of social behavior in a given built environment. After modeling and conducting complex calculations, the DepthmapX program uses the color spectrum of the spatial system axes to measure the index's strength or weakness. The colors used for this purpose are red, orange, yellow, green, light blue, and dark blue, representing varying levels of strength or weakness. The colors symbolize very strong, relatively strong, above average, medium, weak, and very weak relationships, respectively.

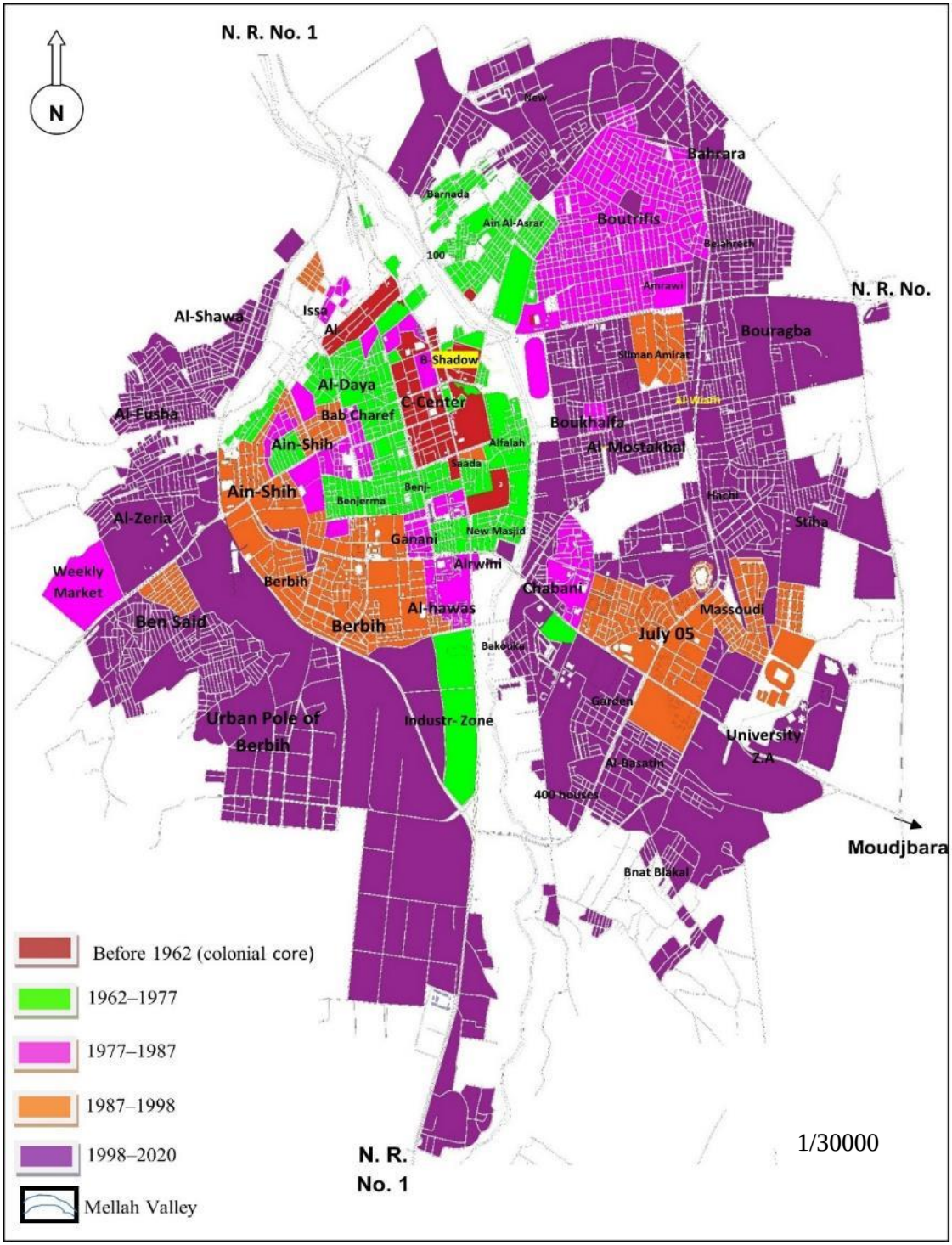

Figure 1. Urban development of the city of Djelfa. Source: (Google Earth Map base map, modified by the Authors).

2.4. Research Methodology

The research adopted a mixed-method approach focused on spatial and behavioral analysis to investigate interaction dynamics between visitors and residents in Djelfa. The process began with defining the main research problem and formulating two hypotheses: one addressing the role of synergy in measuring human interaction, and the other the continued centrality of the historic city center. An extensive literature review was conducted to contextualize the study within broader urban planning discourses and methods.

Subsequently, a digital model of Djelfa's urban layout was prepared using the XDF format; this model was converted into an axial map for advanced spatial analysis. The axial map was processed using DepthmapX version 0.8.0 to measure key space syntax indicators, including global integration (Rn), local

integration (R3, R5), and synergy. The software's color spectrum (from red to dark blue) enabled nuanced readings of integration strength and interaction patterns at various scales.

Findings were interpreted by comparing spatial indices across the historic center, emerging secondary hubs, and isolated neighborhoods, highlighting behavioral implications and spatial transformations. The final step involved deriving practical urban planning recommendations—such as reinforcing the city center, developing Boutrifis as a local hub, and enhancing movement corridors to improve integration—while preparing the research report for academic publication.

3. Results And Discussions

3.1. Global Integration Index (Rn)

Axial global integration is defined as the integration values of axial lines at the infinite radius, which can be used to represent a picture of the integration pattern at the largest scale (Hillier, 1996).

The average global integration index (Rn) for the city of Djelfa in 2020 was low (0.74). This suggests that the city lacks integration and is dominated by depth. A user had to take many detours to reach other axes in the city, but when looking at the axial map displaying the global integration index (Rn), Figure (2), we find some interesting observations:

The global integration index (Rn) accurately shows us the most integrated areas within the space system, which can be accessed with the fewest steps. These areas include the historical city center, characterized by its highly integrated axes (in red), and the adjacent neighborhoods (Ahmed and Boudjemaa, 2023). While we see that the neighborhoods on the outskirts of the city appear to us in dark blue as if they are surrounding the city, they are completely isolated from the heart of the city; although they are newly established and are in the direction of the city's expansion, their planning did not take into account their integration with the city.

Figure 2. Axial map of Djelfa (global integration (Rn)). Source: (Author's analysis based on DepthmapX outputs).

3.2. Local Integration Index (R3) (Integration [HH] R3)

It expresses the possibility of reaching a certain axis on foot from each other axis with three depths. It is considered a local scale because it shows the importance of any street to its neighboring neighborhood.

Table 1. shows the local integration index (R3) for the city of Djelfa in 2020, Source: (Author's analysis based on DepthmapX outputs).

Average value	2,10
Minimum Value	0,21
Maximum value	3,90

According to Table (1), the average local integration index (R3) for the city of Djelfa in 2020 is 2.1 in the current period, indicating that the surrounding neighborhoods or those on the outskirts have witnessed expansions along the same old pattern and axes.

Where we note through the axial map of the city of Djelfa using the local integration index (R3), Figure (3), the emergence of the most accessible spatial axes within the limits of three depths (red and orange), these axes have a very limited local impact as public spaces in the back neighborhoods of the city, where we note well the progression of spaces in these neighborhoods from public to semi-public to private at the level of each neighborhood.

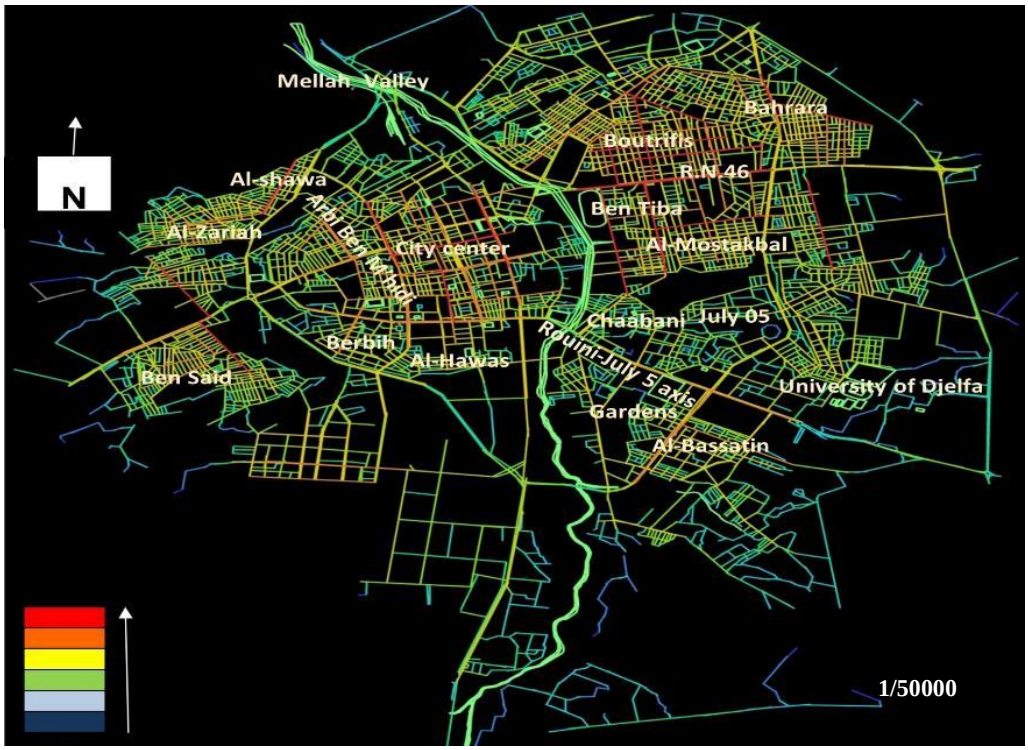

Figure 3. The axial map of the city of Djelfa in 2020 using the values of local integration (Integration R3). Source: (Author's analysis based on DepthmapX outputs).

3.3. Synergy Index (R3 vs Rn)

It refers to the relationship between the two variables: global integration (Rn) and local integration (R3). The scatter plot helps us to show this relationship statistically, which shows the type of this relationship through the value of Pearson's correlation coefficient, as this relationship can be classified as weak, medium, and strong if the following values agree, respectively: (0-0.39), (0.40-0.69), (0.70-1).

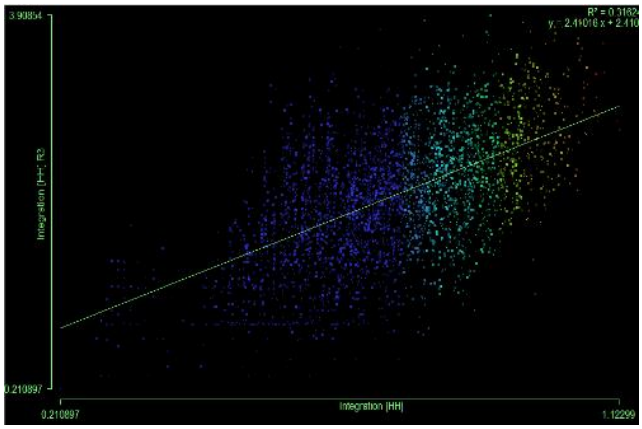

Figure 4. The scatter plot in terms of global integration (Rn) for the city of Djelfa in 2020 shows the Synergy Index. Source: (Author's analysis based on DepthmapX outputs).

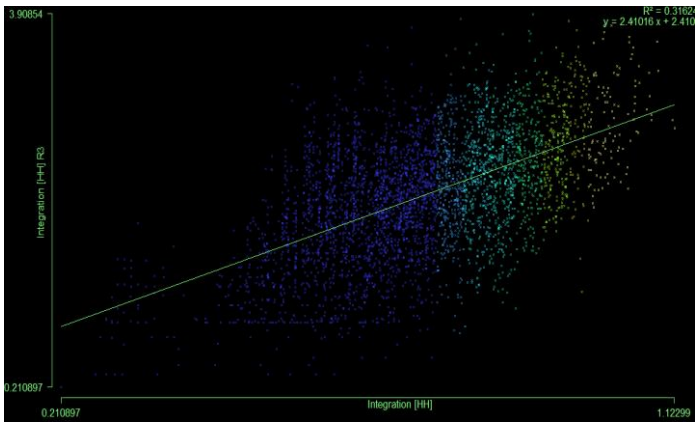

Figure 5. Identifying the axes with a high correlation between local integration (R3) and global integration (Rn). Source: (Author's analysis based on DepthmapX outputs).

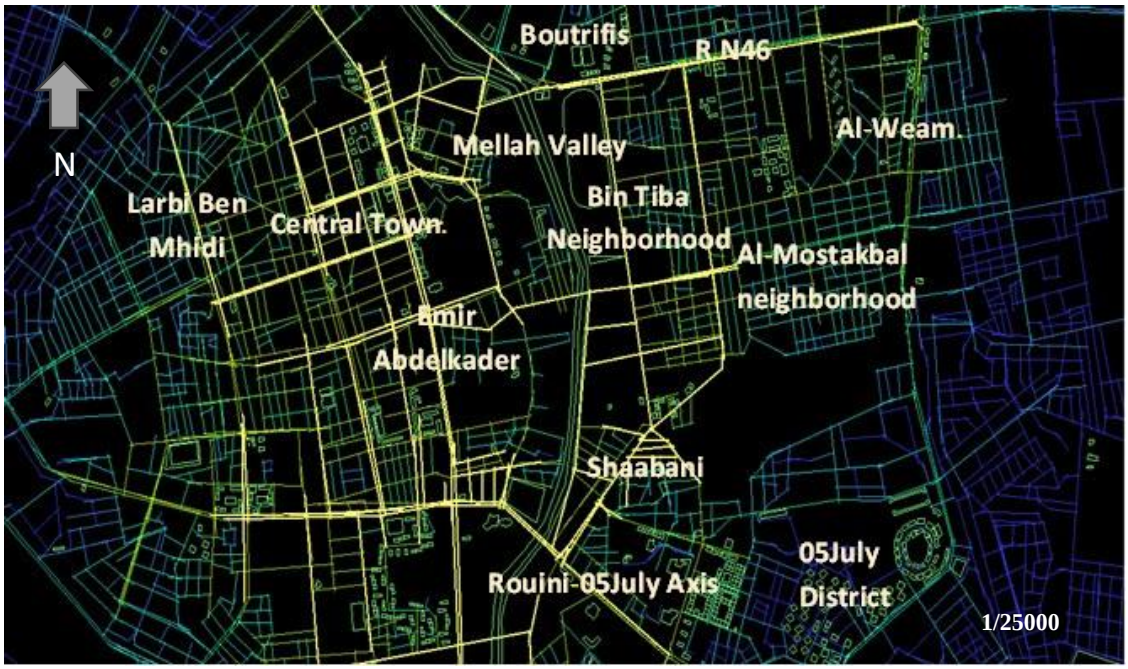

Figure 6. The axes specified on the axial map are shown in terms of global integration (Rn) (the extension of the city center east of Mellah Valley). Source: (Author's analysis based on DepthmapX outputs).

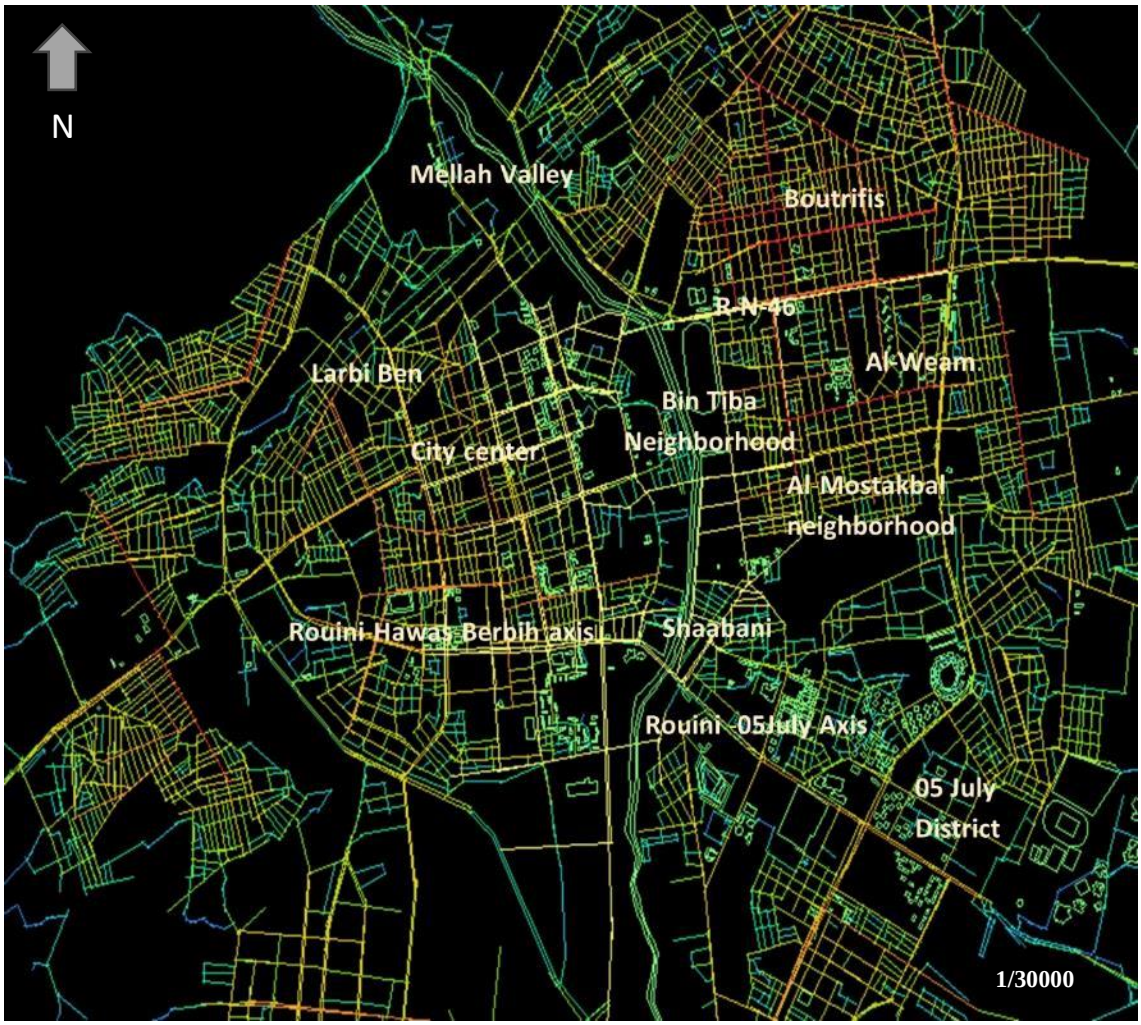

Figure 7. The axes identified on the axis map, in terms of local integration (R3), indicate the emergence of the Boutrifis neighborhood as a secondary local center with poor synergy. Source: (Author's analysis based on DepthmapX outputs).

The scatterplot that illustrates the relationship between local integration (R3) and global integration (Rn) in an urban spatial network—such as that of the city of Djelfa—is a fundamental tool for understanding structural connectivity dynamics and the quality of movement or pedestrian flow within the urban environment.

An analysis of the scatter plot in terms of the global integration (Rn) of the city of Djelfa in 2020 shows that the Synergy Index, Figure (4), is useful for how the local performance of axes (streets or spaces) translates to their overall impact within the larger network.

3.3.1. Points and Their Distribution

- Each point on the plot represents a specific axis or space within the studied urban network.
- Horizontal axis: Global integration (Rn).
- Vertical axis: Local integration (R3).
- Clusters or scatter of points reflect whether the network has interconnected areas or functional separations.

3.3.2. Linear Regression Equation (Y = 2.41016 x + 2.41016)

This equation indicates a positive linear relationship: as the local integration of an axis increases, its global integration generally increases as well, though not perfectly.

3.3.3. Coefficient of Determination ($R^2 = 0.32$)

- This shows that 32% of the variance in global integration is explained solely by local integration, indicating a moderate-strength relationship.
- The spatial structures of the urban fabric in this period contribute in a limited way to the emergence of a reciprocal relationship between the residents of the city and visitors and that movement is relatively restricted between the local spaces and their comprehensive surroundings, so that the short, curved, and blocked sub-axes prevail over the rest of the other types of axes for the spatial system as a whole.

3.3.4. Consistent Areas (High Synergy)

- Represent axes or locations with a good balance between their local and global effects.
- Typically, these are central streets or key structural axes linking neighborhoods or city zones.

If we delve deeper into the analysis of the scatter plot, we can identify the axes with an acceptable correlation or synergy between local and global elements. These are the axes where visitors meet the residents and where there is interaction and movement between the residents and visitors of the city. We can indicate these axes in the scatter plot, as shown in Figure (5), and see their reflection on the axial map in terms of global integration (Rn), as shown in Figure (6). We find important notes:

- A significant number of axes exhibit a correlation between the local and the global, or show high synergy. In addition to their location in the historic city center, this correlation has expanded to include the new borders of the city center, such as the Arbi Ben Mhidi axis to the west and the Rouini-Hawas-Berbih axis to the south.
- The emergence of new axes with good synergy in the new eastern neighborhoods includes the National Road Axis 46, the Al-Mostakbal Axis, the Chaabani Axis, the Rouini-July 5 Axis, and the Al-Weam Axis. These axes on the eastern side support the flow of traffic and interaction between visitors and residents, serving as open spaces that attract both types of users.

3.3.5. Isolated Areas (Medium or Low Synergy)

- Some have high R3 but low Rn: axes mainly serving their immediate surroundings (isolated residential areas). When the axial map is transformed in terms of local integration (R3), Figure (7), the Boutrifis neighborhood appears with its axes with a high value of the local integration index (R3) (red color), and it appears isolated in the global integration (Rn). Figure (2) indicates the prediction of a secondary city center, but with its local characteristics, it attracts the residents of this sprawling neighborhood and does not encourage foreign visitors to enter it.

3.4. Local Integration Index (R5) (Integration [HH] R5)

It expresses the axes that can be reached with a maximum of five depths or five turns, i.e., the transition from studying public spaces to semi-public spaces within the system as a whole. This index in the spatial system of a city can indicate the potential emergence of secondary centers within neighborhoods relatively far from the city center.

Table 2. shows the local integration index (R5) for the city of Djelfa in 2020. Source: (Author's analysis based on DepthmapX outputs).

Average value	1,65
Minimum Value	0,21
Maximum value	2,61

We note from Table (2) that the average local integration index (R5) for the city of Djelfa in 2020 came with a value of 1.65, and this value indicates that most areas of the city of Djelfa support access to it with a depth less than or equal to five depths, and this is what the axial map shows using the local integration index (R5), Figure (8). The urban movement network is characterized by several axes distinguished by high local integration (R5), represented in red and orange on the spatial analysis maps. These axes, extending from the historic city center toward the Arbi Ben M'hidi axis in the west and the Rouini-Hawas-Berbih axis in the south, create a core area that is comprehensively integrated both globally (Rn) and locally (R5). This dual integration makes the historic center and its extensions readily accessible for both residents and visitors.

In contrast, some neighborhoods—such as Al-Shawa and Al-Zaria—appear isolated from the city in terms of global integration, yet possess internally integrated axes that support robust local movement. While these axes currently facilitate neighborhood-level connectivity, their high local integration suggests potential for future development as locally oriented commercial corridors serving residents' day-to-day needs.

Urban expansion has also played a pivotal role, as demonstrated by the extension of the Al-Weam-Bahrara axis and the growth of the Boutrifis neighborhood. The development of new neighborhoods and improved connectivity, especially through National Road 46 linking to Ben Tiba and Al-Mostakbal, has reinforced Boutrifis's status as a secondary local center. The result is a district marked by smooth traffic flow, enhanced accessibility, and strong integration within five direction changes, supporting its emergence as a vibrant urban node.

Similarly, the Rouini-July 5 axis provides a highly integrated corridor that separates the July 5 neighborhood from the Gardens and Al-Bassatin neighborhoods, offering potential for high traffic fluidity. However, its effectiveness is limited by the presence of blind facades (continuous walls on both sides), particularly at key crossroads such as near the Gardens neighborhood and the university, which curtails pedestrian activity and urban permeability.

Collectively, these spatial dynamics illustrate how integrated axes serve as backbones for urban movement and connectivity, shaping the development of centers and revealing both opportunities and challenges for functional integration at neighborhood and city scales.

3.5. Comparative Context Based on the Study Results of the Synergy Index in the City of Djelfa

The results of the Synergy index study in the city of Djelfa indicate that the historic city center maintains its functional and social prominence, with expansion toward the east of Oued Mellah, westward to the limit of Arabi Ben Mehidi Street, and southward to the Rouini-Al-Hawas axis. Additionally, the Boutrifis neighborhood serves as a secondary local commercial hub, alongside neighborhoods that appear isolated from global integration but have corridors with good movement, interaction, and significant local influence. These findings align with international studies examining similar centrality indices in medium-sized cities, where the historic urban core remains the primary hub of activity and interaction, while secondary commercial poles emerge to support urban expansion and enhance local mobility. For example, Delmelle and Casas (2024) highlighted the importance of using centrality indices to understand urban spatial structure and interactions. They demonstrated a comparable central distribution that emphasizes commercial secondary poles stimulating local activity while maintaining spatial interaction between

neighborhoods (Delmelle & Casas, 2024). Other research, such as Shao and Li (2016), confirmed that analyzing attraction and mobility within urban analysis zones supports understanding the interaction between historic centers and secondary commercial poles, similar to the observed case in Djelfa with Boutrifis as a local commercial hub (Shao & Li, 2016). Moreover, the spatial syntax framework underlines the importance of spatial interaction within neighborhoods that are not globally integrated, as is evident in Djelfa, where local interaction dynamics are a crucial factor for the sustainability of these neighborhoods (Lee & Hong, 2013; Lee & Hong, 2013).

Based on these comparisons, it can be said that Djelfa confirms that urban patterns in medium-sized Maghreb and Arab contexts share features with foreign cities. These features include maintaining the central role of historic centers, the emergence of secondary poles, and local interaction within neighborhoods, with variations appearing in the level of global and economic integration.

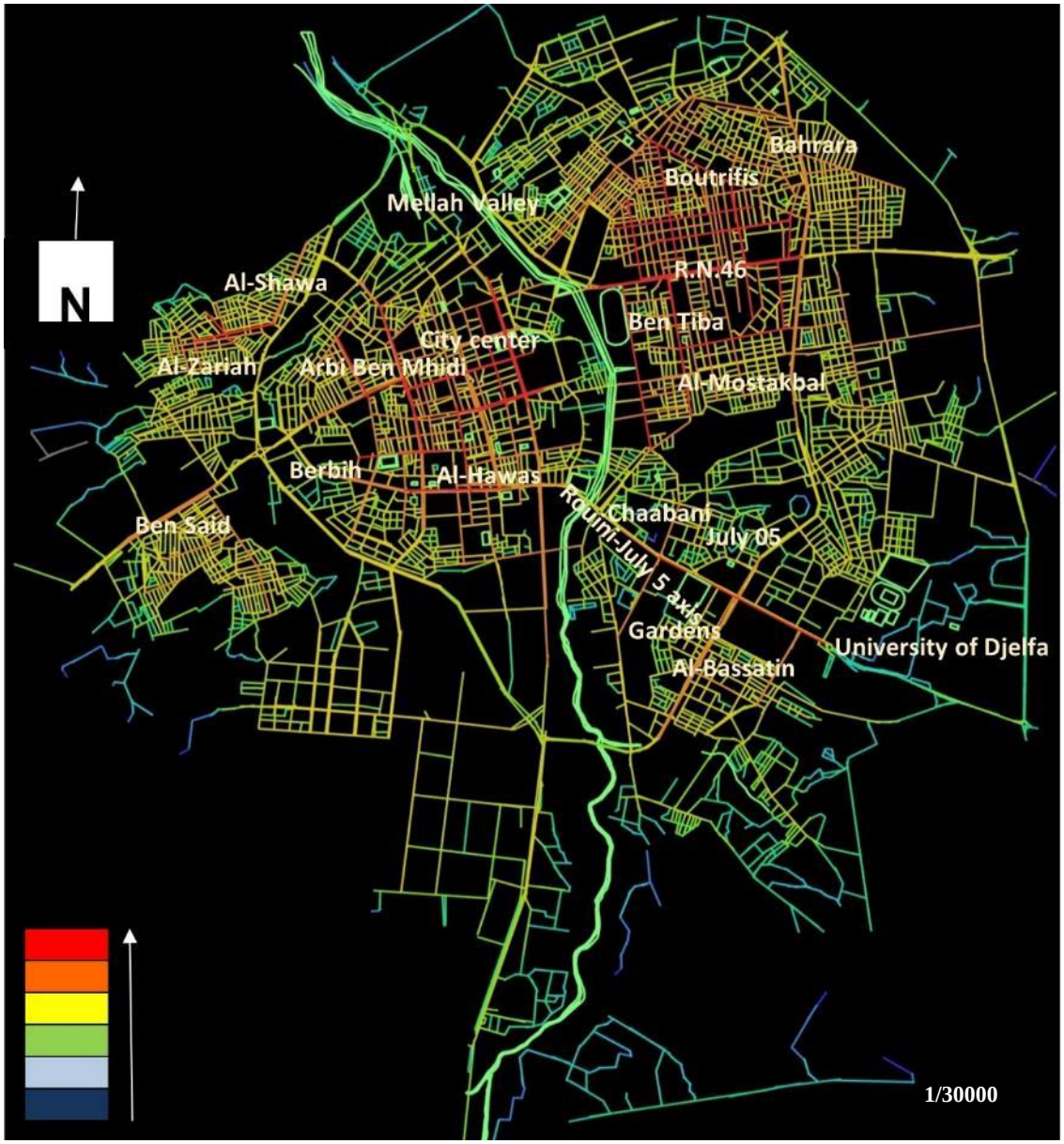

Figure 8. The Axial map of the city of Djelfa in 2020 using the values of local integration (Integration R5). Source: (Author's analysis based on DepthmapX outputs).

3.6. The Relationship Between Indicators R3 and R5 and Their Significance in Spatial Syntax Analysis

Indicator R3 reflects the degree of local integration or connectivity at the neighborhood scale. It represents the accessibility of each axial line within a maximum of three direction changes. The DepthmapX software calculates this indicator for all axes in the urban spatial network and visualizes the results using a

color spectrum ranging from red (highest values) to dark blue (lowest values), Figure (3). On the axial map, R3 highlights especially the peripheral neighborhoods that appear isolated according to the global integration indicator Rn, Figure (3), yet exhibit significant internal movement and strong internal axes, such as the neighborhoods of AL-Shaoua, AL-Zeria, and Ben Said, see Figure (3).

Indicator R5, on the other hand, represents mid-range integration within the city, encompassing larger areas of the urban fabric. It measures accessibility to each axis with up to five direction changes. Similarly, DepthmapX computes R5 values for all city axes and translates them into a color gradient from red (highest values) to dark blue (lowest values), Figure (8). The axial map using R5 reveals the most integrated axes that support both internal movement and connectivity with adjacent surroundings, enabling the emergence of local secondary commercial hubs such as the Boutrifis neighborhood. Although Boutrifis shows weak global integration, Figure (2), indicating limited openness to the wider urban system compared to the historic city center, it demonstrates strong integration according to the R5 indicator, Figure (8).

Thus, the R3 indicator provides insight into axes characterized by internal movement within marginal or isolated neighborhoods, which attract very localized commercial activities. Conversely, the R5 indicator reflects a higher level of movement and commercial activity that, while not as prominent as the city center, exerts influence over multiple neighborhoods.

From a planning perspective, R3 can assist planners in identifying optimal locations for neighborhood-scale facilities such as primary schools, local parks, community gardens, and children's playgrounds. Meanwhile, R5 can guide the placement of facilities with broader influence across several neighborhoods, including middle and high schools, local clinics, and medium-sized sports fields.

The analysis of these two indices through spatial syntax techniques assists urban planners in promoting equitable access to services at the city level and in their spatial distribution.

3.7. Methodological Limitations

One of the main limitations of the adopted methodology is that the axial map analysis does not treat curved axes as single unified lines; instead, it divides them into multiple separate axes during the map generation process. This segmentation can significantly affect the accuracy of the indicators that rely on the number of axis intersections, potentially reducing the reliability of the final results. Consequently, this gap remains a notable shortcoming affecting the validity of spatial analysis. Developers of DepthmapX software need to address this issue to improve the accuracy and representation of curved axes in axial maps and analytical indices.

3.8. Study Limitations

Unlike common practice in many urban studies that depend solely on official maps, the base map used for modeling in this study was independently created by the researcher, utilizing the latest updates from Google Earth. The accuracy of this spatial data was further enhanced by direct field validation, benefiting from the researcher's residency and intimate familiarity with the study area's neighborhoods. This combined approach of digital interpretation and on-ground verification contributes to the credibility of the spatial analysis and minimizes the risks associated with relying on outdated or incomplete official sources.

Nonetheless, the study is limited by the absence of observed quantitative data on pedestrian movement and behavior, as no systematic field surveys of flows or trajectories were conducted. Incorporating such data in the future could provide an additional layer of insight into the dynamics of the integrative movement within Djelfa's neighborhoods.

It is recommended that future research endeavors consider detailed pedestrian movement analysis to render spatial evaluations even more robust and comprehensive.

4. Conclusions

The space syntax analysis conducted in Djelfa has provided significant insights into the dynamics of urban interaction and spatial organization. It confirms that the historic city center continues to serve as the primary hub for social and functional activity, while the synergy index reliably identifies emerging areas for potential secondary commercial development, such as Boutrifis. Despite the limited influence of urban form on reciprocal relationships, as shown by the weak synergy correlation ($R^2 = 0.32$), the findings

highlight the crucial importance of both global and local integration in shaping movement and interactions—particularly the strong local dynamics present in neighborhoods otherwise isolated at the citywide scale. Consequently, it is recommended to preserve and carefully regulate the historic center's gradual expansion by ensuring comprehensive infrastructure and service support. Strategically develop Boutrifis into a vibrant commercial center through transport and public space enhancements. Actively connect isolated neighborhoods by implementing flexible movement corridors that foster greater integration and urban sustainability. The adoption of spatial syntax techniques should be encouraged in future planning to accurately monitor and guide population movements, with an emphasis on gathering actual field data on pedestrian flows to increase reliability and depth of analysis. These combined strategies will strengthen Djelfa's urban structure, ensuring both its functionality and social cohesion in the context of rapid growth and transformation.

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