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Research Article

Evaluating Accessibility of Street Network in Neighborhood by Space Syntax Method: The Case of Çankırı

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Abstract

Designing inclusive cities by creating accessible neighborhoods in cities is one of the top agendas in urban planning and design. Therefore, it is important to examine settlements morphology to find out functional contributions to urban design. In this study, the aim is to find street characteristics that support accessibility by comparing street network of current and zoning plan in the neighborhood. The study was carried out in the Esentepe Neighborhood, which is far away from the city center of Çankırı. The fact that the neighborhood is one of the directions of urban development and is located in an area with low accessibility throughout the city requires the development of this area. The study area was evaluated by the space syntax method. The study was designed in three stages. First, the spatial accessibility of the street network in the Esentepe Neighborhood in its current state was analyzed by creating axial maps. Secondly, integration and connection maps were created to evaluate the accessibility of the street network based on the future development plan of the Esentepe Neighborhood. Finally, the current and master plan of the neighborhood was compared to understand the characteristic of accessible street network in the neighborhood. The study results revealed that integration and connectivity values increased compared to the current plan. The creation of simple, interconnected and intersected axes placed in a certain range increased accessibility of area. The long and continuous central axis providing access to the circular central area and the axes connected to this line have the highest integration value in the neighborhood. Space syntax will be a guiding tool on issues such as the selection, design and development of settlements in city plans. The transportation system, which promotes use of spaces around the residence in settlements planned far from cities, contributes to the evaluation of the social interaction areas for residents. The research develops a proposal method in terms of evaluating the future development of neighborhoods for creating a sustainable transportation system.

Keywords:
Accessibility, Çankırı, settlement morphology, space syntax, street patterns

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INTRODUCTION

Cities are trying to take several measures to solve the local and global problems caused by rapid urbanization, which is the common problem in the world in the 21st century. In order to reduce the urbanization in the city center, settlements are designed far from the city center. Designing accessible residential areas is important for developing better physical infrastructure systems in urban areas and creating livable cities. Settlements located far from the city are good testing areas for the evaluation of the future development of cities and create sustainable urban spaces. In order to prevent increase in social and spatial inequity and contribute to the solution of urban problems, it is crucial to accurately understand and manage the urban pattern which is created by bringing together the buildings, streets, parcels and the main physical components of the city (Günaydın & Yücekaya, 2020). The form of the city is shaped by the urban street network. The city is defined by hierarchical street patterns and residential neighborhoods designed based on the neighborhood unit model (Rofè & Omer, 2012; Omer & Kaplan, 2017). In this context, street networks in the neighborhood are one of the important factors affecting urban development that determine the life quality of cities.

Neighborhoods, which are social and cultural living spaces within the urban open space typologies to solve the transportation problem in the city centers, were first introduced by Perry (1929) at the beginning of the 20th century (Eisner *et al.,* 1993). Neighborhoods are one of the smallest living units of cities. Küçükerbaş & Malkoç (2000) classified neighborhoods as the micro-plan scale where the design begins. Neighborhood units, where social and cultural characteristics are reflected, are important study areas in order to create a transportation system with a strong physical infrastructure. Since transportation problems are not resolved in each of the neighborhood units, which are the smallest living units of cities, accessibility problems arise throughout the city.

Transportation is an important concept at every stage throughout history, starting from primitive settlement to the growth of large metropolises, and has a strong impact on the spatial structure in global, regional and local dimensions (Naryaprağı & Polat, 2020). In order to improve transportation in cities, it is aimed to improve accessibility by examining the land structure and transportation systems. Achieving accessibility to certain areas with a new transportation system also changes the land use structures of those areas in the medium and long term (Gerçek, 1996). The transportation system provides accessibility in public spaces. Accessibility is defined as "the ease or comfort of reaching a particular destination" (Kaplan, 1989). Accessibility means that no person's right to access public space is restricted and its usability is ensured, that everyone can go to every place they go in and out in daily life (school, hospital, shopping mall, restaurant, etc.) and participate in every public activity (Evcil, 2014). The design of an accessible street

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network in residential areas also increases the use of space. One of the most important parameters in providing accessibility in cities is walkability. Walkability is a concept that defines the act of movement that enables reaching from one place to another (Mıhçı & Tanrıverdi, 2021). Walkability, a component of smart, sustainable and livable cities, is the most practical tool for citizens to realize their demands and rights to access and participate in urban life (Akkar Ercan & Belge, 2017). A considerably walkable environment invites walking by way of a well connected path network that provides access to the common places people want to go (Southworth, 2005). In the neighborhoods where individuals live, transportation systems should be arranged in a way that does not hinder individuals and in a highly connected way. The street pattern, i.e. the network system formed by the roads, is another factor that ensures accessibility in the cities. Street patterns are categorized in five ways in land use; gridiron, warped parallel, fragmented parallel, loops on a stick, lollipops on a stick (Southworth & Owens, 1993). The gridiron street pattern has a higher potential for accessibility among these street models than others, with multiple intersections and route options. Grid pattern intersection points are numerous and systematically divided, making its network an alternative for pedestrians and cyclists in the equal distribution of traffic and routing. The advantage of the grid pattern is that it helps to achieve a compact settlement to use the spaces efficiently as it mostly consists of linear roads (Salleh, 2018). For quantifying street patterns, Marshall (2005) combined our Citywide Street network types (grid, linear, tributary and radial) with two types of Neighborhood Street network (tree and grid) (Marshall & Garrick, 2010). Street network classification is used to evaluate many research subjects. Therefore, it is important to consider how this classification relates to street design characteristics in order to provide a safer and more sustainable transportation system.

From a designer's perspective, sustainability can be briefly defined as improving the quality of life of societies without exceeding the carrying capacity of global ecosystems, both at the urban and architectural levels (Oktay, 2001). Sustainability in cities is one of the most important concepts that need to be solved today. There is an urgent need to take progress towards sustainability because the population is concentrated in cities. Sustainable urban planning aims at a mixed use approach that aims at the effective use of land in line with factors such as energy, environmental opportunities and transportation (Tosun, 2013). UN-Habitat (2011) lays out the three principal features of sustainable cities and neighborhoods: compact, integrated, and connected. In this respect, the value of integration and connectivity are the criteria to be taken into account in the accessibility assessment of streets. Özbil *et al.,* (2015) stated that the connectivity of street networks increases the accessibility. Connectivity is one of the criteria that are presented for the design of successful pedestrian network (Southworth, 2005). On the other hand, integration enables the discovery of the smallest and largest potential

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areas of action in the urban system. By calculating integration, an urban grid system can be analyzed, mobility can be estimated and at the same time, data can be generated to clarify its existing mobility (Arslan & Şıkoğlu, 2015). The degree of correlation between integration and connectivity values can be used as a measure of intelligibility and predictability of the whole environment (Bafna, 2003). Correlation analysis can be used in order to evaluate accessibility of urban areas by using space syntax method with connectivity, integration and synergy values.

The space syntax method can calculate the mathematical relationships between spaces (Van Nes & Yamu, 2021). The space syntax method, which emerged as a result of rapidly developing technologies in recent years, analyzes spatial data and was introduced by Hillier and Hanson (1984). It examines the relationship between the social and physical structure of the city. This method analyzes how spatial textures develop by solving the mathematical structure of open spaces. Spatial syntax analysis examines the potential for people to come together in urban open spaces by overlapping the fields of movement and vision (Çil, 2006). In this regard, it is a guide in revealing the movement areas with analysis and the planning of the settlement areas. The aim of this analysis is to build a street hierarchy from the most often used open spaces to the least used in a residential area (Şıkoğlu, 2021). Space syntax offers concrete and comparable analytical data that helps to question the impact of city's complex spatial formation on the city or its role in the differentiation of cities (Üsküplü & Çolakoğlu, 2019). Many studies have found a strong relationship between integration value and usage (Hillier *et al.,* 1993, Özer & Kubat, 2007, Baran *et al.,* 1993; Özbil *et al.*, 2011; Günaydın & Yücekaya, 2020). Therefore, street network with high integration value also has high accessibility. Günaydın & Yücekaya (2020a) evaluated accessibility through the current and proposed design of the campus in a sustainable transportation model review. Öztürk Hacar *et al.*, (2020) examined the relationship between pedestrian density and space syntax measurements by comparing the current and the master plan of the campus. Alemdar & Özbek (2021) examined the relationship between pedestrian mobility and land use in the historical center of Kadıköy using wayfinding methods through street texture. Although the accessibility of street texture in many areas is evaluated with different methods based on current and future plans, for the sustainability of cities it is seen that there is a need for studies evaluated at the neighborhood scale, which is the smallest design unit of cities.

In line with the literature research stated above, this study was carried out in the Esentepe Neighborhood of the city of Çankırı. The reason for choosing this study area is that the Esentepe Neighborhood is located in a separate location from the city center. The neighborhood composes a good sampling area in terms of making field observations with its self-enclosed transportation system. This study examines the impact of changing the existing and the zoning plan street network in the

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neighborhood on accessibility. In this context, the study aims to examine and discuss its functional contributions to urban planning by revealing the morphological structure of the transportation pattern in the neighborhoods. The study aims to clarify how the street network model affects the neighborhood accessibility by comparing the current plan and zoning plan. It was based on the research question *"What should be the characteristics of the streets that increase accessibility in the neighborhoods?"* Firstly, an axis map was created according to the streets in the existing satellite data. After that, an integration map was created according to the axis map, and the connectivity values of the streets were determined. Accessibility level was evaluated according to connectivity values. Secondly, a spatial analysis of the street network was made over zoning map of study area. Finally, street characteristics were evaluated by comparing the accessibility levels of the current and future street network in connectivity and integration maps.

METHODOLOGY

Research case

This study was conducted in the Çankırı city. Çankırı is located on the Istiklal Road, which is on the route between Ankara and Kastamonu. The İstiklal Road, which has historical importance, adds value to the city and as a transit point, it creates a potential for evaluation in terms of the physical development of the Çankırı city. The study was carried out in the Esentepe Neighborhood, which resembles a satellite city located in the southeast direction from the Çankırı city center and designed at a separate point in the city in order to reduce the density in the city. As the city is developing in this direction, the Esentepe Neighborhood is a good sampling area to contribute to its future sustainability. In addition, this area, which has the characteristics of a satellite city, was chosen as a research area because it makes it easy to examine the design of the physical space by creating livable environments. According to the TÜİK (2021), the population of the neighborhood is 1,972 people. The study area is 5 km away from the city center and its geographical location in the city is shown in Figure 1.

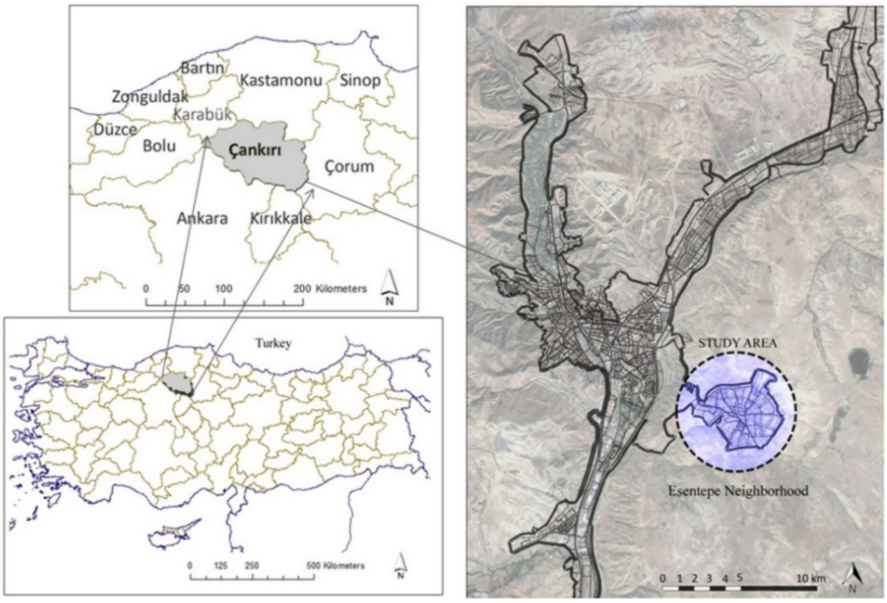

Figure 1. Geographical location of the Esentepe Neighborhood in Çankırı

The study consists of analysis, synthesis and evaluation phases. Space syntax method was used in the research. 1/1000 scale current map and 1/5000 scale zoning plan of the study area, which are provided by the Çankırı Municipality (2021), are used in the research. Çankırı 2021 address-based census (TÜİK, 2021) and field studies were used as basic tools in the study. DepthmapX 0.8 and Autocad 2017 softwares were used to determine accessibility levels.

Space Syntax

Space syntax is a method developed by Bill Hillier and his team in the 1970s to describe and numerically analyze spatial organizations from residential scale to urban scale. The method demonstrates the potential accessibility and perceptibility of streets and alleys that form a street network (Hillier *et al.,* 1993). This method is also a good tool for analyzing the city and making decisions in urban planning and design studies. The space syntax technique that analyzes the relationship between the societies and spatial structures that make it up is based on some theories from residential scale to urban scale (Dalton & Dalton, 2007). Data such as the settlement pattern, the relations between buildings and streets, and the integration of open and closed spaces reflect the social structure of the area (Hillier, 1996). One of the most important properties of the method is that it can visually show how newly designed spatial models work, compare the old and the new, and to some extent, predict future problems in small or large scale designing and planning studies (Kubat, 2015; Günaydın & Yücekaya, 2020a). On the other hand, criticisms of the space syntax methodology are summarized as follows (Kubat, 2015):

- Every researcher can draw a map of slightly different axes of opinion,
- Information on land use cannot be included in the digital environment where building heights and street widths are analyzed,
- Pedestrian sidewalks and urban highways have the same value,

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• When research focuses on only a region of the city rather than the whole, it is left to the initiative of the researcher to decide how to limit the view axes map.

• Viewing axes do not make a difference in evaluating metric lengths,

• Ignoring that the line of sight may be blocked due to differences in topography.

In the space syntax method, integration and connectivity values are evaluated. The intelligibility of a space expresses the relationship between its connection and integration values (Günaydın & Yücekaya, 2020a). The intelligibility of a space is related with the amount of connection and integration of the system, and the formal perception of the space can be explained by the correlation between these parameters (Tanrıverdi Kaya, 2020). Although the relationship between connection and integration value provides the comprehensibility of the space, it is a limitation that land use or structural features such as the presence of obstacles along pedestrian paths related to accessibility, the surface of the pavements, and the slope of the road are not evaluated on the space.

Connection is the statistical term of spaces that can directly be linked to another space (Klarqvist, 1993). Connection is the number of axial lines connecting or intersecting each line in the system (Ahmed *et al.,* 2014). Connectivity value also provides information about the accessibility of the space. The integration value gives the number of connections where each part is joined or separated. Integration of a node is stated by a value that shows the extent to which a node is separated or integrated from a system fully or from a partial system consisting of nodes several steps away (Volchenkov & Blanchard, 2008). Integration maps obtained by space syntax method express pedestrian and vehicle movement in the urban system (Hillier, 2007). The integration value is the point where each part in the system joins or separates and defines how central it is in the system. Open areas that integrate with the settlements are gathering areas which are suitable for commercial, social or cultural activities because of the slowing or stopping of pedestrian movement (Hillier, 1984, Hillier, 1996, Gündoğdu, 2014; Tanrıverdi Kaya, 2020). The integration value indicates accessibility, where a high value indicates a high correlation between the axes and a low value indicates a low connection between the axes. This value is of great importance in describing how movements operate within the urban system.

Axis maps created in order to reveal the utilization potential of the roads in the space syntax method are created by drawing the longest and fewest number of lines or sight lines passing through every accessible place in an urban area or building based on a scaled map (Özer, 2006). These maps explain where and how to reach the individual in a spatial organization, what kind of relationships exist between the functions and the spatial composition that make up this composition, and the movement within the space (Gündoğdu, 2014). With space syntax analysis, the hierarchy of the least and most used axes in the settlements is formed. The map is formed by calculating the integration value on the axial map created by drawing the axial lines, and by ranking the six different values from the largest to the smallest according to the spatial integration value shown in different colors. In the space syntax method, the most important factor determining the mobility in the area is the integration value (Özbek, 2007). Axes with high integration value express the axes that are accessible within the space pattern and have strong connections with the network structure, while axes with low integration value represent the axes that are difficult to access, separated from the space pattern (Hillier *et al.,* 1993). The integration value of the axial line, which is evaluated by calculating and averaging the changes in direction required to reach one place to another for all spaces in the system, determines how much this line is used in the system.

Analytical Framework

The study is focused on the comparison of the spatial analysis based on the current plan and zoning plan street network in the Esentepe Neighborhood. It was carried out in three stages: analysis of the current street, analysis based on future transportation planning and comparison of the spatial features resulting from these two designs.

In the first part of the study, roads were drawn on AutoCAD over the satellite image of the Esentepe Neighborhood. After that, this drawing was transferred to DephtmapX software and the axial map was created. By analyzing the axial map, integration and connectivity maps were created. Analyzes were made on these maps and the current accessibility situation of the study area was revealed.

In the second part of the study, the 2022 zoning plan of the Esentepe Neighborhood, which is planned for the future, was taken as basis. The street network of the study area was analyzed according to the zoning plan in the AutoCAD file, which is obtained from the Çankırı Municipality. Axial maps were created according to the roads transferred to the Depthmap X 0.8. The software creates axes according to the longest and shortest connections within closed lines. In the axial map the axes with the longest and most intersections were ranked according to their density, and integration and connectivity maps were created. Integration maps are important to explain how both vehicle and pedestrian movements work within the urban system and to understand how often public spaces are used (Hillier, 2007). The integration value obtained in the space syntax analysis shows the effect level of accessibility, and this value decreases from red to blue.

In the last part of study, evaluations were made on the development of the transportation structure by comparing the current and the future situation. In this study, by comparing the results obtained with the space syntax method, which allows the comparison of the current situation and the future plan, answers are sought for how accessibility values are affected based on the sustainable transportation system model. In order to create sustainable neighborhoods, the impact of the street network on change was examined.

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In order to determine the street network characteristic of the neighborhood, Marshall & Garrick (2011) classification, which are Linear tree (LT), Tree Tributary (TT), Radial Tree (RT), Grid Tree (GT) and Linear Grid (LG), Tributary grid (TG), Radial Grid (RG), Grid grid (GG) were used. This model was evaluated on connectivity and integration maps of the existing study area and zoning plans. By correlation of connectivity and integration value, scatter values of intelligibility values were obtained. The current and zoning plan accessibility levels are compared on the synergy graphs. This study seeks to answer how connectivity and integration values affect accessibility. The conceptual flow chart describing the study method is given in Figure 2.

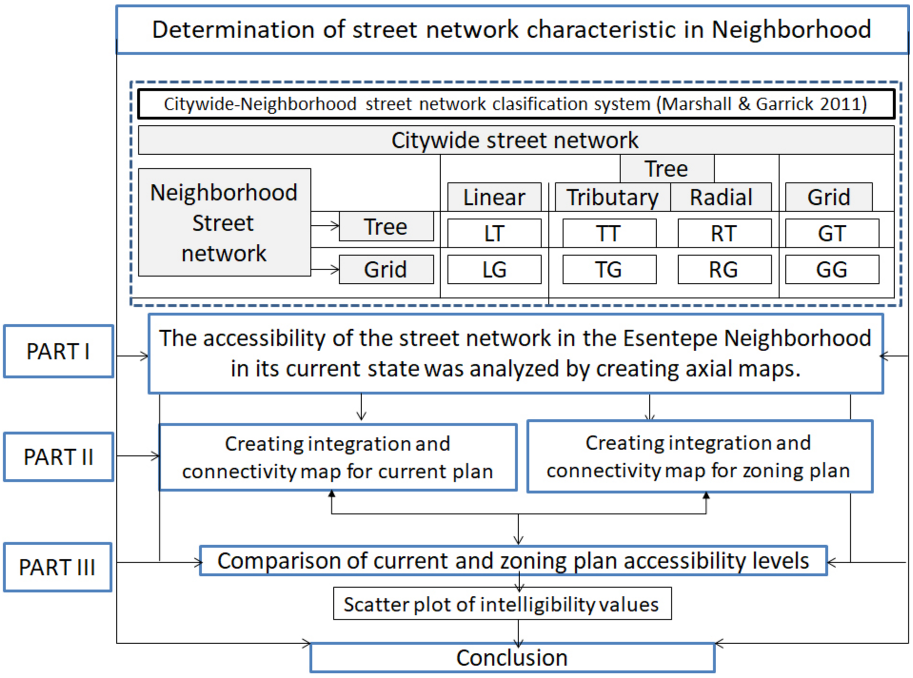

Figure 2. Study method scheme

RESULT AND DISCUSSION

Evaluation of the Current Plan

The Esentepe Neighborhood is located in the southeastern part of the Çankırı city center and is under development. In the first part of the study, existing street network is created. In this context, axes were drawn on the satellite image regarding the existing situation of the area. The satellite map of the study area is shown in Figure 3. There are 18 streets on the current map and it has been observed that the street network has irregularly spread from the center of the neighborhood.

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Figure 3. Satellite image of the Esentepe Neighborhood

The axial maps were created based on the neighborhood satellite image. Integration and connectivity values were analyzed for evaluating accessibility. The integration value is the point where each part in the system joins or separates and defines how central it is in the neighborhood street network. Integration value obtained in the study gives the number of connections where each part joins or separates. The integration value obtained in the analysis shows the degree of influence of the visible areas, and this value decreases from red to blue. Integration map of current plan is given in Figure 4a and connectivity map of curent plan is given in Figure 4b. The integration and connectivity values of the streets in the neighborhood are given by calculating on the DepthmapX (Table 1).

a

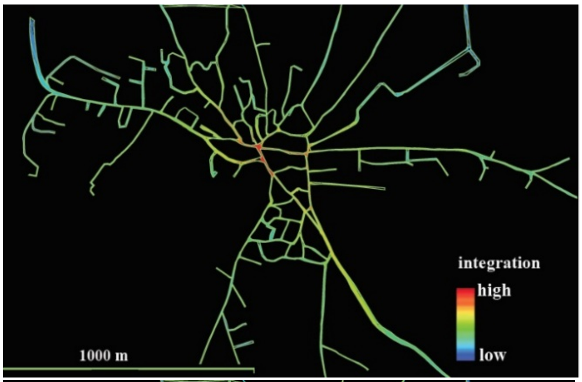

Figure 4a. Integration map of current plan

b

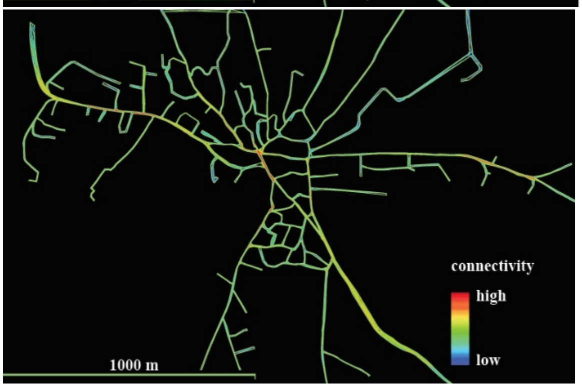

Figure 4b. Connectivity map of current plan

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Table 1. Integration and connectivity values of streets in current plan

	Streets	Integration value	Connectivity value
1	Cami Street	1.12	3
2	Çağlar Street	0.77	4
3	Su deposu Street	0.71	2
4	Tuzla Street	0.9	3
5	Tuzla-2 Street	0.63	3
6	Gökçe Street	0.88	5
7	Akyol Street	0.85	4
8	Esentepe Street	0.88	7
9	Bahçeler Street	0.94	4
10	Onbaşı Street	1.04	5
11	Okullar Street	0.67	4
12	Çamaşırhane Street	0.9	4
13	Doğantepe Street	0.98	6
14	Birlik Street	0.98	6
15	Fidan Street	0.68	4
16	Eğitmen Street	0.7	6
17	Başağa Street	0.65	4
18	Demir Street	0.81	3

It is seen that the current map of the Esentepe Neighborhood has morphologically dispersed from the center. The neighborhood street network classification is Radial tree (RT). When the connectivity and integration maps showing the metric accessibility level are examined, it is seen that the accessibility level decreases as you move away from the center. The areas with the highest level of accessibility are close to the center, while low accessibility areas are the farthest areas where the connections are fragmented in the neighborhood. The places with the highest level of accessibility are the regions close to the center, while the places where the level decreases are the farthest regions where the connections are interrupted in the study area. Neighborhood access is provided by two main central axes: Esentepe and Akyol streets. The Esentepe Street is the longest axis connected to the city and has the highest connectivity value. It became apparent that the accessibility level of the axes connecting to the city center is also important in the area. The Akyol Street, which connects with the Esentepe Street, passes through the middle of the neighborhood. It is seen that this street has a high level of accessibility. The streets of Doğantepe, Birlik, Cami, Tuzla, Gökçe, Bahçeler, Onbaşı, which are connected with each other in the center of the neighborhood, have high integration and connectivity values. The central axis providing access to the circular central area and these streets connecting to this line are also the axes with highest accessibility in the area. These streets also have high integration and connectivity values. Central axis that provides access to the circular center area and these streets that are connected to this line are the axes with the highest access in the area.

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Accessibility value is high in these axes, as they form a centralized network model that is interconnected. They are also connected to the Esentepe Street, add connectivity to the system as they are the longest hangers and ensure continuity. Although the accessibility level of other axes spreading from the center is high, the access value of these axes reduces as the distance from the center decreases. The integration and connectivity value of other transportation axes in the area is low due to their lack of continuity, distorted directions and dead-end streets, and these streets reduce the level of accessibility in the system.

Evaluation of the Zoning Plan

The Çankırı Esentepe Neighborhood Revision Zoning Plan was entered into force according to the council decision dated 07.03.2022 and numbered 63 (Çankırı Municipality, 2022). The roads and land uses (sports, education, park, trade, cultural housing area etc.) are located in the proposed plan. The Esentepe Neighbourhood in the zoning plan is shown in Figure 5. Integration and connectivity of zoning plan maps are created to evaluate accessibility. Integration map of zoning plan is given in Figure 6a, connectivity map of zoning plan is given Figure 6b. In accordance with these maps, the integration and connectivity values are calculated. Integration and connectivity values of 14 streets that maintain their status according to the current map are seen in Table 2.

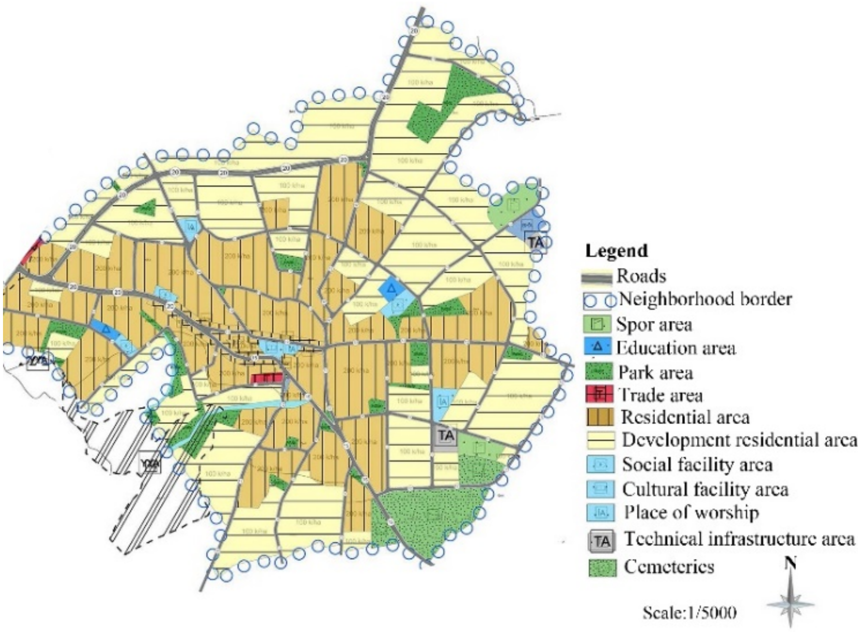

Figure 5. Zoning plan of the Esentepe Neighborhood (Çankırı Municipality, 2022)

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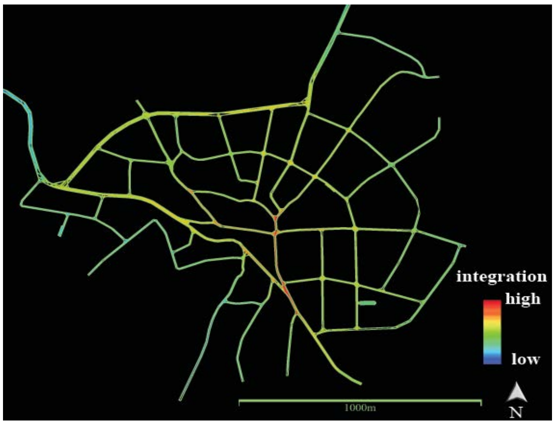

Figure 6a. Integration map of zoning plan

Figure 6a. Connectivity map of zoning plan

Table 2. Integration and connectivity values of streets in current plan

	Streets	**Integration value**	**Connectivity value**
1	Cami Street	1.06	3
2	Su deposu Street	0.71	2
3	Tuzla-2 Street	0.63	3
4	Gökçe Street	0.88	5
5	Akyol Street	0.85	4
6	Esentepe Street	0.88	7
8	Onbaşı Street	1.04	5
9	Okullar Street	0.67	4
10	Doğantepe Street	0.98	6
11	Birlik Street	0.98	6
12	Fidan Street	0.68	4
13	Eğitmen Street	0.7	6
14	Başağa	0.65	4

According to the zoning plan, the street network is designed as radial grid (RG). The street network is getting closer to the grid system. Integration value shows the pedestrian and vehicle movement and the centrality value of the axes in the system. There are more intersected streets in the zoning plan. The region where axes intersect in the center reaches a high value. The streets of Esentepe and Akyol, which connect the neighborhood to the center, are not change in the zoning plan. They have a high integration and connectivity value in the street network.

The streets of Doğantepe, Birlik, Gökçe, Onbaşı, which have high integration and connectivity values among all axes in the current situation map, also have high values in the zoning plan. It was observed that the connectivity and integration values of the other axes were low. There is a circular expansion towards the regions where the accessibility level is very low. The streets of Çağlar, Tuzla, Bahçeler, Çamaşırhane, Demir, which are on current plan, have lost their form and have undergone a change in the zoning map. It has been found that the streets with high accessibility values in the current plan also maintain their form in the zoning plan and have high connectivity and integration values.

Comparison of Current and Zoning Plan Accessibility Levels

In the study, first, the accessibility situation of the Esentepe Neighborhood in the province of Çankırı was analyzed. For this purpose, segment analysis was performed and an integration map measuring the accessibility value was created. In the integration map of the province of Çankırı, the maximum value is 2521.18, the average value is 1649, and the minimum value is 4.02. In the integration map, it is seen that the Esentepe Neighborhood has a high level of accessibility with a yellow rank. The integration value of the axes located within the neighborhood is above the average throughout the province. Therefore, it turns out that the neighborhood is integrated with the city and open to development. The integration map of the province of Çankırı is given in Figure 7.

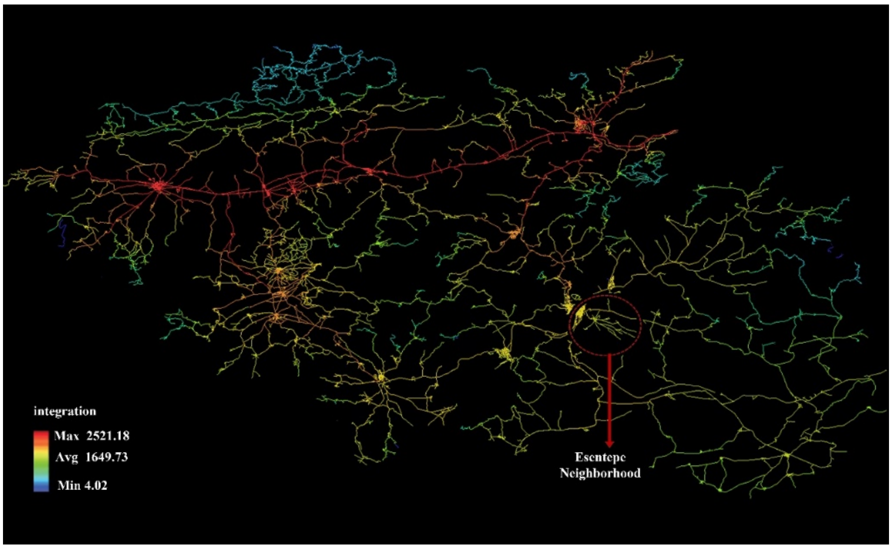

Figure 7. Çankırı city integration map

In order to determine the difference between the accessibility levels of street in the Esentepe Neighborhood current plan and the zoning plan, a comparison was made based on the minimum, maximum, and average values of all axes in the connectivity and integration maps. In both plans, the integration value was examined first. In the current map, the maximum value of integration is 1.14, the average value is 0.68, and the minimum value is 0.38. The maximum value of integration in the zoning plan is 1.26, the average value is 0.88, and the minimum value is 0.44. It was revealed that there is a 30% increase in the average integration value with this transportation plan proposed in the zoning plan. Figure 8a

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shows current map of integration values and Figure 8b zoning plan of integration values (max., min and avg).

a

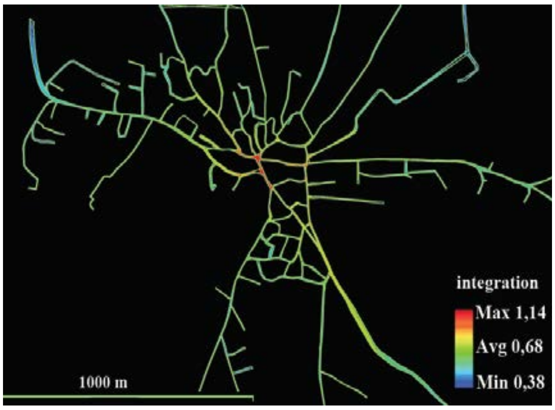

Figure 8a. Current plan of integration values

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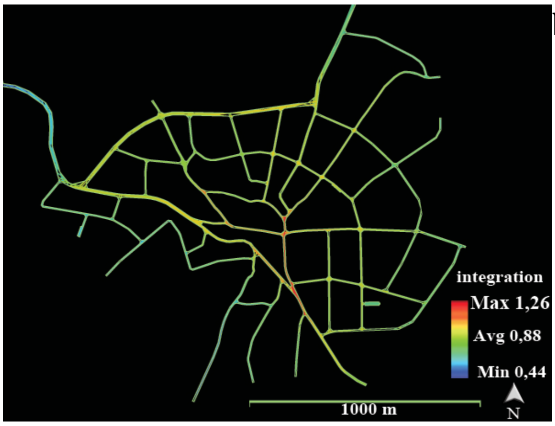

Figure 8b. Zoning plan of integration values

When it is compared with the current plan, the integration value of the street network in the zoning plan is higher. The rise in the integration value shows that the accessibility of the neighborhood transportation network has also increased. In addition, culs-de-sac streets with low accessibility in the current plan are not included in the zoning plan. In the proposed transportation map, the radial axes expanding outward from the main center have a high integration value. Current plan of connectivity values is given in Figure 9a, zoning plan of connectivity values is given in Figure 9b.

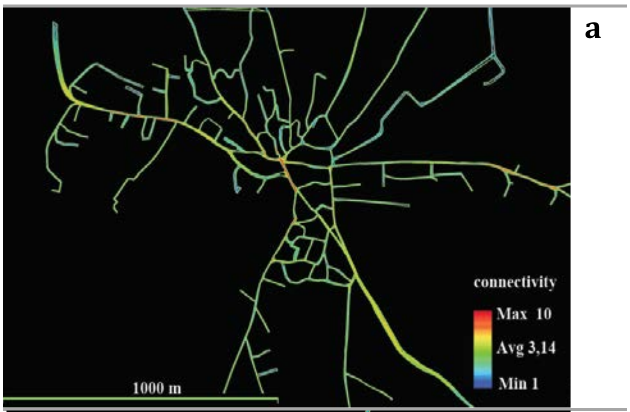

Figure 9a. Current plan of connectivity values

Figure 9b. Zoning map of connectivity value

Connectivity has a maximum value of 10, an average value of 3.14, and a minimum value of 1 on the current plan. The maximum value of integration in the zoning plan is 7, the average value is 3.47, and the minimum value is 1. It was revealed that there is a 9% increase in the average connectivity value with the transportation plan proposed in the zoning plan. It was also found that the connectivity value has a lower increase than the integration value. The decrease in the number of streets included in the transportation system in the zoning plan and the decreases in the number of intersections and number of axial lines are the reasons for the low increase in connectivity. Synergy graphs were created by considering the values obtained from the correlation of integration and connectivity map. The effect value of this relationship was calculated according to the formula consisting of these maps correlation. The synergy graph of the current plan is given in Figure 10a and the synergy graph of zoning plan is given in Figure 10b.

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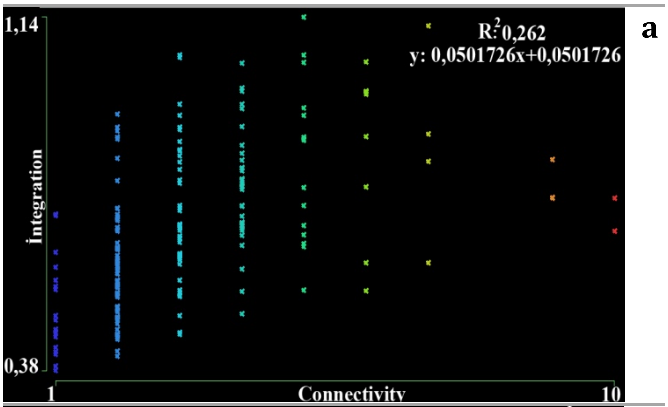

Figure 10a. Scatter plot of intelligibility in current map

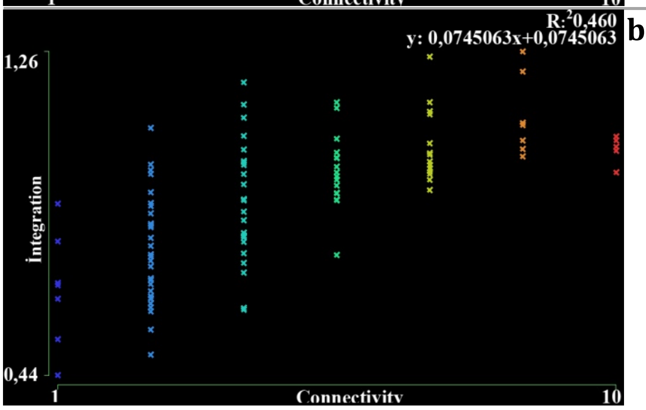

Figure 10b. Scatter plot of intelligibility in zoning map

Considering the synergy graphs obtained from the correlation of integration and connectivity values, there was a 75% increase in the proposed map compared to the current map. This result shows that the current situation has high connectivity and choice alternatives, but accessibility can be increased with simpler, functional and resolved designs. There are some changes in spatial characteristics in street networks. In order to examine this change, the maximum, minimum, average, standard deviation, count values were evaluated. All of the integration and connectivity values in the current zoning plan are given in Table 3.

Table 3. Current and zoning plan connectivity and integration values

	Current plan values		**Zoning plan values**	
	Integration value	**Connectivity value**	**Integration value**	**Connectivity value**
Max	1,14	10	1,26	7
Avg	0,68	3,14	0,88	3,42
Min	0,38	1	0,44	1
Std Dev	0,16	1,68	1,17	1,55
Count	205	205	108	108

As a result of the analyses, an increase is observed in the integration and connectivity value and the accessibility level of the zoning plan of the neighborhood compared to the current plan. While the integration value increased by 30% in the zoning plan, the connectivity value increased by 9%. Compared to the current plan, connectivity decreased while integration increased in standard deviation values in the zoning plan. In

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the master plan, a lower standard deviation in the link value usually means that the data is more accessible or predictable. On the other hand, the integration value increase in the master plan improved the neighborhood design in terms of pedestrian and vehicle use and public land use. Although the average value of the connectivity value increased, its maximum value decreased. The reason for this decrease is the lower number of axis lines. It was seen that one of the most important factors supporting accessibility in neighborhoods is the street network model. Street network with more intersections, route options, and more connections have a higher level of integration. The combination of the connectivity value, which ensures the connectivity of the streets and the integration value, which indicates the intersection of the streets, guides the evaluation of the accessibility level. It was observed that there are similar axes between the regions where the accessibility values of the streets are high in both plans. The streets with high accessibility values in the current plan have been effective in forming the zoning plan.

This study differs from other studies in that it evaluates the correlation of connectivity and integration values on the current and future plans to design an accessible street network in neighborhoods. The study findings of Alalouch *et al.,* (2019) provided an analytical framework through which master plan proposals for new areas in the city can be assessed in terms of how land-use distribution may change as a result of the proposed street network. Street network accessibility provides information to study many topics. There are many researches on investigating street network accessibility of neighborhood. Jabbari *et al.,* (2021) assessed the condition of accessibility and connectivity provided by streets network to pedestrians' walkability by using historical documentary technique and space syntax analyses. It shows that the street network affects the distribution of people in terms of pedestrian movement flows and that access to these movement flows is highly correlated with the walkability of the neighborhood pedestrian movement flows and that the access to these movement flows is highly correlated to the neighborhood walkability (Bielik *et al.,* 2018). The other study results show that relational properties of street layout and design explain walking behaviour (Baran *et al.,* 2008). It is clear that street network analysis in neighborhoods contributes to accessibility. Li *et al.,* (2021) stated that there is an effect and relationship between the accessibility structure and its spatial vitality of the street network in their studies. The research findings of Lebendiger & Lerman (2019) also show the significant role of spatial accessibility analysis in transit planning. There is also a need to clarify how the street network characteristics should be designed. Rifaat *et al.,* (2012) stated that the design philosophy of a disconnected, curvilinear street network results in the creation of a series of physical barriers to movement between different parts of the city and neighborhoods. While it is stated that the curved design of the streets in the neighborhood to increase the pedestrian safety and accessibility value is effective (Perry, 1929), it was found that the culs-de-

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sac streets in the study area reduce the connectivity value of the roads. Due to the diversity of the topographical structure in the neighborhoods, it is not possible to apply this subdivision in certain regions. Although grid or curved street arrangements are considered on the zoning plan, regions with slopes in the three-dimensional structure of the land are a limiting factor for accessibility. For this reason, future studies that consider the slope factor in the street network design gain importance.

According to the neighborhood street network classification developed by Marshal & Garrick (2010), the study area has transformed into the grid system in proposed plan. In this study, it was revealed that the linear, connected and grid street network support accessibility. On the other hand, while assessing street network this classification is useful for reseach. Kim & Sohn (2002), in their urban street analysis results in different areas using space syntax theory, concluded that urban configuration affects the physical formation of cities. In his research, Has (2022) compared the route change of historical places in the Erzurum City Center and their present and past accessibility and integration due to the expansion of the city, and determined that the place, which is a valuable commercial building today, has not lost its feature in the past and today. In the study of Günaydin & Yücekaya (2020b), it was found that as the city grows, the values measuring the integration and connectivity relationship decrease. In the study of Şahin Körmeçli (2023) evaluating the Çankırı city accessibility, it was seen that the city center has high accessibility, and the city needs development in different directions. Topçu & Southworth (2014) evaluated the livability of residential areas in nine different grid street models of San Francisco neighborhoods and emphasized that accessibility, comprehensibility levels and density criteria are inversely proportional to the degree of livability in the study areas. This study, compared to other studies, concluded that the characteristic features of the street network affect the accessibility of the neighborhood, and as the neighborhood design is developed in master plans, accessibility increases, which in turn affects urban development. It is practical to examine this classification in terms of revealing different subject in other studies in determining the character of the street network. Although the adopted model has been used effectively, it may not be the optimal choice. This is one of the limitations of the research.

CONCLUSION

Residential areas are designed away from the center in order to solve the density problem that occurs in city centers with the increasing population as a result of rapid urbanization. There is a need for accessible and sustainable design of residential areas, which are located far from the city center. The street network, which is one of the most important factors shaping the urban form, should be examined within the neighborhood. Neighborhood units that have emerged to solve transportation problems are the best observation areas for this. The

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Esentepe Neigborhood, which is located at a different point from the center of the city of Çankırı, which was selected as the study area, was evaluated with the current plan and the zoning plan of the street network by space syntax method, and the results of the accessibility level were compared. As a result of the study, the level of accessibility in the zoning plan increased compared to the current plan. The creation of simple axes that intersect with each other in the zoning plan, in a certain rhythm, i.e. intervals, increased the accessibility of the space. It was observed that the accessibility value decreased as you move away from the center in the neighborhood. The long and uninterrupted streets passing through the middle of the neighborhood expanding from the center and connecting to each other have a high potential in terms of accessibility. On the other hand, it was revealed that culs-de-sac streets in the area have a low level of accessibility and continuity in the zoning plan cannot be provided. Connectivity and integration values guided the layout of the neighborhood's accessibility and land uses. It has been determined that the integration and connection values have increased in the zoning plan when compared to the current plan. Increasing integration and connection values in the zoning plan will be effective in increasing land use by increasing the accessibility of the neighborhood street network. According to the street network design, the high accessibility in the center has shaped the location of land uses more intensively in the center. In the zoning plan, it is seen that land uses such as housing, trade, education, sports and park areas are located in areas with high integration and connection values. It has been determined that the current condition of the streets is a guide in neighborhood design and that it would be beneficial to determine land use decisions in advance in terms of creating accessible neighborhoods. It was found that the current state of the streets is a guide for neighborhood designs and that it would be beneficial to determine land use decisions in advance to create accessible neighborhoods.

As Çankırı has a single-centered urban macroform, the number of residences in the center is increasing. The city is open to development with axes in different directions connecting to the center. Settlements like the Esentepe Neighborhood connected to the city center and similar to satellite cities should be evaluated in terms of accessibility. This study is based on the hypothesis that the characteristics of the street network have a significant impact on neighborhood accessibility. In this respect, the space syntax method was used to answer the research question of how the street network of the neighborhoods should be designed accessible. Designing every neighborhood in cities as accessible will contribute to the sustainability and livability of the city as a whole. The smallest design units for the sustainability of cities are neighborhoods, so if each neighborhood is designed to be accessible, both walkable and livable cities will be created. This study contributes to determination of the change before and after a design study to be realized in the city in the future. It also proposes a model for the sustainability of cities with an

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evaluation made by looking at the relationship between the city as a whole and the neighborhood scale.

Street network classification is one of the major factors that determine the use of space in neighborhoods. Increasing the level of accessibility by using the space syntax method tool while creating street networks in residential areas is important to create livable cities. This study uses the space syntax method to contribute to the database for the development of urban morphology. The space syntax method has been a guiding tool for the creation and evaluation of residential areas in an accessible way by solving the mathematical structure. The method has an important place in identifying and solving post-design problems by analyzing spaces with different characteristics. Topçu (2009) stated that the space syntax method represents an important development in terms of obtaining a more meaningful result by examining the relationship between economic structure and spatial configuration instead of the theme of urban design, pedestrian mobility and morphology. Space syntax offers a range of analytical techniques to represent and analyze urban topology to explore the connection between the city form and its function, and analyze urban topology (Lebendiger & Lerman, 2019). In this context, this method is a good method evaluation for the solution of the problems in cities whose dynamism is constantly changing.

As a matter of fact, it is stated that livable cities are accessible, usable, shared and integrated spaces where social groups and all individuals come together freely and comfortably (Günaydın & Yücekaya, 2020). In order to ensure livable cities, it is necessary to develop sustainable street design in the neighborhood, which is a physical design tool. The development of the obtained street design criteria in the neighborhood units of local governments in different cities will contribute to social cohesion in societies by increasing the livability of cities. Evaluating street accessibility at the neighborhood scale in large cities and developing design guidelines can contribute to urban sustainability.

While the current plan is generally discussed in the studies based on the transportation model in the creation of sustainable neighborhoods, in this study it is important to evaluate the development plan and examine its contribution or deficiencies to the future spatial characteristics. The study will create new ways for other studies for examining the contribution of the sustainable transportation model to spatial characteristics, studying the use of space according to accessible regions and social interaction in neighborhoods. The research proposes an evaluation model by comparing the current and zoning plans with the space syntax in order to evaluate the development of cities in the future and to create an accessible transportation model.

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Resume

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