Interpretations and Comparisons of Pedestrian Movement and Land Use Activities in Kadıköy Region Using Space Syntax Method

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Abstract

Prevailing theories of urban form suggest that pedestrian movement characterizes land uses, which in turn take advantage of 'natural movement' generated by the grid configuration. The present paper investigated a configurational method of the urban grid for transit movement and as the main generator of movement patterns. A morphological method, namely space syntax analysis, was employed in the Kadıköy region, with an aim to understand, how the pedestrian movement was generated via a vis the urban layout. Axial analyses include defining the central cores of the settlement and determining the most intense movement in those centers, whereas segment analysis determines the scales and limits of the movement towards the points in such centers. Accordingly, axial maps were developed and analyzed in order to forecast the general functioning of Kadıköy grid. Measures of 'axial integration' for properties of the grid and segment analyses in micro-spatial characteristics of Kadıköy were used to investigate transit movement with an aim to gain an insight into movement patterns. Furthermore, correlation of segment and axial analyses were also performed to better simulate the movement. The present paper aimed to investigate the density of pedestrian movement by the characteristics and syntactic properties of urban space that identified limitations in the prediction of movement.

Keywords
pedestrian movement; space syntax; land use effects; İstanbul

1. Introduction

Urban design, public spaces are referred to as continuous and integrated spatial systems that connect every physical element that has an impact on social and economic dynamics within the urban setting. Well-designed spaces with connectivity systems promote pedestrian movement and support a vivid and viable range of uses. Streets are the key elements of this network, which constitute the structure of the urban fabric that is effective on human behavior in the way they use, spend time, and move, which directly affect locations of land use patterns. A conceptual approach through movement patterns was used as the analysis method for the purposes of the present paper.

Space syntax theory aims to describe the consequences of human activities, including pedestrian flow and land use, by means of axial line analyses of road networks (Yamu,

Poplin, Devisch, De Roo, 2017:137; Zhou, 2012:76). It is a kind of spatial language that can provide an insight into the relationship between a spatial form and human behavior. The space syntax theory and its analytical methods have primarily been applied to morphological analysis of architectural design and urban forms (Cuesta, Sarris, Signoretta, Moughtin, 2012:77; Shirazi, Keivani, 2019:101). The space syntax theory features several computational measures used with axial maps in an urban context. The primary syntactic measures of space syntax are connectivity, integration, and control values that are calculated on the basis of the axial lines of the road network structure (Hiller, 1996). The Space Syntax method can efficiently interpret and predict pedestrian flow through spatial configurations to correlate the syntactic parameters of space syntax, including connectivity, integration, and density (Brebbia, Galiano-Garrigos, 2016:240). Hillier's Theory of

Natural Movement suggests that street centrality (the configuration of the urban grid) itself is the main generator of pedestrian movement, which emphasizes the importance of urban form. (Zhang et.al., 2022:3)

Understanding the pattern of formations and development of settlements is not merely about the urban form per se. Community relations and types of location used in the settlement are also an effective factor with regard to the formations of the settlement. All those data incorporating the interface features, including settlement texture, relations between buildings and streets, physical fabric of locations, and integration of indoor-outdoor spaces, etc. are the reflection of the social structure of the region in question. The present study aimed to investigate correlations between the variables of the built environment and walking behavior of individuals –evaluating differences based on the uses of the space– street segments and to determine the most reliable measures both in micro and macro scale to analyze the relation between walking behavior and the built environment in Kadıköy.

Space syntax is both a *theory* of urban planning and design and a software-based *technology*. It is an evidence- based approach to planning and design, with a focus on the role of spatial networks in shaping patterns of social and economic transactions. Through a configurational analysis of a street network, the Space Syntax methodology investigates relationships between spatial layout and a range of social, economic, and environmental phenomena. Those phenomena include patterns of movement, awareness, and interaction; land use density, land use mix and land value; urban growth and societal differentiation; safety and crime distribution (Charalambous, Mavridou, 2012, p. 58). Space syntax is a research method within urban systems to understand the spatial distribution of social and economic activities, pedestrian movement, land use and urban centers. It aims to understand how societies produce spaces upon a reading of the spatial development by people in the historical process together with social processes. The method was created on the basis of the data maps of the settlement, the sociological and cultural development stages of that place, and was developed to make determinations based on the foregoing data (Özbek, 2019, p.142). Developed by Bill Hillier and his colleagues in the 1970s the said method allows research to be performed on both an urban and architectural scale.

2. Method

In this research, analytical software of DepthmapX 0.8.0 which is one of the tools of the Space Syntax method has been used to examine the syntactic measures and built-environment factors that affect pedestrian volume in different land-use zones. In addition, land use maps were made with on-site observations in order to understand the ground floor usage diversity of the streets. Study area has been chosen as Kadıköy region which is one of the oldest residential and commercial spaces that dates back to 1000 B.C. in Istanbul. Study area incloses Caferağa, Osmanağa, Rasimpaşa and Hasanpaşa regions which are located in Kadıköy central district where examined with axial, segment and intelligibility analysis of Space Syntax method to comprehend through its movement patterns that trigger the daily routines in social and economic activities angles. Definitions of these analyses are explained throughout in this paper simultaneously with the study itself. Our results from this research brings up the determinant factors of pedestrian volume in different land-use areas. Space Syntax analysis assisted us to find out urban vitality in the Kadıköy center region through predicted pedestrian movement that could help to promote the built environment for both architects and planners.

The study area includes Osmanağa, Rasimpaşa and a part of Caferağa neighborhoods which are the most central neighborhoods of Kadıköy. Osmanağa Neighborhood is located at the intersection of the main transportation arteries with the highest daily population and trade volume. Söğütlüçeşme Street, is the main artery connecting the Kadıköy harbor through the inner parts of Kadıköy, and the bull statue which is one of the landmark symbol of Kadıköy. Rasimpaşa is one of the main historical neighborhoods of Kadıköy and a large part of the neighborhood has the status of urban and historical Site. Rasimpaşa neighborhood covers Haydarpaşa meadow, where Haydarpaşa station is located, in the north, and Yeldeğirmeni District, which has a historical urban texture, in the south. Caferağa neighborhood, on the other hand, is one of the oldest neighborhoods and has a high daily population. The neighborhood is locally known as Moda. The historical Kadıköy market is also located within the boundaries of this Caferağa neighborhood (Figure 1).
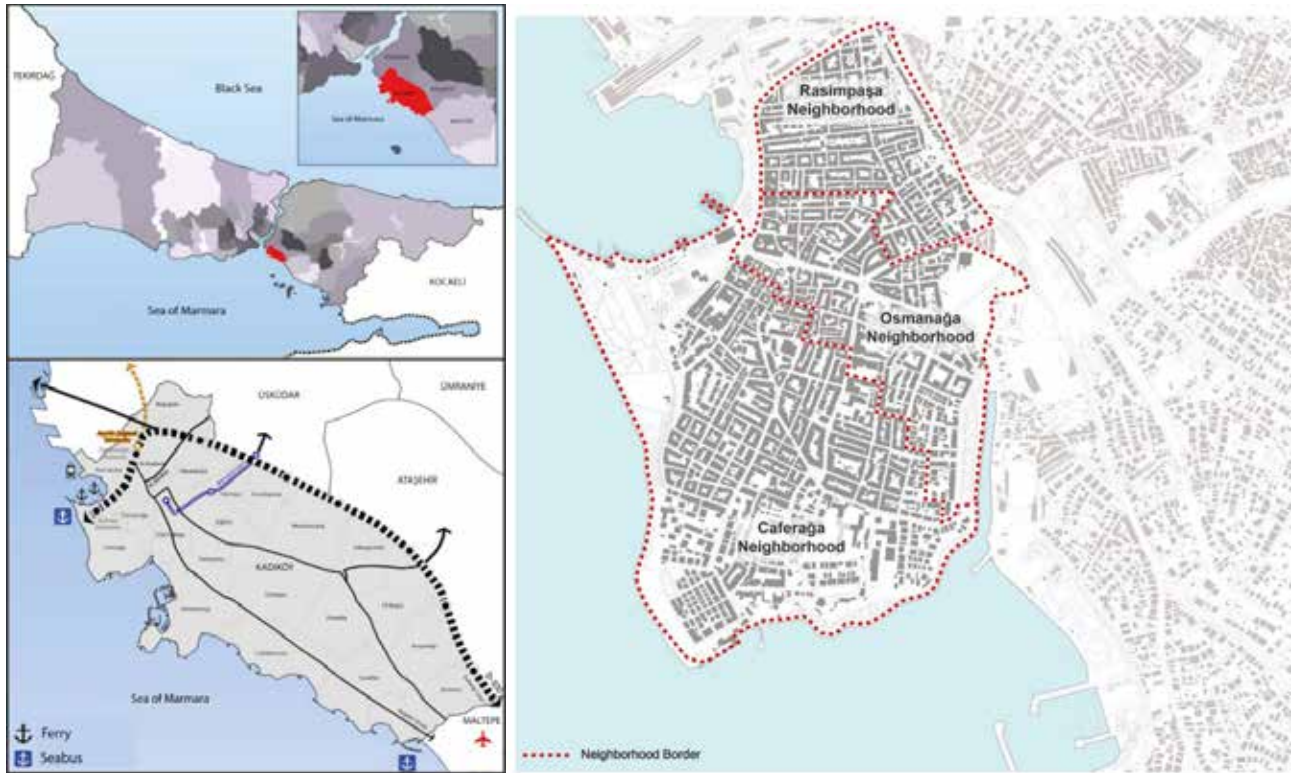
Figure 1. Kadıköy in İstanbul City on top left, It's neighborhood settlements on bottom left (Kadıköy Belediyesi, 2019) and Study areas in Kadıköy on the right   (prepared by authors)

3. Analysis of Kadıköy

Several studies, which employed the Space Syntax method, are suggestive of the fact that space syntax theory is a useful technique for investigating pedestrian movements (Hillier, Hanson, 1984; Lee, Yoo, Seo, 2020:3). Accordingly, the present study aimed to determine the movement patterns of pedestrians using the Space Syntax method within the scope of the study. Pedestrians decide, which way to use and in which direction to go, vis a vis the spatial structures of the streets, where. Hillier and Hanson (1984) suggested that spatial formations had an impact on pedestrian mobility in the form of movement patterns. Natural movement constitutes a part of urban pedestrian mobility determined by the spatial fabric (Dissart, Seigneuret, 2020:170). In the context of Space Syntax, interaction between physical spatial configuration and movement flow is generalized and identified by the 'natural movement' term, which indicates the extent to which the pedestrian movement is determined by the spatial configuration (Car-

mona, Tiesdell, 2007: 255; Thériault, Des Rosiers, 2013, chapter 5). Based on the foregoing definition, Hillier proposed the term Natural Movement in the system, the ratio of urban pedestrian mobility created by the grid itself. The Space Syntax method analyses and describes the structure of the city with based on three important parameters: connectivity, integration, and intelligibility (Hillier, Hanson, 1984). This method is an analytical tool and a morphological method.

Axial and Connectivity Maps of Kadıköy

One of the main environmental features that could have direct or indirect impact on active transport and physical activity is connectivity (Berrigan, Pickle, Dill, 2010:2). Street connectivity, as a maker of pedestrian accessibility to destinations, systematically has been associated with walking.
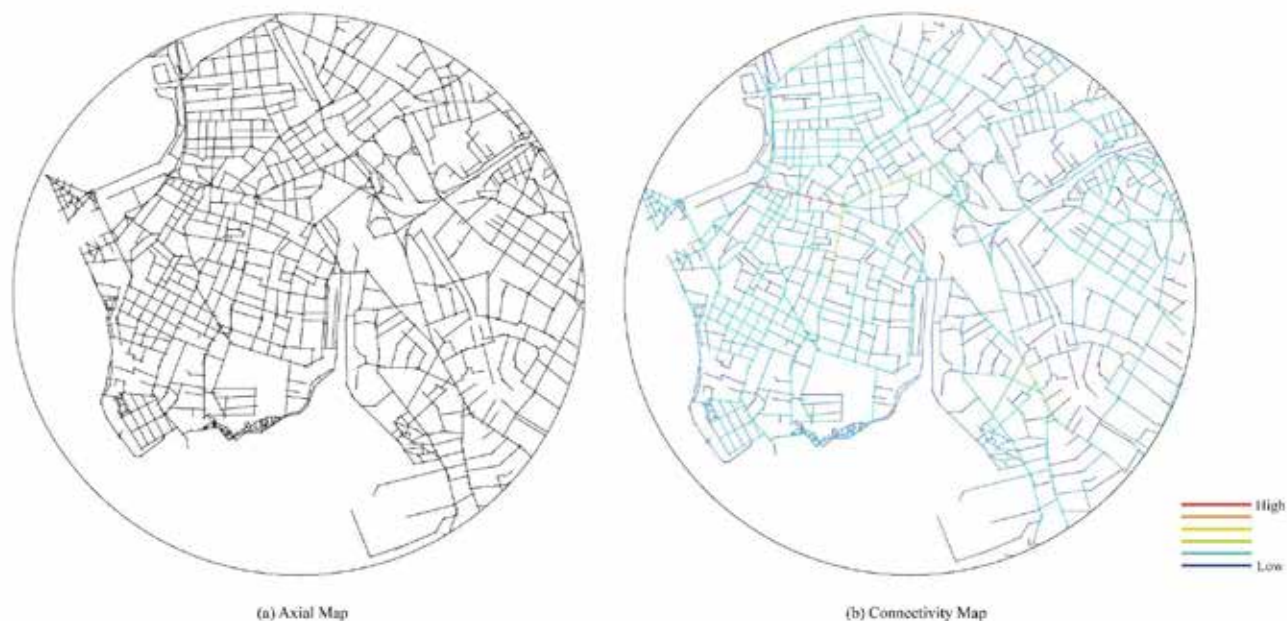
(a) Axial Map

(b) Connectivity Map

Figure 2. Axial map and connectivity maps of Kadıköy region (prepared by authors)

In the first stage of the study, which was designed to serve as a main introduction to analysis, axial maps were developed. Forming the basis of settlement, axial maps help with collection of data that allows to determine the longest distance a person moves in the settlement towards various directions defined as the longest visibility lines in the urban system. Axial maps are a fundamental tool in Space Syntax created by Bill Hillier and colleagues (Babalis, 2007: 52). These lines are drawn in such a way to obtain the longest to shortest lines passing through all open areas. The longest lines indicate the preferred streets with highest perceived accessibility. As for the second step, connectivity map shows how many direct connections each axis has with its direct neighboring axes. In other words, connectivity measures the number of spaces immediately connecting to a space of origin (Hillier, Hanson, 1984:103) The dark blue lines have one to two connections, whereas the yellow and red lines indicate up to 32 connections (Figure 2).

Axial integration is strongly associated with connectivity. Fewer changes of direction changes in a certain street towards all other streets in the system, produce higher integration, hence it creates inter-accessibility. In brief, the longer the axial line in an urban area, the higher its connectivity to other lines and the higher its integration value, and vice versa (Yamu, Van Nes, Garau, 2021:8). Integration is formed upon measurement of the movements with the least and most potential in the urban system. A city grid system analysis can be performed and mobility can be predicted, while at the same time providing data to explain the mobility, upon calculation of the local and global integration in each correct system. Layouts are related to the number of intersections of axial lines. Therefore, the concept of depth is used instead of metric distance in the method (Figure 3).
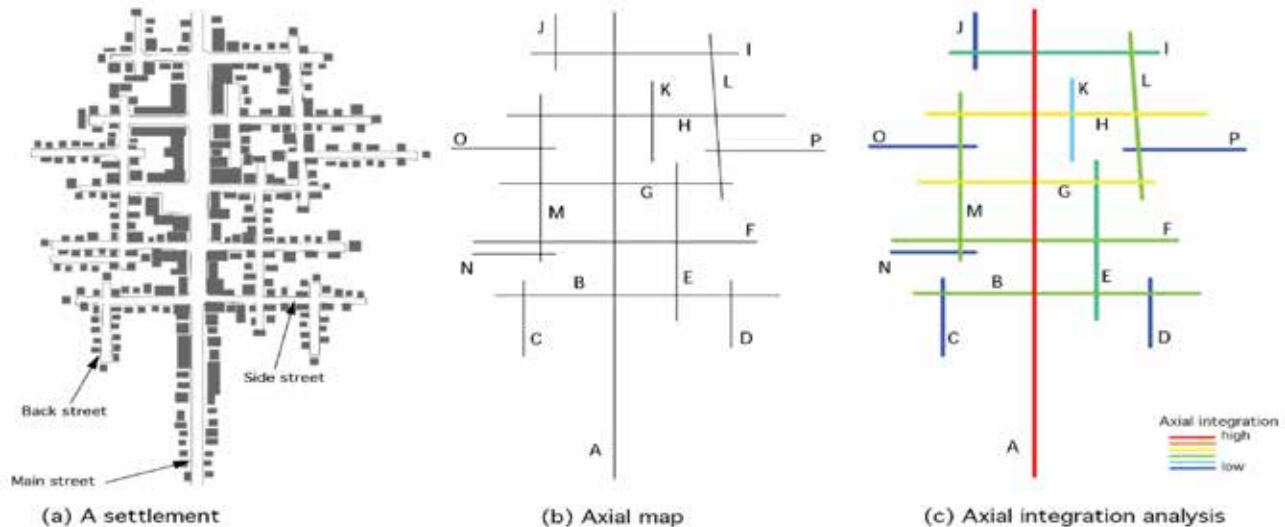
Figure 3. An axial map (b) and a global axial integration analysis (c) of a settlement (Yamu, Van Nes, Garau, 2021).

Urban areas are defined and investigated based on the depth or shallow degrees of the axial maps. Therefore, axial and segment analyses were carried out using analytical software of DepthmapX 0.8.0 to reproduce morphological analysis covering the Kadıköy region. Recent studies suggested that angular analyses proved to serve as a more useful method to understand pedestrian flow compared to metric and topological analyses (Sharmin, Kamruzzaman, 2018:544; Hillier, Iida, 2005: 559; Omer, Kaplan, 2019).

Global and Local Analysis of Kadıköy
Global integration indicates the degree of accessibility that each axial line has with other axial lines to enable large-scale movement, whereas, local integration indicates the degree of localized accessibility between an axial line and its adjacent axial lines, and the control value of space syntax (Lee, Yoo, Seo, 2020:3). Local analyses aim to understand pedestrian movement in the local system, which indicates a degree of accessibility of the street system with adjacent segments. Local integration values identified many local clusters with high local integration values across Kadıköy. Red axes show streets with the highest integration values, where the blue axes indicate the most segregated ones. Within the scope of the research, global and local integration analyses of the region in the central Kadıköy were performed using the DepthmapX program. Integration analyses give an insight into the mobility and integration levels of the urban open spaces, indicating the most integrated and the most segregated regions (Figure 4).

Global integration analyses generally identify the strong axes in the whole system. The roads formed by such axes provide clues that the movement could be dense at those points, and also indicate different land uses and strong connections to other regions. In the context thereof, the Bull Statue manifests itself as a hub and the focal point of the strong movement based on the global analyses for Kadıköy. From this point, Söğütlüçeşme street towards the north-east direction, passes through the Kadıköy Municipality Building, then weakens and connects to the system. In addition, Bağdat Street, which cuts this street perpendicularly, is a strong axis as well. Söğütlüçeşme street, which connects the Bull Statue to Kadıköy dock, Bahariye Street, a pedestrian-only area, and the first section of Kuşdili Street are some of the strong connections in the large system.

Based on the results of the local integration analysis, the accessible points of the inner structure of the region can be differentiated. Accordingly, by keeping the Bull statue and its surroundings as a center again, Yeldeğirmeni section has a strong structure within itself and another system formed by the grid-ordered streets on the Moda side has strong accessibility as well. Upon local analyses, Fahrettin Kerim Gökay Street, which also keeps the grid structure, emerges as an important axis.

Space Syntax is a method used to measure spatial accessibility in segment analyses, including the integration analyses. The difference of segment analysis is that it also
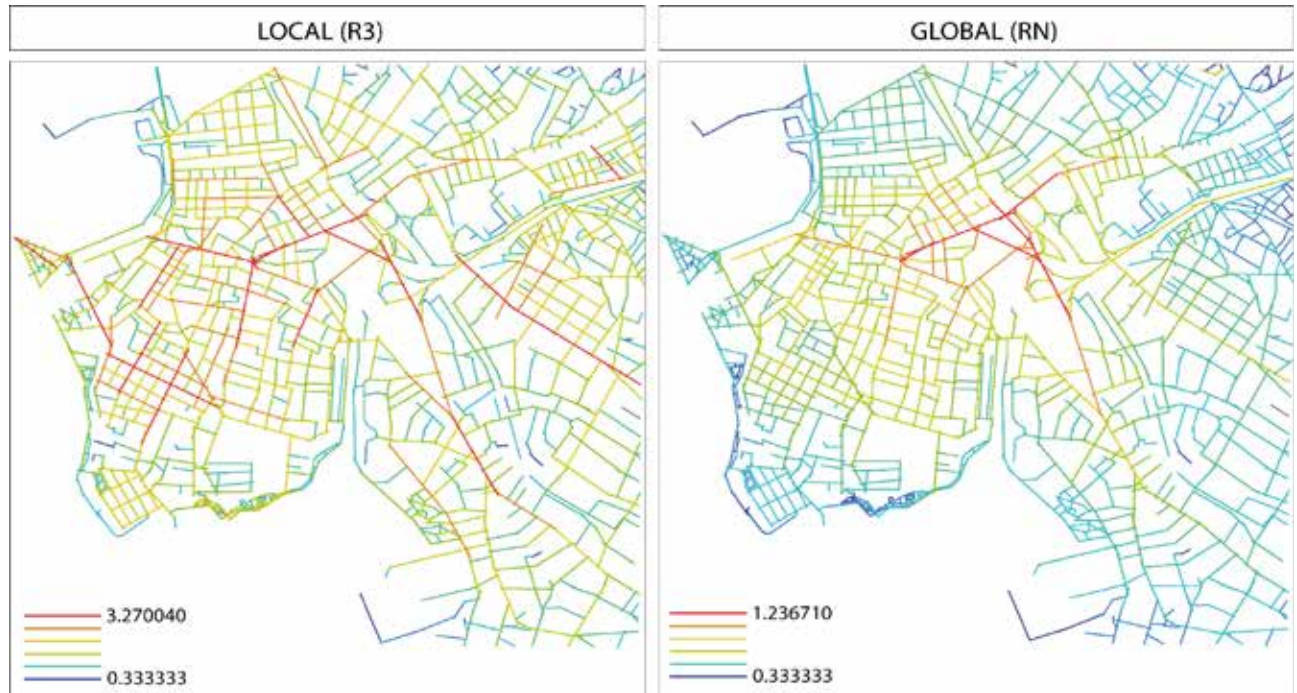
Figure 4. Global integration value (left) and local integration value (right) of road segments in Kadıköy (prepared by the authors)

includes angles formed by intersections of lines, upon which the choice of routes from those intersections can be determined. The indicators and topological distances used in addition to the axial lines are formed by the intersection of the lines that define the segment map based on angularities between the axial lines and the distances measured in the respective sections of the axial lines.

Angular Segment Analysis of Kadıköy
To create a segment map, the axial map is broken down into segments at each street intersection. In recent years, the use of georeferenced road-center lines became more popular for the generation of a street network model (Yamu, Van Nes, Garau, 2021:12). Adding the metric radius to the various angular segment integration and choice analyses shows a higher degree of correlation with socio-economic data compared to the topological radius alone (Hillier, Yang, Turner, 2012).

Segment-based angular analyses were performed both in local and global scales that were indicative of different features in activities, actions, and uses of what was developed an output as a result of the analyses of Space Syntax. Analyses can be based on a 200m-scale for a description of the pedestrian movement, a 400m- or 800m-scale

for intermediate walking distances, and a 1200m-scale which allows a measurement of vehicular and ring roads. Accordingly, in Kadıköy region, the seaside areas near Moda district were more walkable in a range of 400 meters. Kadıköy center area was also accessible and connected throughout a 800m-scale, which is a base structure of historical Kadıköy region. Upon an improvement of the scale through 1200 meters, the outer rings, including Söğütlüçeşme and Halitağa Street connections were also accessible by walk. (Figure 5).

Segment angular choice measures the through movement potential of linear structures (e.g. streets and corridors). Through-movement refers to the movement passing through shortest routes from all points to all other points in the layout. The measure of Choice was suggested to predict through-movement (Hillier, Burdett, Peponis, Penn, 1986). Segment angular integration measures the to-movement potentials of linear structures. To-movement refers to the movement to a space as a destination from all others. The measure of Integration was suggested to predict the to-movement. Red denotes a high to-movement potential, where blue indicates a low to-movement potential (Figure 6).

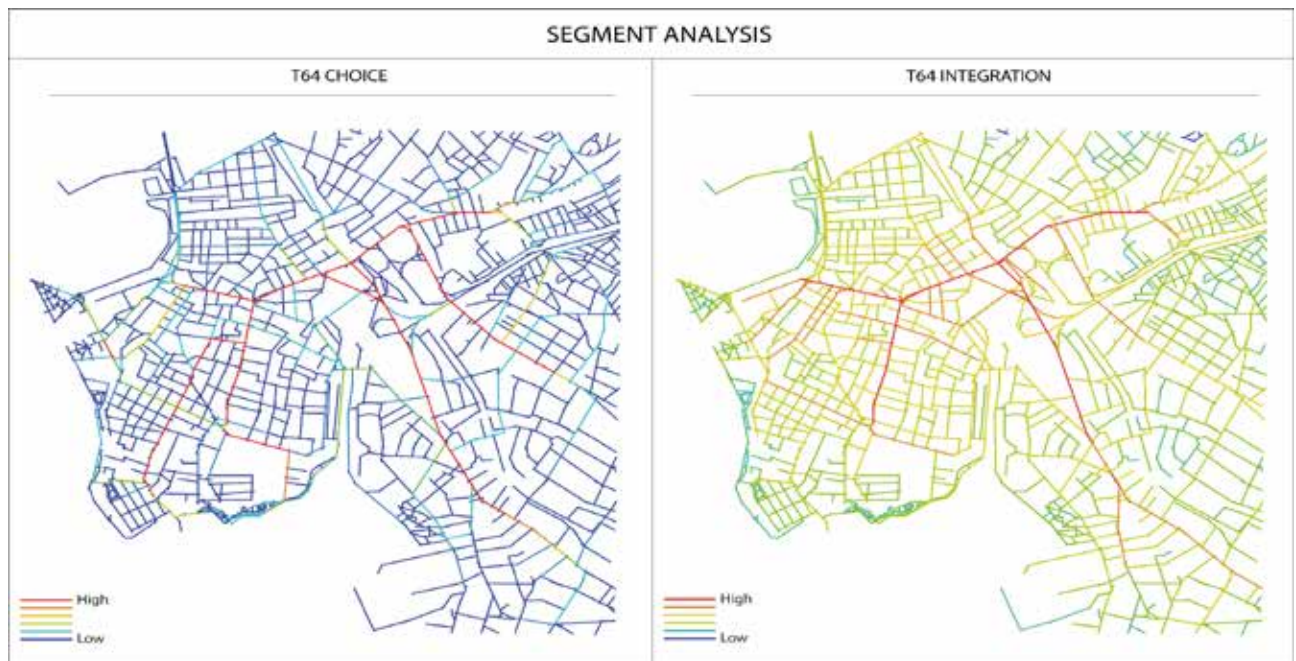**Figure 5.**   Segment Choice Analysis in the range of 400-1200 meters (prepared by authors)

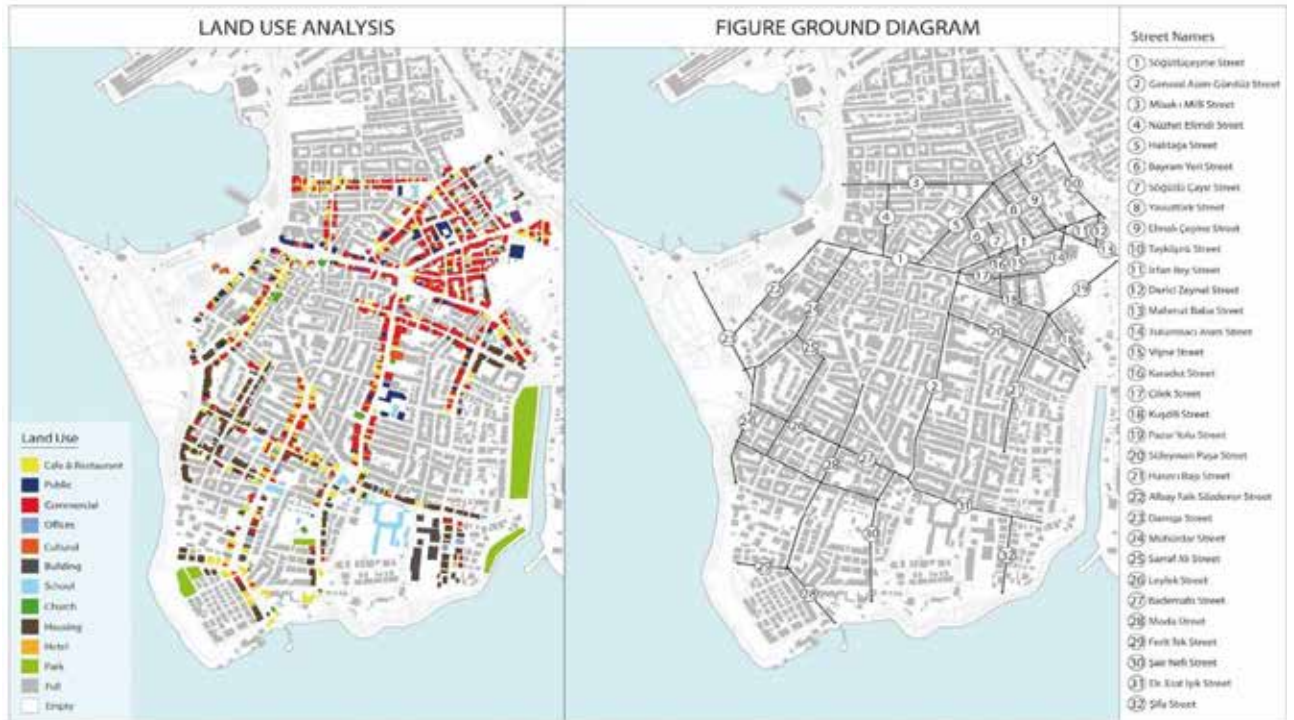**Figure 6.** Choice value (left) and integration value (right) of road segments in Kadıköy (prepared by the authors)

Figure 7. Study area land use analysis and important streets (prepared by the authors)

Land Use Analysis of Kadıköy

Land use mix is one of the cornerstones for urban sustainability vis a vis functional segregation and zoning policies. It was also conceptualized as a key ingredient necessary to support walking and a prerequisite for urban proximity dynamics (Carpio-Pinedo, Benito, Lamíquiz, 2021: 23).

Upon the ground floor uses analysis of Osmanağa Neighborhood, Söğütlüçeşme Street, Kuşdili Street, Çilek Street, Süleymanpaşa Street, Nüzhet Efendi Street, and the beginning of General Asım Gündüz Street, the foregoing had dense retail-trade, where the number of residential uses in the neighborhood was less compared to the number of office and commercial uses (Figure 7).

The mobility in the neighborhoods within the scope of this study as suggested by the Space Syntax method in the system had higher values of accessibility. This data was overlapped and assessed by the ground floor land use and figure-ground diagram analysis. Those analyses aimed to see how the said areas were connected to the city center and whether there was a correlation between land use data and accessibility and mobility (Figure 8).

Figure 8. The overlaps of land use analysis and 1200 meters choice analysis (prepared by the authors)

3. Discussion and Conclusions

Along with the retail uses, including cafes, restaurants, and hotels, there were also educational and residential uses on the streets of **Rasimpaşa** Neighborhood. There was a high concentration of cafes and restaurants along with accommodational buildings on Misak-I Milli and Halitağa streets. Gazi Mustafa Kemal Paşa school was located at the intersection of those two streets indicative of educational use. In Nüzhet Efendi Street (Figure 10), there were hotels besides retail-commercial businesses. On the other hand, ground floor residential use was also observed in Elmalı Çeşme Street.

Caferağa neighborhood, one of the oldest neighborhoods of Kadıköy, had the highest range of daytime population among others. Located on Moda Cape, the neighborhood, was mostly referred to as the Moda District. The Moda District is one of the most reputable districts of Istanbul thanks to its seaside, historical background, architectural qualities, and restaurants. At the same time, it is well-known for its icecream shops and tearooms located on the nostalgic tram line. In Caferağa neighborhood, Mühürdar Street is located in the historical Kadıköy open market where the ground floor usages were mostly spared for cafes and restaurants. At the junction of Mühürdar Street and Leylek Street, residential uses were concentrated on the ground floor. In the junction of Moda Street meets with Leylek Street, the uses for cafes and restaurants on the ground floor were more dense as regards the retail uses (Figure 10).

Figure 9. Nüzhet Efendi Street- Misak-ı Milli Street- Yavuztürk Street (photographs by the authors)

Figure 10. Moda Street, Leylek Street and Mühürdar Street (photographs by the authors)

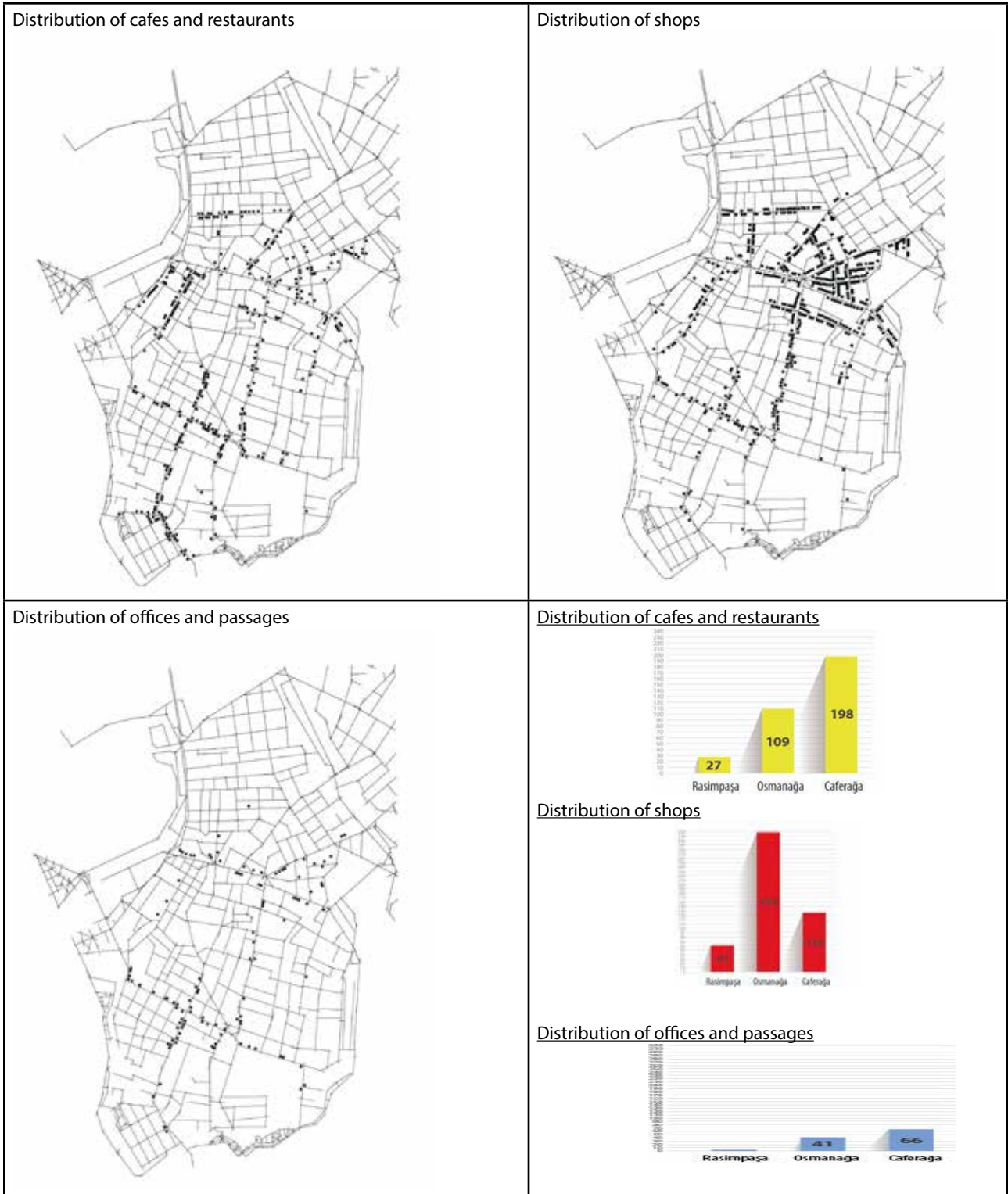**Figure 11.** Söğütlüçeşme Street- Bahariye Street- Kuşdili Street (photographs by the authors)

Distribution of cafes and restaurants	Distribution of shops
Distribution of offices and passages	Distribution of cafes and restaurants

Figure 12. Distribution of cafes and restaurants, shops, offices and passages in study areas (prepared by the authors)

Table 1. Local integration values of three neighborhoods with their Evaluations.(prepared by authors)

CAFERAĞA NEIGHBORHOOD	Emin Bey, Leylek Street and Bademaltı Street (A)	Moda Street (B)	Saadettin Street (C)
R3 Value	2.990849	2.500265	1.381203
Sidewalk	Yes	Yes	No
Presence Of Shops	Yes	Yes	No
Evaluation	This axis consists of the junction of three streets. There are mostly residential areas on Emin Bey St. Shops, cafes, restaurants and schoolson Leylek St., and cafes and restaurants on Bademaltı St.	There are lots of cafes and restaurants along the Street also the end of the road connects to the beach road.	The Street has no connection with other streets as it is a dead end. Therefore the street is only used by residences.
OSMANAĞA NEIGHBORHOOD	Söğütlüçeşme Street (A)	Kuşdili Street (B)	Özpark Street (C)
R3 Value	2.990849	2.500265	1.381203
Sidewalk	Yes	Yes	Yes
Presence Of Shops	Yes	Yes	No
Evaluation	Söğütlüçeşme St. Connects to Hasanpaşa Neighbourhood following the six road (Bull), which is the meeting place from Kadıköy pier. There are usually restaurants, shops and banks on the Street. The Street leads to Söğütlüçeşme Marmaray and metrobus station, which is the important transfer point of Kadıköy, and Kadıköy Municipality.	Kuşdili Street in the 1920's, shops where car manufactures,car mechanics, blacksmiths and hardware stores were constantly operating were lined up on both sides of the Street. Kuşdilli Street leads to the Yoğurtçu Park and Kurbağalıdere (Kuşdili watercourse).	The Street has no connection with other streets as it is a dead end. The Street is generally used as a parking lot by the residents.
RASIMPAŞA NEIGHBORHOOD	Yavuztürk Street (A)	Elmalı Çeşme Street (B)	Ortaç Street (C)
R3 Value	2.851881	2.622736	0.947875
Sidewalk	Yes	Yes	Yes
Presence Of Shops	Yes	Yes	No
Evaluation	During the management of I.Abdulhamid (1774-1789), four windmills had been constructed in Yeldeğirmeni to supply the need for flour for the palace and the city. These windmills had been destroyed in 1903. The place where these two streets (Misak-ı Milli and Yavuztürk St.) connect and become a square is where the last remnants of these windmills are.	The Street which can be entered from the right side of the Söğütlüçeşme Mosque reaches to Halitağa Street. There is a school on the Street. Also there are many shops and cafes along the Street.	There are residences along Ortaç Street, which is a dead-end Street. At the same time, Sidonya Hotel is located on this Street.

Osmanağa neighborhood had a very high level of commercial activities. Within the boundaries of Kadıköy district, the foregoing was the only neighborhood, which maintained more offices/workplaces than residential spaces. It had a quiet and dynamic daytime nature as one of the centric neighborhoods of Kadıköy located close to the intersection of transportation networks with a number of commercial units, including cafes, bars, and restaurants (Figure 11)

A comparison with regard to the ground floor uses of the above three neighborhoods (cafes, restaurants/shops, and offices) indicated that Caferağa Neighborhood had the highes number of cafes and restaurants, while Osmanağa had the highest number of retail shops. Contrarily, Rasimpaşa Neighborhood had the least number of ground floor activities, but hosted mainly residential areas (Figure 12).

Belonging to our local integration analysis there are a number of streets that have indicated a high degree of accessibility patterns. In Table 1 these comparisons have been made with their ground floor features.

The analysis in Kadıköy confirmed Hillier's crucial processes regarding the urban development. The micro-economic scale businesses like cafes and shops aim to adapt the settlement to the overall development of the city, through its global spatial structure. The present study confirmed that the interaction was well facilitated by the distribution of commercial activities and pedestrian movements. Movement patterns in Kadıköy had a significant relationship with its structural system. Thanks to its long history, Kadıköy developed its own spatial logic that connected with its surrounding urban spaces.

To create a well-functioning built surroundings, spatial structure is crucial rather than its architectural quality, or open spaces that gives form to space. This approach leads us to think more about the network systems when it comes to designing the urban spaces. Strong spatial structures are determinant factors that create land usage and designing forms. Land use strategies trigger the density of people in streets. With the help of this method it is possible to calculate the potentials of urban spaces and their effects for future development of cities.

Conflict of Interests
The authors declare no conflict of interests.

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