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ANALYSING THE RELATIONSHIP BETWEEN SPATIAL CONFIGURATION AND LAND USE OF THE ORDU CITY WITH THE SPACE SYNTAX APPROACH

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Highlights:
- zones with high global integration have squares, recreational areas and high-density commercial areas;
- mismatch between the results of intelligibility and synergy analyses and the land use pattern in the study area;
- relatively low pedestrian mobility in areas with high levels of intelligibility;
- more isolated places in zones with low intelligibility.

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Abstract. Cities, which are a product of human societies and the construction of civilization, are places where individuals spend a significant part of their daily lives. In this respect, the way urban space is organized and the qualities it possesses deeply affect urban life and usage practices. In this context, the research aims to reveal the relationship between spatial configuration and land uses in the region defined as the core of Ordu city centre with analytical methods. The main method followed in the study is based on the space syntax approach, which quantitatively reveals the spatial structure that constitutes the city. As a result of the study, a consistent relationship was found between the findings obtained from axial analysis and the uses in the space. The zone with the highest intelligibility is Zone 6, which is characterized by low-density commercial areas. The zone with the highest synergy value is Zone 7, which includes urban residential areas and low-density commercial areas.

Keywords: Ordu city, space syntax, spatial configuration, urban space, urban planning.

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1. Introduction

The concept of space is a multifaceted concept that covers the internal and external living environments of individuals (Yan et al., 2019; Zlatanova et al., 2020). However, space is defined as a place that separates people from their environment to a certain extent, where all actions of individuals are performed and experiences are experienced (Tumertekin & Ozguc, 2002; Nalbant, 2016). Urban spaces are characterized by unique patterns formed by physical, social, and psychological interactions (Kürkçüoğlu & Ocakçı, 2015). Urban spaces are produced and gain meaning by city dwellers. Along with lived experiences and symbolic spaces, discourses and narratives also shape urban spaces (Aceska et al., 2019). Patterns of human mobility give meaning to urban space by creating ways of experiencing it (Kutlay & Karadoğan, 2022). Cities consist of physical spaces, defined morphologically as "mass" and "space". The term "mass-space" refers to the relationship between built-up areas (mass) and open or unbuilt areas (space) within a city. This concept encompasses the physical composition and spatial configuration of urban areas, including the distribution of buildings, streets, and open spaces within the city (Maretto et al., 2020; Jiang et al., 2021). Buildings constitute occupancies as masses, whereas open spaces such as parks, squares, courtyards, markets, streets, and avenues constitute voids. These gaps, which are also defined as urban open spaces, are important components of the urban fabric as a network system and form the basis for individuals to move as pedestrians in urban spaces (Kürkçüoğlu & Ocakçı, 2015).

Urban spaces, as a common product of societies, are places where individuals who make up the society spend a significant part of their daily lives. Therefore, the qualities of urban space and how it is constructed significantly affect individual and social life. The space syntax approach is important in understanding urban space fiction using quantitative methods (Hillier & Vaughan, 2007; Kubat, 2015). Conceptually, space syntax refers to the methodological processes developed to analyse spatial structuring in cities and the relationships between spaces and buildings (Johnsson & Camporeale, 2022). These processes provided a theoretical basis for the interaction of spaces within the urban spatial network and provided an analytical and quantitative perspective (Zaninović et al., 2018; Khairanisa, 2022). The space syntax approach is widely used in various fields because it facilitates the analysis of spatial configurations in urban spaces of various scales and contexts and their effects on human behaviour. Urban design, architecture, landscape architecture, and transport planning are among the research disciplines in which the space syntax approach has been adopted (Liu et al., 2015; Yamu & Nes, 2017; Ascensão et al., 2019; Trapero et al., 2020; Yin et al., 2021). The space syntax approach, which reveals pedestrian movements and land use through axial analysis of road networks, has significantly influenced the study of urban design (O'Neill et al., 2006; Fahri, 2023). Additionally, the space syntax approach is used to determine the walkability status, assess urban sprawl and the built environment, and analyse the spatial characteristics of historical urban areas and contemporary cities (Yamu & Nes, 2017; Ascensão et al., 2019; Griffiths & Vaughan, 2020; Yin et al., 2021; Turgut, 2022; Roozkhosh et al., 2022; Kuzulugil et al., 2023). Determining the level of urbanization, optimizing public transportation and determining visitor movement patterns in museums are other research topics that use space sequence methods (Liu et al., 2015; Eldiasty et al., 2020; Elgamal et al., 2020; McMurtrie, 2022). The most widely used software for space syntax analysis and visualization is depthmapX (DepthmapX Development Team, 2024). This software is preferred by researchers to other software in the field because it can calculate various parameters important in space syntax analysis and create axis maps (Meziani, 2017; Xu et al., 2020; Rao et al., 2022). It can process data related to spatial hierarchy, connectivity, integration, and visibility (Jabbari et al., 2021; Kustiani & Khidmat, 2022). The in depthmapX software allows for easy visual and spatial analysis at various scales, from building to city level. It also enables quick data processing and direct visualization of the spatial network hierarchy (Jabbari et al., 2021; Eltarabily, 2022).

Cities are intricate systems that are influenced by social, economic, and environmental factors (Bettencourt, 2013; Schläpfer et al., 2014; Hu, 2015). The spatial organization of cities has a direct impact on economic activities, social interactions and environmental sustainability. Analysing the spatial configuration in the city provides a powerful tool for designing, forming and transforming urban functional space (Karimi, 2017). In the context of urban planning, it is crucial to understand the interaction between spatial planning and land use for sustainable development (Nae et al., 2019). Analysing spatial relationships in long-standing urban core areas can lead to sustainable projects and improve the liveability of cities by contributing to decision-making processes (Mohareb, 2013). However, there is no research on the complex relationship between the concepts of spatial configuration, land uses and pedestrian mobility, which affect and mutually feed each other, in the city of Ordu, which contains elements with different characteristics. The study was conducted in the city center of Ordu, Turkey. This area is considered the heart of the city and includes public and commercial buildings, parks, squares, and pedestrianized streets that promote ground-floor use. The first hypothesis of the study is that there is a consistent relationship between the findings of the axial analyses and the land uses in the city. The other hypothesis is that there is compatibility between the results of intelligibility and synergy analyses and the main land use pattern in the city. The main purpose of the study is to reveal the relationship between spatial organization and dominant land use patterns by using the space syntax method. By understanding this relationship, it is aimed to pioneer the development of sustainable spatial strategies to increase the level of liveability in the city.

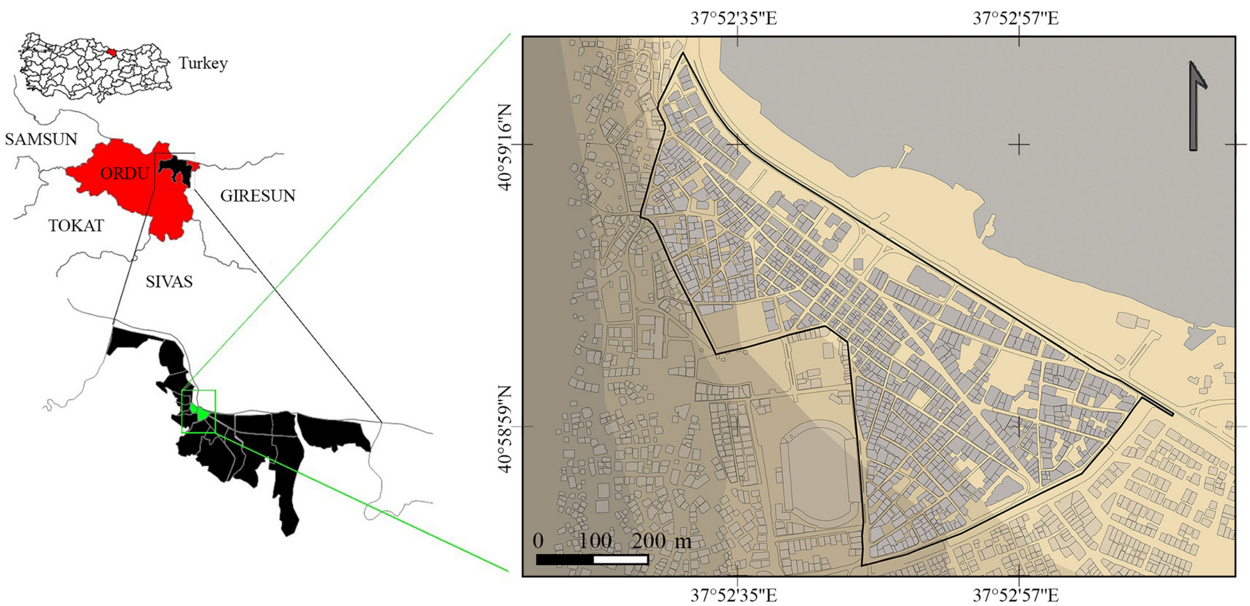

Figure 1. Location map of the study area

2. Study area

The study area was located in the core city center of Ordu, one of the cities in the Black Sea region of Turkey (Figure 1). The total area of the study site, which corresponds to two neighbourhoods, Düz and Şarkiye, is approximately 28 hectares in size. Although the resident population in the area is approximately 4551 inhabitants (TURKSTAT, 2024), it is known that this population is exceeded many times especially during the daytime. In the study area, public buildings such as the municipality building, historical buildings, educational buildings, commercial buildings such as cafes and hotels, and urban residences are located together. The presence of pedestrianised areas such as squares and urban parks causes intense pedestrian mobility in the area. The study area, which includes high- and low-density commercial facilities, hosts many visitors not only from the city center but also from other districts during the day.

3. Methods

The methodology followed in the study is based on quantitatively revealing the relationship between spatial configuration and the main types of land use in the study area. Space syntax was used as an effective approach to reveal the spatial configuration. Space syntax provides a quantitative tool for evaluating spatial relationships in cities (Khairanisa, 2022). In this respect, it strengthens the hand of researchers in reaching highly objective results by going beyond personal and subjective opinions. Providing important techniques for observing and understanding the urban landscape, the space syntax approach has significantly influenced the field of urban design (O'Neill et al., 2006). One of the most powerful aspects of the space syntax approach is its ability to explain pedestrian movement and land use through axial line analysis of road networks (Fahri, 2023). As a result, space syntax was chosen as the most appropriate method to achieve the objectives of this study due to its quantitative and spatial outputs.

The basic data used in the study are the zoning plan of the region including the study area obtained from the local government and OpenStreetMap data for the road network. The data obtained were organized and prepared for analysis by cutting them according to the boundary of the study area. As indicators of the spatial configuration in the study area, connectivity, global integration and local integration parameters, which are important components of space syntax analysis, were calculated. Then, intelligibility and synergy values based on the correlation of these parameters are revealed.

3.1. Calculation of space syntax parameters

The current plan of the study area and OpenStreetMap data were used to calculate the basic parameters used in the space syntax analysis. The plan of the study area was converted into .dxf format and transferred to the depthmapX 0.8.0 software, where the axial map, which forms the basis of all syntactic parameters, was created (DepthmapX Development Team, 2024). Then, using the same software, connectivity, global integration and local integration parameters were calculated and assigned as attributes to the axes in the axial map. Finally, the axial map was transferred to QGIS 3.16.6 geographic information systems software with the attributes of the relevant variables, visualized and converted into a map (QGIS Development Team, 2024).

The connectivity value describes the connection strength among axes in a given area with neighbouring axes. The total number of other axes intersecting any particular axis determines its connectivity number. Axes that intersect with several others in the area exhibit a high connectivity value, while those intersecting fewer axes have a lower connectivity value (Hillier & Hanson, 1984). Connectivity was calculated using the formula in Equation (1), where C_i represents the connectivity value of axis i, and k is the number of intersections of axis i with other axes.

$$C_i = k. \quad (1)$$

The integration value varies between global and local scales. Global integration highlights an axis's relationship with axes throughout the entire system, while local integration focuses on its relationship with axes within a specific distance (Hillier & Hanson, 1984). Integration value serves as a crucial evaluation criterion in axial analyses, offering insights into space utilization and mobility (Sharmin & Kamruzzaman, 2018). It reveals how each axis within an area is connected to other axes. Typically, urban axis systems feature roads that are long and straight, resulting in high integration values (Yıldırım, 2018). To calculate integration values, it is necessary to determine the mean depth. The mean depth is computed by assigning a depth value to each space based on its distance from the original space, summing these values, and then dividing by one minus the number of spaces in the system (n–1) (Hillier & Hanson, 1984; Equation (2)). Integration values are then determined using the formula in Equation (3), which represents the average depth (D_i). While global integration applies this algorithm to all axes within an infinite radius, local integration calculates the integration value of axes within a specified radius (Hillier, 2007; Hillier & Vaughan, 2007).

$$D_i = \frac{\sum_{j=1}^{n} d_{ij}}{n-1}; \quad (2)$$

$$I_i = \frac{n(\log_2\left(\left(n+2\right)/3\right)-1\right)+1}{\left(n-1\right)\left(D_i-1\right)}. \quad (3)$$

3.2. Zoning of the study area

The study area was divided into zones based on dominant land uses, and a regional land-use map was generated (Figure 2). Zones 1, 2, and 3 are bordered by the Black Sea coastal way and the sea. Zone 1 is predominantly oc-

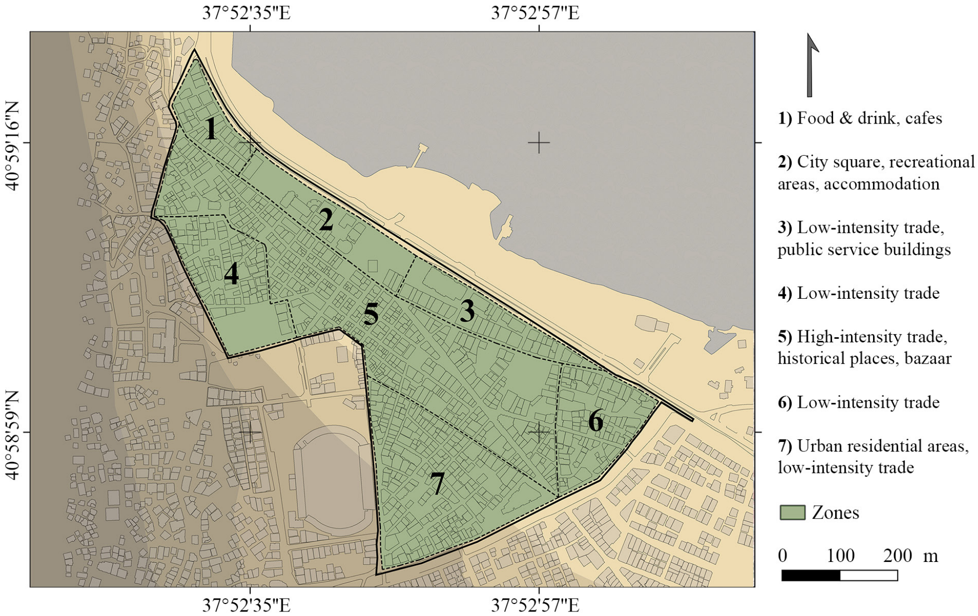

Figure 2. Zones defined on the basis of the most common land use

cupied by eateries, drinking establishments, and cafes. Zone 2 comprises the city square, various recreational areas, and accommodation structures, such as hotels and guesthouses. Similar land utilization is observed in Zones 4 and 6, primarily consisting of low-density commercial areas. Unlike Zones 4 and 6, Zone 3 incorporates public service buildings, including the municipality and notary public office, in addition to low-density commercial areas. Zone 5 encompasses a pedestrian zone commonly known as "Fidangör," characterized by intense commercial activities. This zone also corresponds to the area referred to by locals as the "bazaar," housing historical landmarks like the Church of Düz Mahalle. In contrast to the other six zones, Zone 7 is distinguished by a concentration of urban residential areas and low-density trade.

3.3. Calculation of intelligibility and synergy values

The correlation between global integration (Integration [HH]) and connectivity is defined as intelligibility. The higher the correlation between the variables, the greater the intelligibility. The concept of intelligibility, as proposed by Hillier (1996), is closely related to the idea of legibility developed by Lynch (1960). Intelligibility serves as an indicator of ease of movement, depending on the cognitive quality offered by the spatial configuration in the city (Orsini, 2018). Furthermore, this value helps determine the extent to which the entire space is clear for users (Zabihi et al., 2021).

The correlation between global integration (Integration [HH]) and local integration (Integration [HH] R3) is defined as synergy. Theoretically, the higher the correlation between the variables, the greater the synergy (Li et al., 2017). A high synergy value indicates that the general structure and the local structure are becoming more closely aligned (Orsini, 2018).

To calculate the intelligibility and, synergy values for the seven zones within the study area, the relationship between the variables was depicted through scatter plots. Subsequently, R^2 values were computed and presented on the graphs. These procedures were executed on the Google Colab platform, leveraging the online capabilities of the Python programming language. Google Colab, a cloud-based Jupyter notebook service, provides an interactive and serverless environment for code development (Palasundram et al., 2021; Wang et al., 2022). The numpy, matplotlib, seaborn, and sklearn libraries were used for data processing, calculations, and data visualization (Hunter, 2007; Pedregosa et al., 2011; Harris et al., 2020; Waskom, 2021).

4. Results and discussion

Space syntax analysis is an effective method used to identify areas with high potential for social interaction in cities (Munro & Grierson, 2016). In recent years, it has been observed that the number of studies based on the space syntax method has increased. In the study by Trapero et al. (2020), which examines the geographical and geometric accessibility of Toledo, Spain, using the space syntax method, studies focusing on the relationship between the space syntax approach and spatial use are systematically compiled and presented in a table format. Table 1 displays some examples of studies conducted using the space syntax method in cities with different land uses. The city and country where the studies were conducted, the parameters used in the evaluation and the reasons for the choice of these parameters are explained in detail.

Connectivity is one of the most basic parameters of spatial sequence analysis. The connectivity map in Figure 3 represents an increasing connectivity score from blue to red. The axes with the highest connectivity in Ordu city center are Süleyman Felek, Sırrı Paşa, and Osman Paşa streets. Süleyman Felek Street, which is approximately 922 meters long, is a combination of two axes, one of which is a pedestrianized area closed to vehicle traffic. The connectivity value of each of the axes forming the street is 19, which is the highest value in the study area. According to spatial sequence analysis, a high connectivity value indicates that a large number of areas are connected to a certain area (Xu et al., 2020). A high connectivity value for an axis means that the area has good accessibility, is located in the center of a regional traffic line, or is easy to reach for most people because it has a high frequency of use (Heo et al., 2021). Connectivity value is closely related to integration, length of axial lines, and movement (Rashid et al., 2006).

Table 1. Examples of research carried out using space syntax approach in cities

Year	Authors	Study area	Parameters	Reason for using the parameters
2007	Hillier and Vaughan	Micro and macro scale urban segments	Integration	To examine the interaction between the urban matrix and the behaviour of urban space users
2007	Min et al.	Seul (South Korea)	Integration, connectivity, depth	To analyse the spatial use of different regional types such as commercial and residential areas in the context of spatial configuration
2014	Mahdzar and Safari	Kuala Lumpur	Integration, connectivity	To examine the effect of the spatial configuration of office and factory buildings in city centres on the comprehensibility of urban space
2015	Lamíquiz and López-Domínguez	Madrid (Spain)	Integration, connectivity	To investigate the relationship between the accessibility of street links and the physical environmental characteristics related to spatial utilisation and pedestrian use
2013	Griffiths et al.	London (UK)	Integration, connectivity, depth, choice	To examine the historical and morphological aspects of the use, change and continuity of the main street and its surroundings in two different suburbs
2017	Kim and Yang	Samcheong-dong (Seoul/South Korea)	Integration	Analysing the physical characteristics of the space and street connections with the space syntax method and developing factors for the stimulation of commercial use
2019	Alalouch et al.	Muscat (Oman)	Integration, control, choice, normalising least angle choice	Investigation of the relationship between the spatial use distribution of spatial regulations and the structure of the street connections of the space in neighbourhoods with a tendency to develop
2020	Lee et al.	Seoul (South Korea)	Integration	Analysing the spatial configuration of land use zones with different characteristics by spatial sequencing method and comparing it with pedestrian volume

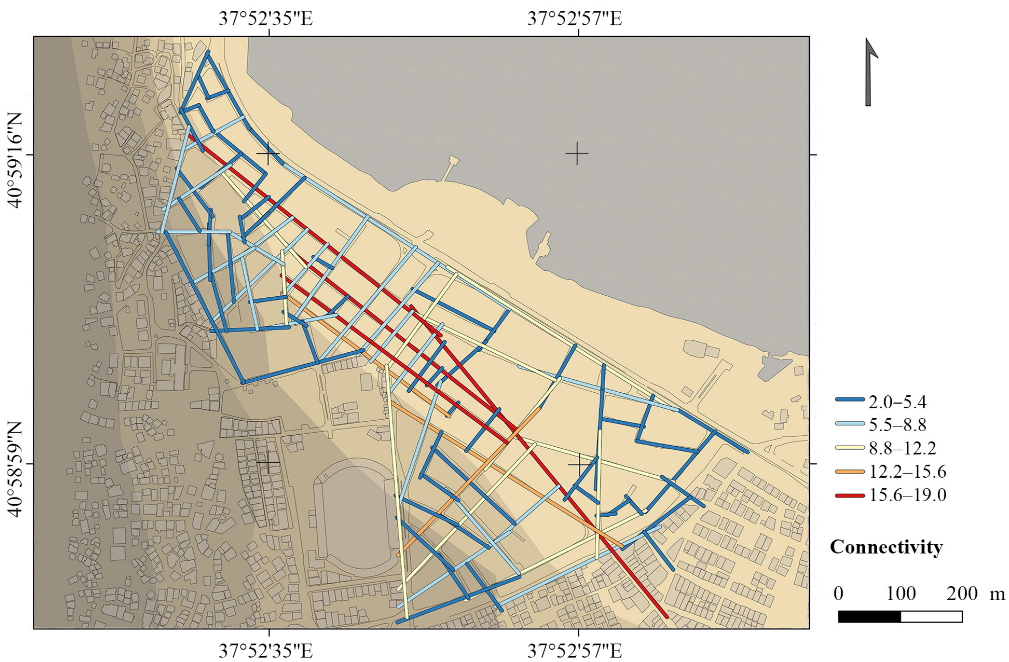

Figure 3. Syntactic analyses of Ordu – connectivity map

Another syntactic analysis conducted in the study area is the integration analysis. In this context, global integration (Figure 4) and local integration (Figure 5) maps of the area were generated. Global integration measures the average depth of an axial line to all other axial lines in the entire road network, providing an understanding of the overall connectivity and accessibility of the urban area (Xu et al., 2020). On the other hand, local integration involves calculations within a limited radius to assess the integration and accessibility of an urban area at a more local scale (Yamu et al., 2021). A study has indicated that external visitors to an urban area tend to navigate streets with high global integration values, while residents prefer streets with high local integration (Li et al., 2016). The global and local integration values of the axes in Ordu city center largely overlap (Figures 4, 5), suggesting that both residents and external visitors may concentrate on certain axes in the city center.

Figure 6 shows the distribution of connectivity, global integration and local integration values of the seven zones forming the study area in the form of a box plot. The dashed red line in the figure represents the overall average for each parameter. In Zones 2 and 3, the connectivity averages of the axes are above the general average. This

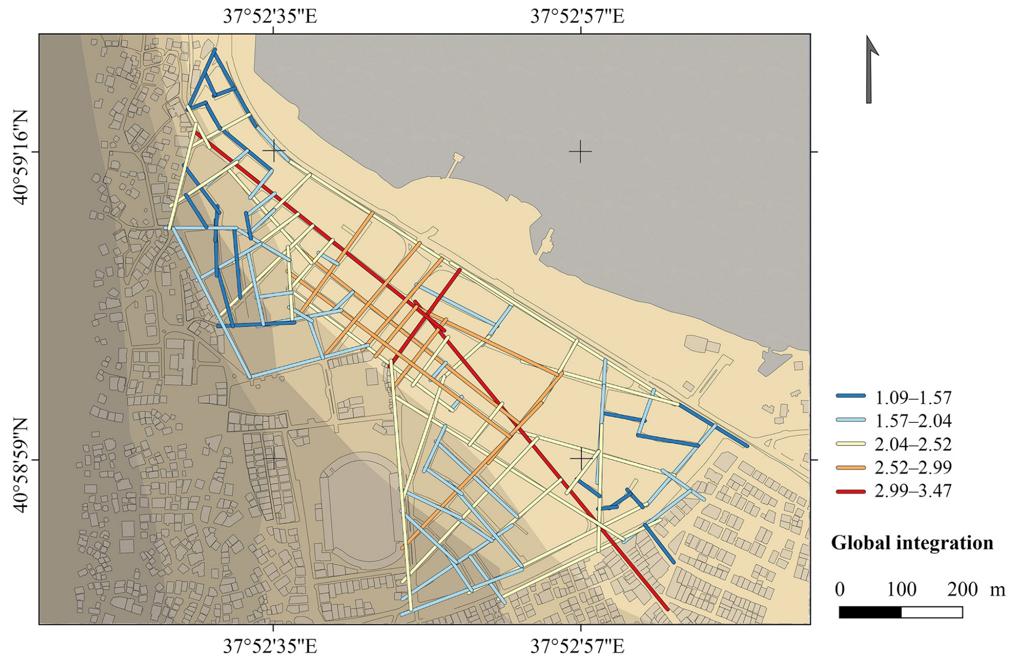

Figure 4. Syntactic analyses of Ordu – global integration (Integration [HH])

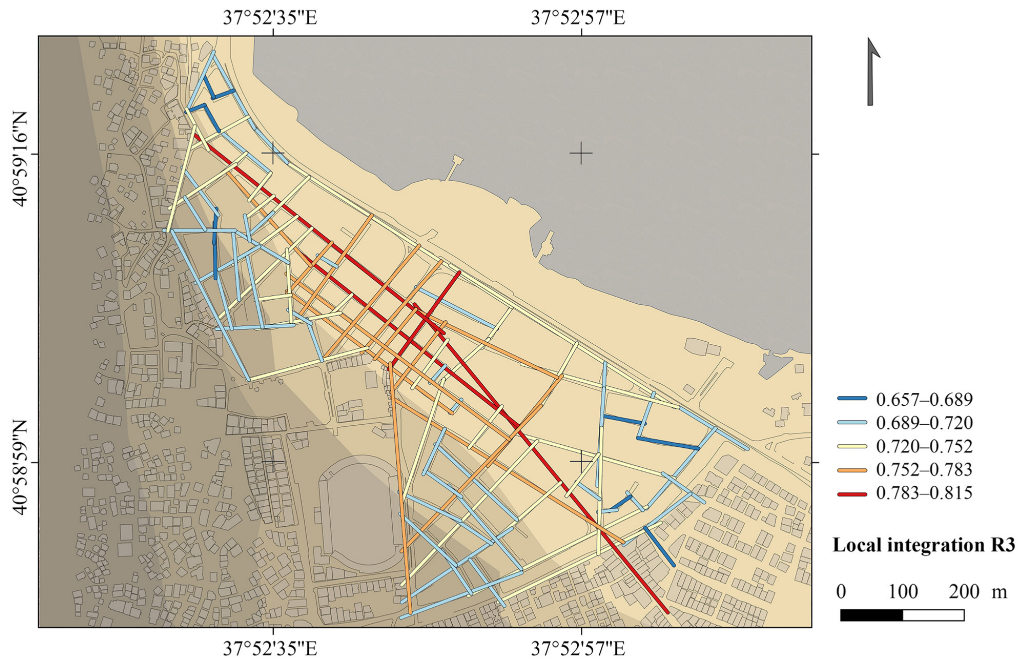

Figure 5. Syntactic analyses of Ordu – local integration (Integration [HH] R3)

indicates that these zones have relatively higher accessibility and high pedestrian utilization (Heo et al., 2021).

The average global integration (Integration [HH]) value, which provides information about the general accessibility and connectivity of the urban area (Xu et al., 2020), is above the general average in Zones 2, 3 and 5. These zones include intensive uses such as city squares, recreation areas and high-density commercial areas. In the zones where the global integration parameter has low averages (1, 4, 6 and 7), there are more introverted functions such as low-density commercial areas and urban residential areas. Local integration (Integration [HH] R3) averages are also in line with the global integration values. The zones with the highest average local integration are Zones 2 and 3 as in global integration. Zone 5 is slightly above the average of global integration. Studies indicate a positive relationship between integration and utilitarian walking (Baran et al., 2008; Hajna et al., 2016; Kang et al., 2017). Utilitarian walking; unlike recreational walking, it refers to an active mode of transport that is not done for exercise, but to fulfil daily routine purposes and tasks (Kang et al., 2017; Coughenour et al., 2019; Perchoux et al., 2019). Zones 2, 3 and 5, where both global and local integration averages are high, are expected to have high utilitarian walking in these zones as they include the city square, public service buildings, high-density commercial areas and the market. It is thought that the employees working in the workplaces and offices located in these zones and the visitors coming to this area to shop exhibit a non-recreational utilitarian walking pattern.

The scatter plots in Figure 7 show the correlation between global integration (Integration [HH]) and connectivity for each zone. The relationship between global integration and connectivity is defined as intelligibility, and the higher the correlation between the variables, the potentially higher the intelligibility. The average intelligibility values for the zones and their spatial distributions are also given in Figure 8. According to the results of the analysis, Zone 6 has the highest intelligibility (R^2 = 0.94). Zone 4 has the lowest level of intelligibility (R^2 = 0.63). It was observed that more isolated spaces were located in the zones with low intelligibility. Therefore, the results for this zone coincide with the reality of the area, but, unexpectedly, the intelligibility value is high in Zone 6, which is characterized by low-density trade. Moreover, the intelligibility values of the most advantageous zones in terms of connectivity, and global and local integration are far below the overall average intelligibility. Conversely, the Zones (1 and 6), whose intelligibility average is above the general average, are disadvantaged in terms of basic syntactic parameters. Ahmed et al. (2014) state that settlements with organic character have the highest intelligibility values

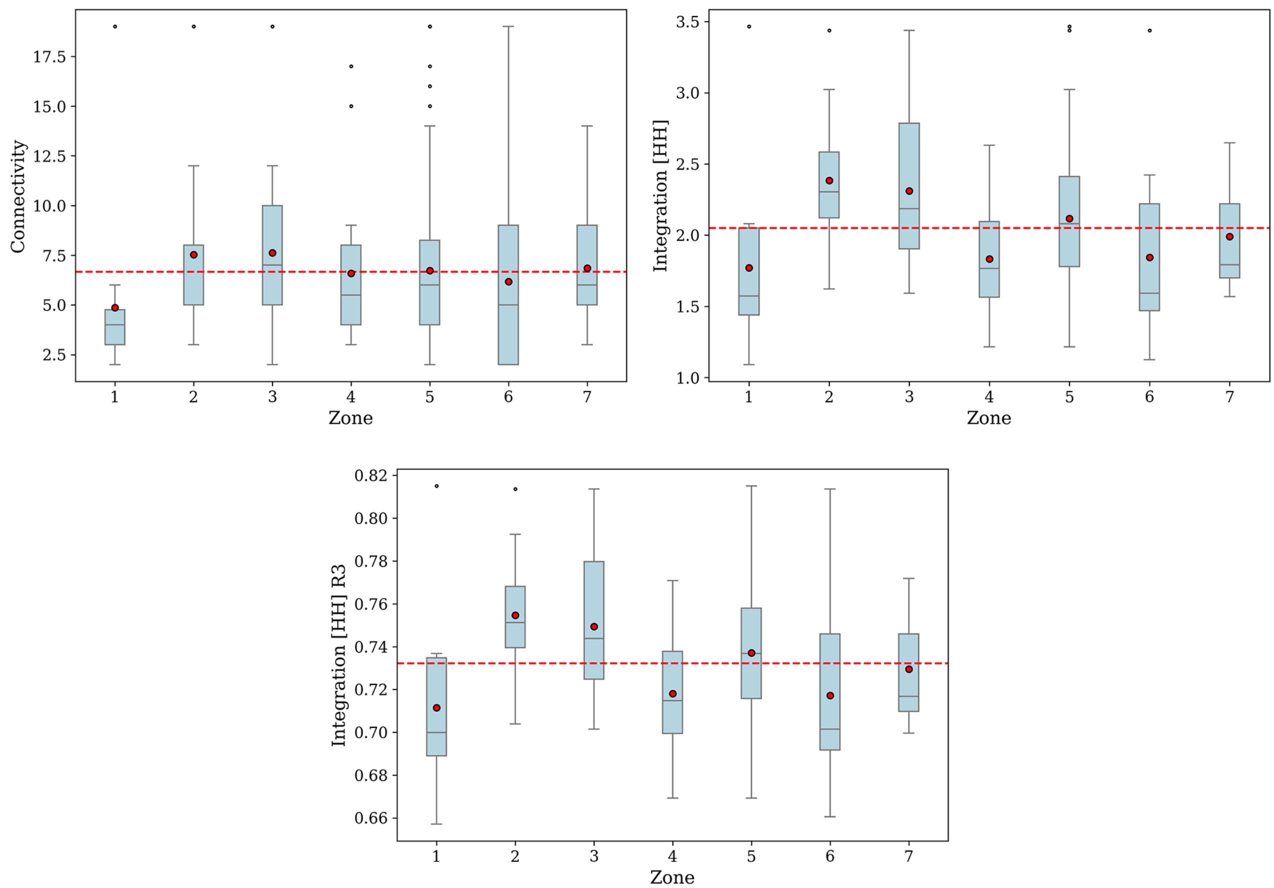

Figure 6. Box plot of the distribution of connectivity, global integration (Integration [HH]) and local integration (Integration [HH] R3) values of the zones

and show more connectivity (Ahmed et al., 2014). The fact that the zones within the study area exhibit a relatively more inorganic form may have revealed the discrepancy between intelligibility and other parameters. However; this discrepancy between the findings may indicate that the components of the axial system in the city can be easily understood and interpreted, but the interactions between the components are limited.

The scatter plots in Figure 9 show the correlation between global integration (Integration [HH]) and local integration (Integration [HH] R3) for each zone. The relationship between global and local integration is defined as synergy and theoretically, the higher the correlation between the variables, the higher the synergy. The average

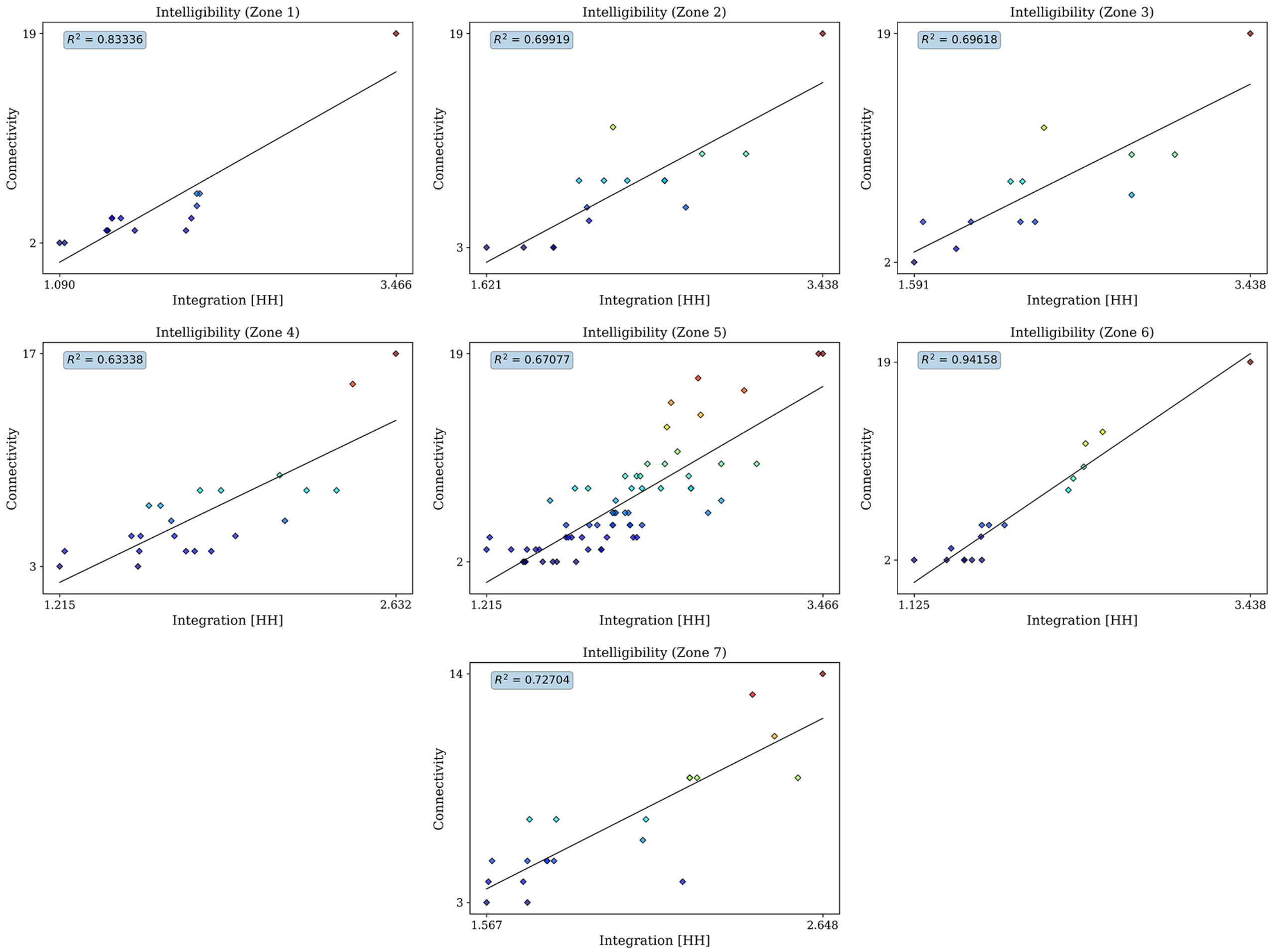

Figure 7. Scatter plot of global integration (Integration [HH]) and connectivity of the axial map – Intelligibility analysis

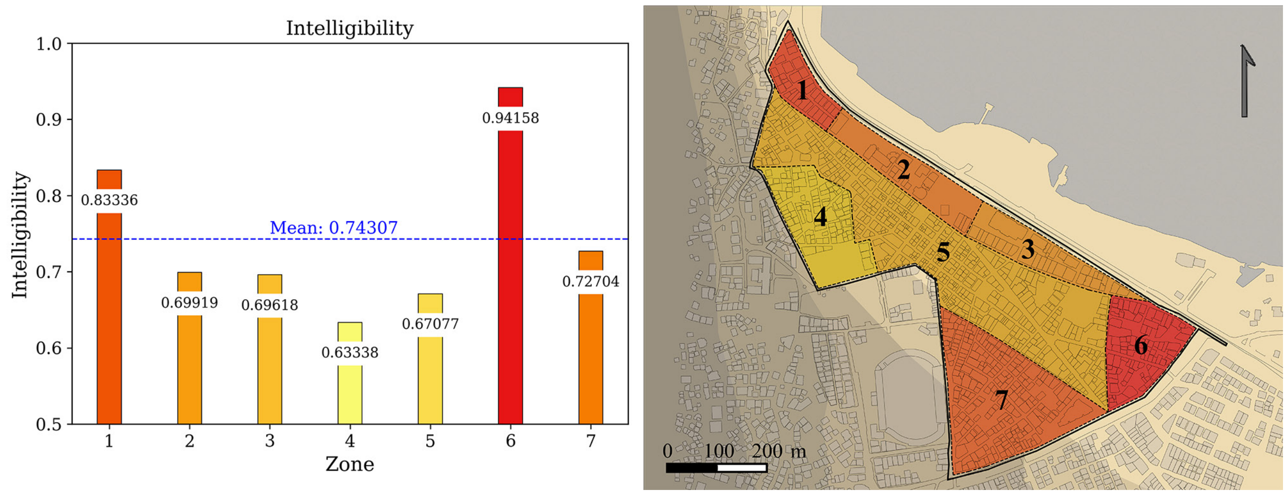

Figure 8. Average intelligibility of the zones (left) and spatial distribution (right)

synergy values for the zones and their spatial distributions are also given in Figure 10. The zone with the highest synergy value in the study area is Zone 7 (R^2 = 0.99833). The relatively lowest synergy value is found in Zone 1 (R^2 = 0.98337). There is a very low difference between the zone with the highest synergy value and the zone with the lowest value. In all zones within the study area, the synergy value is above 0.98 and very close to the absolute positive value of 1. The fact that the zones have a high correlation and synergy value means that the local structure in the zones in the study area approaches the general structure (Orsini, 2018). Therefore, it is seen that the local integration characteristics in the zones are quite compatible with the general integration characteristics of the whole area.

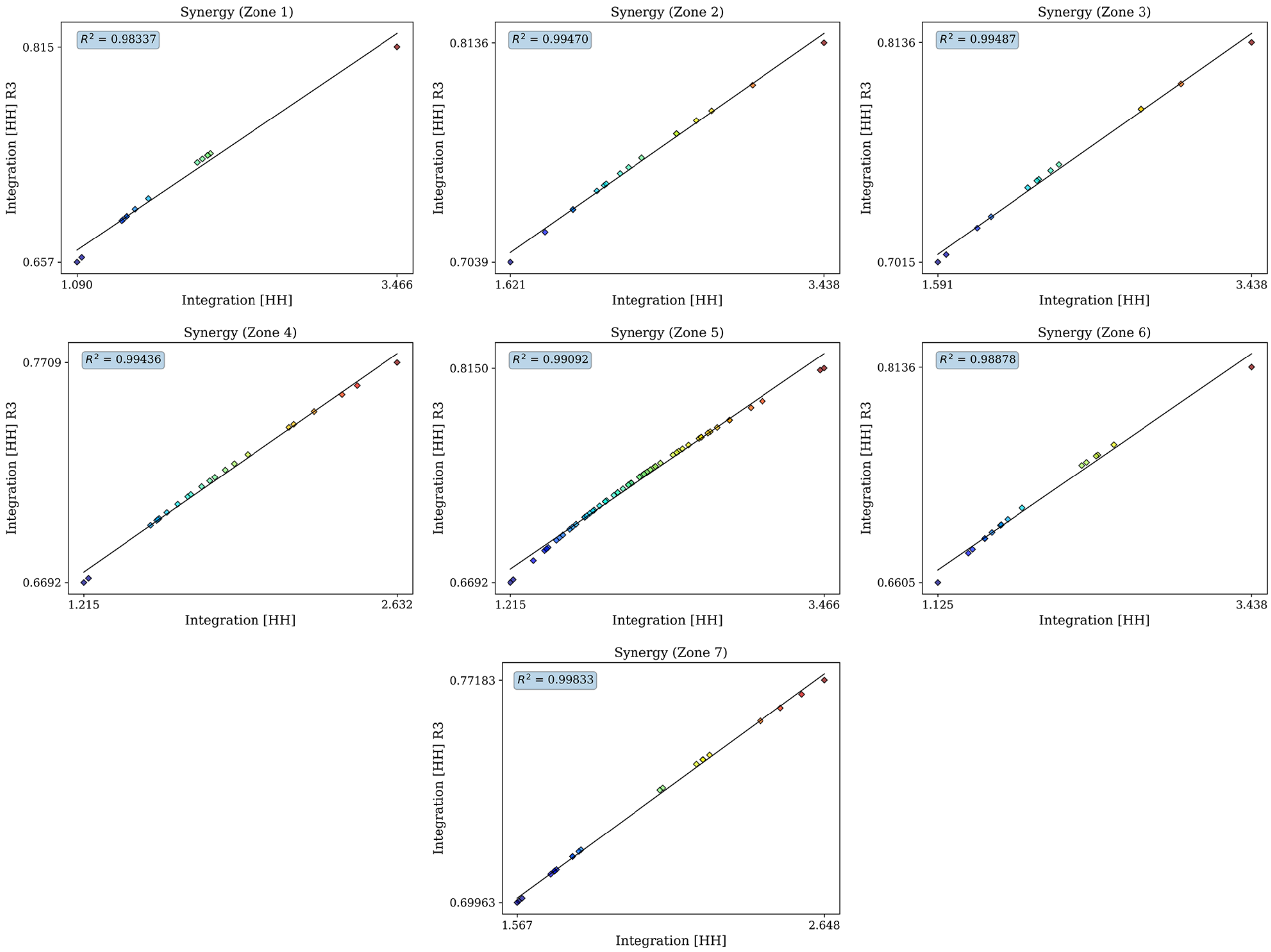

Figure 9. Scatter plot of global integration (Integration [HH]) and local integration (Integration [HH] R3) of the axial map – Synergy analysis

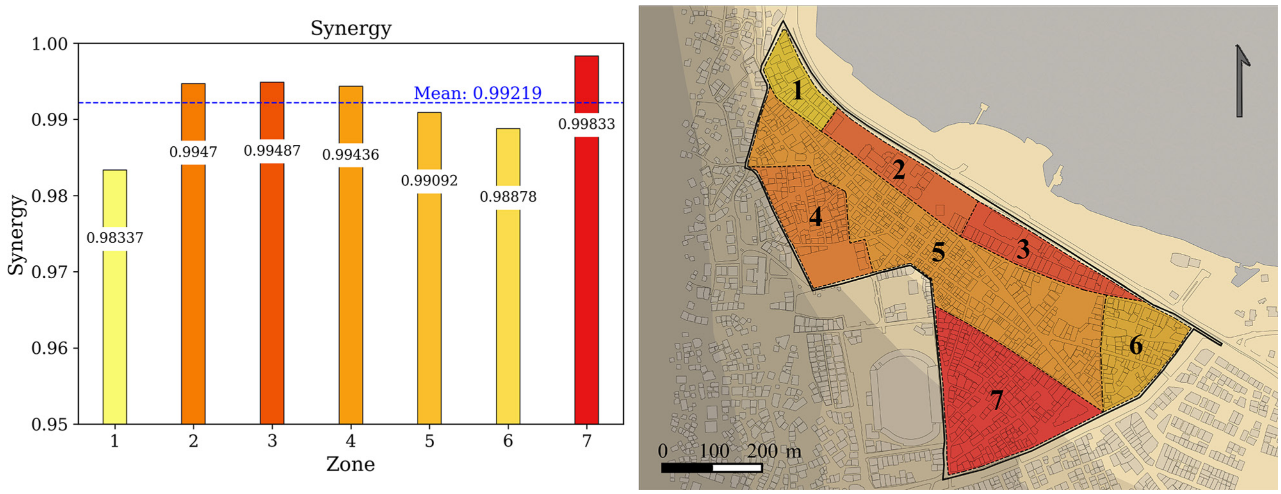

Figure 10. Average synergy values of the zones (left) and spatial distribution (right)

5. Conclusions

The main purpose of the research is to reveal the factors that determine spatial mobility and facilitate movement within the space in the region, which is described as the core of Ordu city center, in the light of the space syntax approach. In this context, a regional utilisation map was created in order to examine the relationship between the use of urban space and spatial configuration. The research area was divided into seven zones in line with different land use characteristics. For each zone, connectivity, global integration and local integration values were obtained as the basic parameters of the space syntax approach, and the intelligibility level and, synergy analyses of the area were made. In the city center, the axes with the highest connectivity are Süleyman Felek Street, Sırrı Paşa Street and Osman Paşa Street. The global and local integration values of these axes with high connectivity values are also higher than the other axes in the city center. There is an intense pedestrian mobility on these axes. There is a high correspondence between the spatial outputs of the research and the actual pedestrian use in the study area. Zone 6 has the highest level of intelligibility, which is defined as the correlation between global integration and connectivity. While it is theoretically expected that areas with high levels of intelligibility are more preferred by users, this zone has a relatively low usage compared to the other six zones. The research was carried out in a core area corresponding to a very small part of the city center. Therefore, the results cannot be generalised for the city center. However, it provides a basis for more comprehensive studies. In future studies, the boundaries of the study area can be expanded. In addition to this, the spatial relationship between the city core and the historical urban fabric located immediately next to the study area should be analysed. In conclusion, urban spaces, which have an important place in the daily lives of urbanites, are places where economic, social and environmental interactions take place. For this reason, addressing the relationship between the spatial configuration and the behavioural patterns of urbanites in all aspects is important in establishing social sustainability and increasing the liveability level in cities.

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