Planlama 2019;29(3):259–270 | doi: 10.14744/planlama.2019.61687

ARTICLE / ARAŞTIRMA

The Organization of Urban Space and Socio-Economic Characteristics: A Graph Theory-Based Empirical Study Using Hierarchical Cluster Analysis

Kentsel Mekân Organizasyonu ve Sosyo-Ekonomik Yapı: Hiyerarşik Kümeleme Analizi Kullanılan Grafik Teorisi Temelli Ampirik Bir Çalışma

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ABSTRACT

The relationship between the socio-economic factors and the organization of urban space has not received adequate attention in the literature. This study aims to answer the question: Is the organization of urban space associated with social and economic characteristics? The city of Izmir, Turkey, has been selected as the study area and the neighborhoods over 300 in number are grouped into 6 clusters based on their similarities pertaining to the social and economic indicators using hierarchical cluster analysis. The neighborhoods which are closest to the cluster centers selected as the cluster representatives. The organization of space in the representative neighborhoods is quantified using graph theory indices. The results from the ANOVA performed at the global level (or at the neighborhood level) and the post hoc Fisher's least significant difference tests performed at the local level (or at the node or edge level) both reveal that neighborhoods with different social and economic characteristics have different spatial organizations, and they are different in terms of the network accessibility levels measured through graph theory indices. The findings clearly indicate more developed social and economic conditions co-exist with more developed network topologies. The empirical findings of the present study put forward that the planning process is far from providing similar urban spatial organizations for people that differ in social and economic characteristics, and that is a major real-life problem. It is clear that we cannot and should not enforce similar spatial layouts in all neighborhoods, but

ÖZ

Kentsel mekânsal yapı ve kent formuna ilişkin yapılmış olan geçmiş tarihli çalışmalarda, sosyo-ekonomik faktörler büyük ölçüde göz ardı edilmiş, mekânsal yapı ile sosyo-ekonomik yapı arasındaki ilişki araştırma konusu edilmemiştir. Bu çalışma: "Kentsel mekân organizasyonu sosyal ve ekonomik özelliklerle ilişkili midir?" sorusuna cevap vermeyi hedeflemektedir. Çalışma alanı olarak İzmir şehri seçilmiş ve 300'den fazla mahalle sosyal ve ekonomik göstergelere ilişkin benzerliklerine göre kademeli kümeleme analizi kullanılarak 6 kümeye ayrılmıştır. Küme merkezlerine en yakın mahalleler, küme temsilcisi olarak seçilerek temsilci mahallelerde mekânın fiziksel organizasyonu, grafik teorisi endeksleri kullanılarak ölçülmüştür. Mahalle düzeyinde gerçekleştirilen tek-yönlü varyans analizi ile düğüm ve bağ ölçeğinde gerçekleştirilen çoklu karşılaştırma testleri (seri t-testleri) ile elde edilen sonuçlar, farklı sosyal ve ekonomik özelliklere sahip mahallelerde kentsel mekânsal organizasyonunun da farklı olduğunu, bu mahallelerde ölçülen ağ erişilebilirlik seviyelerinin farklı olduğunu ortaya koymaktadır. Bu bulgular, daha gelişmiş ağ topolojilerinin daha gelişmiş sosyal ve ekonomik koşullar ile birlikte varolduklarını ortaya koymaktadır. Bu çalışmanın ampirik sonuçları, planlama sürecinin sosyal ve ekonomik özellikleri farklı olan insanlara benzer kentsel mekânsal organizasyonlar sunmaktan uzak olduğunu ve bunun önemli bir problem olduğunu ortaya koymaktadır. Tüm mahallelerde benzer bir mekânsal organizyon olamayacağı ve olmaması gerektiği

Received: 15.02.2018 Accepted: 22.07.2019
Available Online Date: 07.10.2019
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we can work for achieving a heterogeneous social and economic structure within each neighborhood through urban policies and development plans. The method described in this study can then be used to assess the degree of success in achieving this aim.

Keywords: Hierarchical cluster analysis; graph theory; organization of urban space; social and economic characteristics.

açıktır. Ancak kentsel politikalar ve imar planları aracılığıyla her mahallede heterojen bir sosyal ve ekonomik yapı elde etmek için çalışabiliriz. Bu çalışmada açıklanan yöntem de bu amaca ulaşmada ne kadar başarılı olunduğunu ölçmek için kullanılabilir.

Anahtar sözcükler: Kademeli kümeleme analizi; grafik teorisi; kentsel mekan organizasyonu; sosyal ve ekonomik yapı.

Introduction

The study of cities to capture the relationship between the social and economic processes and the urban spatial organization has received considerable attention in the literature. Urban geographers and city planners have explored the urban settings in diversified ways to understand the ways that the cities function, including the spatial structure of settlements and their connections to the social and economic lives of their inhabitants. However, cities have invariable differences in their internal availability of resources, the levels of social status, and the levels of infrastructure and service distribution.

The urban form influences the daily life of urban residents regarding the movement from residential areas to places of work; the movement of children to schools; the mobility in residential areas for inhabitants, accessibility to shops, parks and recreational areas. These daily urban activities, in turn, influence the social and economic characteristics of the cities and their spatial structures.

However, a review of the studies on the urban spatial structure and the urban form reveals that the social and economic factors are largely disregarded. The studies focusing on the urban spatial structure have clearly failed to explain the relationship between the social processes and the urban spatial structure or the urban pattern.

This paper aims to test whether there is a relation between the spatial structure and the social and economic characteristics of the inhabitants. The hypothesis that the *organization of urban space* is associated with social and economic characteristics is tested. The city of Izmir, Turkey, has been selected as the study area, and the organization of space is quantified using graph theory indices.

Socio-economic Classification of the Urban Space

The classification of urban areas into sub-groups or homogenous areas became prominent in the 1920s when Burgess (1925) developed the *concentric model* of the urban structure to examine the city of Chicago. Some of his assumptions were purely based on economic and social indicators, but the heterogeneous nature of cultural and social aspects of the urban space was also considered in forming rings around the city center (Burgess 1925). Although the concentric model has been criticized extensively, it has provided some form of a basis for the study of urban areas as at today. Homer Hoyt was one of the first critics of the Burgess concentric concept. Hoyt (1939) used rent values to classify the urban space into sub-divisions, later known as sectors. These sectors were mainly based on the rent values, which segregated the urban space into low, medium, and high-class residential areas (Hoyt 1939). The Hoyt sector concept was built upon the Burgess model considering social and economic data, but the urban space was broken up into sectors, instead of rings.

The *social area analysis*, initially developed in the works of E. Shevky, M. Williams and W. Bell (Shevky and Williams 1949; Shevky and Bell 1955), has later become the mainframe in explaining the social differentiation in urban areas. The social area analysis comprises of three main indices to categorize urban neighborhoods into social patterns. The indices were the urbanization index, the social rank index, and the segregation index. A number of researchers including Bell (1953), Van Arsdol et al. (1958), and Theodore and Egeland (1961) used the social area analysis framework to study the social patterns in urban neighborhoods with a variety of modifications to the original framework. The social area analysis has also been criticized, despite its general applicability in the comparative study of inter-city and intra-urban areas. These critics argued that the theory had no strong and convincing theoretical foundation, and failed an empirical test altogether (Van Arsdol et al. 1958; Abu-Lughod 1969).

Van Arsdol et al. (1958) undertook an empirical investigation of the theory of social area analysis comparing three independent variables and two identified criteria. Abu-Lughod (1969) also tested the social area theory in Cairo, Egypt. Haggerty (1982) explored the impact and the variations in the patterns of social contacts in urban neighborhoods considering the social-economic and environmental characteristics of the urban neighborhoods. Haggerty (1982) postulated that the physical form of the neighborhoods contributed to some level of influence on the social contact of the residents in the study, but the most prominent set of factors involved were the socio-economic characteristics (Haggerty 1982). Bell (1953), Van Arsdol et al. (1958), and Theodore and Egeland (1961) also aimed to partition the urban space into sub-areas applying social and economic classifications.

The categorization of the urban population into groups has contributed to improve the understanding of the organization of urban space; to ensure equitable access to public spaces and urban public amenities including education, health, and recreation; and provided a yardstick for inter and intra-urban comparative analysis for regional development and planning. However, the studies that aim to classify the urban setting into homogenous areas have mostly been depended on socio-economic variables and concentrated on the social and economic dynamism of the urban structures. The spatial organization of the sub-areas has been largely neglected.

The Organization of Urban Space

Urban morphology is the study of physical urban form. It comprises the study of human physical habitats and the processes of their formation. The roots of the field go back to as early as 1899, when the classical work of Otto Schuüller, *Über den Grundriß der Städte* (On the Layout of Towns), was published (Larkham 1996; Hofmeister 2004; Ayhan and Cubukcu 2010). Within the urban morphology framework, the urban spatial structure has been studied in different contexts by different researchers to understand the content, the characteristics, the formation, the layout, the problems, and the challenges in cities. However, capturing and explaining the urban form is not an easy task (Kostof, 1991).

Morris (1972) and Mumford (1961) provided an extensive survey of urbanization through history. Gallion and Eisner (1950) and Kostof (1991) summarized the development of urban forms and patterns from a historical perspective. Holmes (1962) gave a brief account of the formation of cities, the failures of early planning strategies, and policies to solve the challenges of urban planning in the areas of human habitation and natural environment.

A great portion of the studies on the organization of urban space is based on the assumption that the urban space has been largely shaped by the developments in transportation and communication infrastructure. Glaab and Theodore (1967), Barrett (1983), and Cronon (2009), for example, focused on how transportation and communication systems developed over the centuries, considering their contribution to the shape and expansion of the urban patterns. In an earlier study, Hansen (1959) developed a gravity-based model to understand how accessibility shape land uses in urban areas concluding that the accessibility to developable lands and employment could be used to explain and estimate the distribution of population growth in urban areas.

There have been different aspects of the study of organization of urban space in connection to the social, demographic and economic characteristics of residents in residential and urban neighborhoods (Burgess 1925; Hoyt 1939; Harris and Ullman 1945; Mack and McElrath, 1964; McElrath, 1965; Boarnet and Greenwald, 2000; Camagni et al. 2002; Omer and Goldblatt 2012; Cohen et al. 2013). These studies approximated the spatial structural components with a biased outlook of the urban geographic space without an objective observation of the components, the structure, the form and the functionality of the urban spatial structure. There has been a concerted effort by urban researchers to establish a relationship between social processes and the urban spatial structure, but these have provided conclusions and theories, which are usually complex and impracticable.

The Relation Between the Organization of Urban Space and the Social and Economic Characteristics

The "social" aspect of the urban structure consists of the individuals and the activities they partake in the built-up environment (Adolphson 2011). The built-up environment and the social structure form the urban structure. The social structure consists of the relationships that exist among the individuals in a geographic area. The urban layouts alter with the changes in economic, social, and technological characteristics (Rashid, 2017).

A limited number of studies have dealt with the different aspects of the organization of urban space in connection to the socio-economic characteristics of inhabitants in urban neighborhoods. Camagni et al. (2002), for example, suggested that the emergence of new land consumption and urban growth is partly due to the changes in lifestyle patterns and spatial developments, which are both influenced by the social and economic characteristics in the case of the city of Milan, Italy. Camagni et al. (2002) argued that, in terms of relative socio-economic and income levels of residential areas, differences in mobility patterns, time, and mode could slightly be influenced by the urban physical form upon which growth occurs. Omer and Goldblatt (2012) showed how the socio-economic residential differentials depicted in Tel Aviv, Israel correlates with the spatial configuration in terms of variations and similarities between areas including the linkages and breakages between spatial organizations of these areas. Cohen et al. (2013) examined the sizes and distribution of urban parks in four cities in the U.S. They concluded that the sizes and numbers of parks are similar in the two different urban settings. Finally, Cubukcu (2015) concluded that religion may affect the organization of urban space by examining the spatial structure of street networks in Izmir, Turkey in the 19th century using graph theory-based indices.

However, the relationship between the socio-economic factors and the organization of urban space has not received adequate attention in the literature. The relationship between urban spatial formation and the socio-economic dynamics of the inhabitants of urban areas has not been thoroughly explored. The studies focusing on the relation between the organization of urban space and the social processes have been limited in number and scope. This study aims to answer the question: Is the organization of urban space associated with social and economic characteristics?

Data and Analyses

Accessibility is defined as the level of effort to overcome physical distance or spatial separation (Allen et al., 1993). It is an important concept for urban planners in that it reflects the possibilities for activities, such as work or shopping, available to residents in a neighborhood, a city or a metropolitan area (Handy and Niemeier, 1997; Bhat et al., 2002). Accessibility to public services, the potential for social and economic interaction, the possibility of getting from home to a multitude of destinations offering a spectrum of opportunities for work and play are what keep inhabitants in metropolitan areas (Ingram, 1971; Morris et al., 1979; Handy and Niemeier, 1997; Handy and Clifton, 2001). Measuring accessibility is a very common and solid approach to spatial simplifying (Miller, 1996; Murray and O'Kelly, 2002; Kwan et al., 2003).

Various researchers have developed different measures of accessibility, and these measures have been applied in a wide range of disciplines (Allen et al., 1993). Bhat et al. (2002) categorized accessibility measures as cumulative opportunity measures, gravity-based measures, utility-based measures, spatial separation, and time-space measures. In all these measures, the available or potential transportation network is regarded as an integral component.

More recently, spatial network approach has become a vital topic in the study of accessibility. Although the theoretical background of the Graph Theory was developed in the 1960s in the works of Kansky (1963) and Hagget and Chorley (1969), the applications to real urban problems have been realized in the 2000s (Sevtsuk and Mekonnen, 2012). Network measures provide a very conducive platform for measuring the levels of accessibility using a Geographic Information System (G.I.S). This enhances easy determination of differences in accessibility in local areas in the urban settlements. In the case of urban street networks, edges typically represent street segments, and nodes denote the junctions where two or more edges intersect (Porta et al. 2006; Sevtsuk and Mekonnen, 2012). In this study, graph theory indices are used to capture the urban spatial organization.

The city of Izmir, Turkey, has been selected as the study area and there are a number of reasons for that. First, Izmir is a fairly populated city with over four million inhabitants living in a total built-up area of roughly 12.000 square meters. It is situated by the Aegean Sea in the West of the Anatolian Peninsula and has the second largest seaport in Turkey, backed by a diversified economy including a vast number of exporting manufacturing sectors. Izmir has over neighborhoods by the year 2019.

A set of procedures is applied to create the database used in this study. The neighborhoods in Izmir are first classified into clusters using hierarchical cluster analysis. That is to say, the neighborhoods over 300 in number are grouped based on their similarities pertaining to the social and economic indicators. The social-economic data used in the hierarchical cluster analysis is available from the European Union Internal Migration Integration Project (IGEP) completed in 2010 in cooperation with Izmir, Ankara, Bursa, and Istanbul Metropolitan Municipalities. The IGEP was initiated in 2008 by the Ministry of Foreign Affairs using European funds (Akyıldız, 2017). The aim of the project was to help lessen the negative effects of internal migration on local inhabitants. The IGEP was managed by had a budget of over 8 million euros and was completed in 18 months (Ministry of Foreign Affairs)[1].

There are eight indices developed and calculated at the neighborhood level within the IGEP study framework: (1) population not in the workforce (dependent population), (2) density of unemployment, (3) density of unemployed people with no occupation, (4) density of literates that are not graduated from any school, (5) density of illiterate women, (6) density of handicapped, (7) density of unpaid family workers, and (8) an education score. The data used in the calculation of these indices come from two different data sources: (1) household data available from the Turkish Statistical Institute and (2) 1924 site surveys completed during the project. Although the details regarding the calculation of these indices are not provided by the data publisher, the index values are available upon request at the neighborhood level.

There are a few good reasons to use the IGEP data to measure social and economic variables. Firstly, it is comprehensive as it covers the Izmir metropolitan area thoroughly. Secondly, the data is available at the neighborhood level, which is a perfect match for this study as the aim is to test whether the organization of urban space is associated with social and economic characteristics at the neighborhood level. Thirdly, the time period that the IGEP data is collected matches the time period of the spatial data available. The spatial data available from the Izmir Metropolitan Municipality for the year 2010.

Two of the seven IGEP indices, namely "density of literates

[1] https://www.ab.gov.tr/_46071.html

that are not graduated from any school" and "density of illiterate women" are not used in the analysis, since they are highly correlated with the education score variable, where r=-0.732, p<0.001 and r=-0.833, p<0.001 respectively. The descriptive statistics for the six variables used in the analysis are presented in Table 1. Remark that for all the indices but the education score, the lower the index value, the better the neighborhood is.

There are 340 neighborhoods included in IGEP data. Although a great portion of these neighborhoods is predominantly residential, some of them are not. In order to eliminate the non-residential neighborhoods, the percentage of buildings with residential use are derived at the neighborhood level. The neighborhoods with at least %80 of the buildings in residential use are considered in the study. Also, the neighborhoods with missing or incomplete IGEP data are omitted from the data set. The final data set includes 293 neighborhoods and their spatial distribution is presented in Figure 1.

A hierarchical clustering procedure is applied with the aim of groping neighborhoods that are similar in social and economic characteristics. In hierarchical clustering procedures, basically two approaches are available: agglomerative and divisive. In agglomerative hierarchical clustering, the procedure of clustering is from bottom to top, where each member is assigned to a larger group in each step. In divisive hierarchical clustering, the procedure is from bottom to top, where all members are initially in the same group and the heterogeneous groups are divided into subgroups in every iteration. Owing to the fact that the number of members (observations) is not very large (n=293), an agglomerative cluster procedure is followed.

As seen in Table 1, the ranges of the IGEP indices vary considerably. Thus, the variables are z-score standardized prior to applying the cluster method. *Ward's minimum variance method* (Ward, 1963) using a *dissimilarity matrix* based on "Euclidean" distances is applied in generating the agglomerative *hierarchical clustering* procedure. Ward's algorithm minimizes the total within-cluster variance considering all variables in question. The dendrogram produced as an output of the hierarchical clustering procedure is shown in Figure 2.

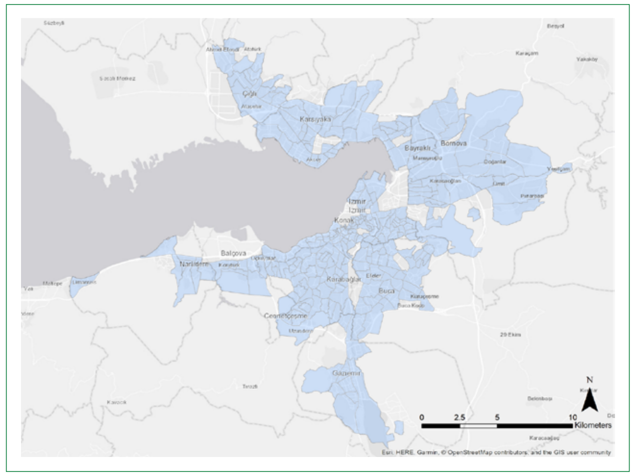

Figure 1. The neighborhoods included in the analyses (n=293) (The base map is created using the ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license).

Since analyzing all the subgroups is not possible, an algorithm to assess the optimum number of clusters is needed. The *average silhouette method* is one of the most common methods used to determine the optimal number of clusters

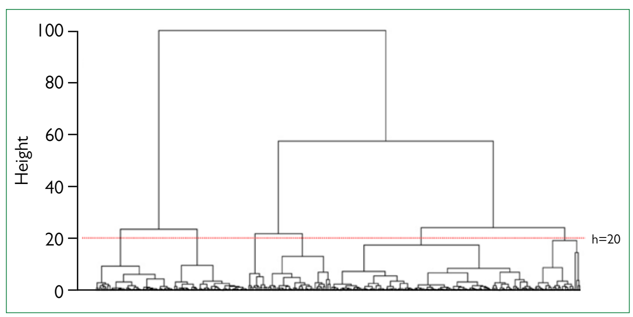

Figure 2. The dendrogram produced as an output of the hierarchical clustering procedure (n=293).

Table 1. The descriptive statistics for the social and economic indices used in the study

Variables	n	Minimum	Maximum	Mean	SD
Population not in the workforce (Dependent population)	340	0.12	1.24	0.99	0.15
Density of unemployment	340	0.00	4.16	1.07	0.37
Density of unemployed people with no occupation	340	0.00	3.63	1.02	0.43
Density of handicapped	340	0.00	403.15	5.20	29.86
Density of unpaid family workers	340	0.00	6.76	1.09	0.60
Education score	332	-8.18	7.88	-0.87	2.83

SD: Standard deviation.

in hierarchical clustering procedures. As shown in Figure 3, the optimal number of clusters derived from the average silhouette method is 6. Remark that the average silhouette width is the highest when the number of clusters is equal to 6. Cutting the dendrogram in Figure 2 at a reasonable height of 20 (h=20) results in 6 clusters (Fig. 4). The number of neighborhoods in each cluster or subgroup is presented in Table 2.

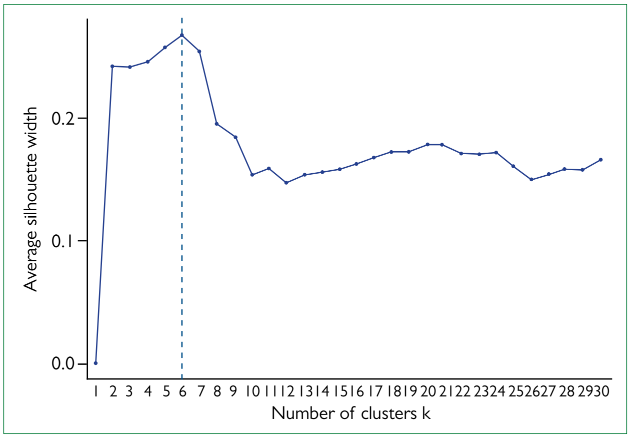

Figure 3. The optimal number of clusters derived from the average silhouette method (n=293).

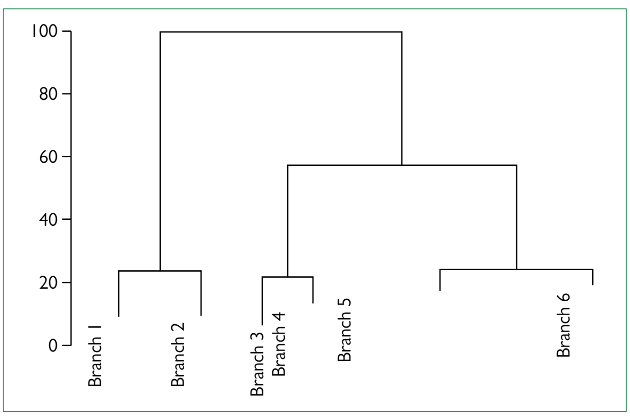

Figure 4. The clusters (n=6) obtained by cutting the dendrogram in Figure 2 at a height of 20 (h=20).

Table 2. The numbers of neighborhoods in each cluster

Cluster	Number of neighborhoods
1	45
2	47
3	28
4	123
5	38
6	12
Total	293

The most crowded cluster is *Cluster 4*, where all indices are close to the index means. *Cluster 3* is similar to Cluster 4 in many ways, but it has a higher density of unemployed people with no occupation and a lower density of unpaid family workers. *Cluster 2* is characterized by the highest education score and the lowest density of unpaid family workers. *Cluster 5 and Cluster 6* have the lowest education scores. However, there is a major difference between these two clusters. *Cluster 5* has the highest density of unemployed people with no occupation, whereas *Cluster 6* has the highest density of unpaid family workers. Finally, Cluster 1 is characterized by high education score and high population not in the workforce, and low density of unemployment (Table 3, Fig. 5).

After clustering 293 neighborhoods into 6 clusters, the next hassle is to obtain the neighborhoods that represent each cluster best, in the sense of the social and economic indicators. To do that, the cluster plot for the 6 clusters is obtained (Fig. 6). Since there are 6 indices, a dimensionality reduction procedure is applied to visualize the data on a 2D space. The neighborhoods which are closest to the cluster centers in Figure 5 are selected as the *cluster representatives*. The 6 representative neighborhoods for the clusters 1 to 6 are: (1) Fevzi Cakmak (Balcova), (2) Mithatpasa (Konak), (3) Adalet (Bayrakli), (4) Refet Bele (Karabaglar), (5) Kadifekale (Konak), and (6) Turkyilmaz (Konak), respectively. The spatial distribution of the representative neighborhoods is shown in Figure 7.

The organization of space in the representative neighborhoods is quantified using graph theory indices. As a branch of mathematics dealing with graphs, the graph theory has been successfully adapted to many different fields (Bin and Zhongyi, 2010). A graph includes two basic components: nodes (or vertices) and edges (or links), and graph theory-based network accessibility indices have been developed to examine the spatial organization of space quantitatively. In a number of studies, including Borusso (2003), Crucitti et al. (2006), Buhl et al. (2006), Cubukcu (2015), Cubukcu and Cubukcu (2017), and Rashid (2017) streets are used to examine the spatial similarities and differences in urban settings. Following these studies, graph theory-based network indices are calculated using the street layouts. The layouts of the streets pertaining to the 6 representative neighborhoods used in the analyses are presented in Figure 8. Note that only the residential areas in these neighborhoods are taken into consideration. Also, a 20-meter buffer is applied from the representative neighborhood boundaries to include the streets residing close to the boundaries.

The total area, the total number of nodes and edges with total edge lengths for the representative neighborhoods are presented in Table 4. The largest representative neighborhood is Adalet (Bayrakli), and the smallest is Turkyilmaz (Konak). The

Table 3. Cluster means for the social and economic indices used in the study (z-score standardized)

Cluster	n	Education score	Density of unemployed people with no occupation	Population not in the workforce	Density of handicapped	Density of unemployment	Density of unpaid family workers
1	45	0.6466	-0.5049	0.4145	-0.1437	-0.2485	0.1409
2	47	1.7023	-0.2980	0.0569	-0.1500	-0.7017	-0.1796
3	28	0.1754	0.6818	-0.2863	-0.0812	-0.1327	-0.7298
4	123	-0.3857	-0.1917	0.1422	-0.1212	-0.0211	-0.1050
5	38	-1.1524	1.3481	0.2958	-0.1003	0.9518	0.3021
6	12	-1.0873	-0.1640	0.3593	-0.0104	0.7614	2.3633
Average	293	0.0332	0.1582	-0.0177	0.0275	-0.1182	0.0150

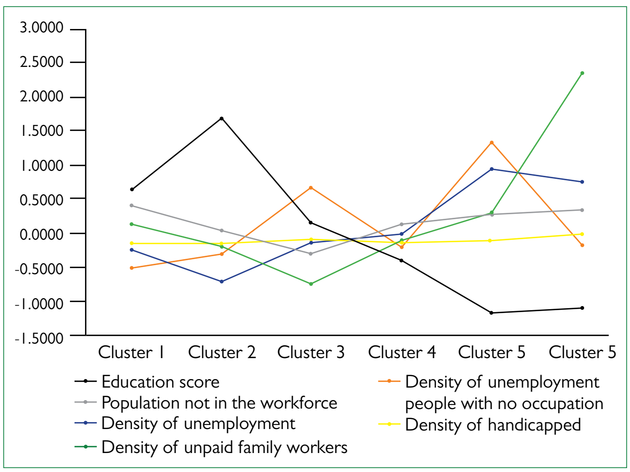

Figure 5. Cluster means for the social and economic indices used in the study (z-score standardized) (n=293).

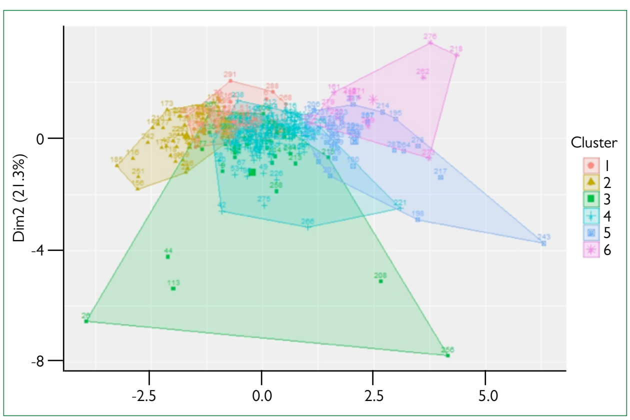

Figure 6. The cluster plot for the 6 clusters with their cluster centers (n=293).

Figure 7. The representative neighborhoods (n=6) (The base map is created using the ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license).

neighborhood with the highest number of nodes, edges and the highest total length of edges is also Adalet (Bayrakli), followed by Refet Bele (Karabaglar) and Fevzi Cakmak (Balcova), respectively (Table 4).

Following Cubukcu (2015), six basic graph theory indices are calculated at the neighborhood level: (1) edge density, (2) edge sinuosity, (3) eta index, (4) node density, (5) order of a node, and (6) beta index. First, all indices are derived at the neighborhood level, or that is to say the global level. Next, three of these indices, namely "eta index (or the average street segment length)", "order of a node" and "edge sinuosity" are calculated at the edge or node level, or the local level. Remark that the remaining three indices, node density, edge density and beta index are measures of concentration and cannot be calculated at the node or edge level by nature.

Among the six indices considered, *node density* is derived by dividing the total number of nodes to the total area. *Edge density* is derived by dividing the total length of edges to the total area. *Eta index* is the average edge length, derived by dividing the total edge length to the number of edges. *Edge sinuosity* is the measure of straightness of the edges and derived by dividing the shortest distance between the two ends of an edge to its

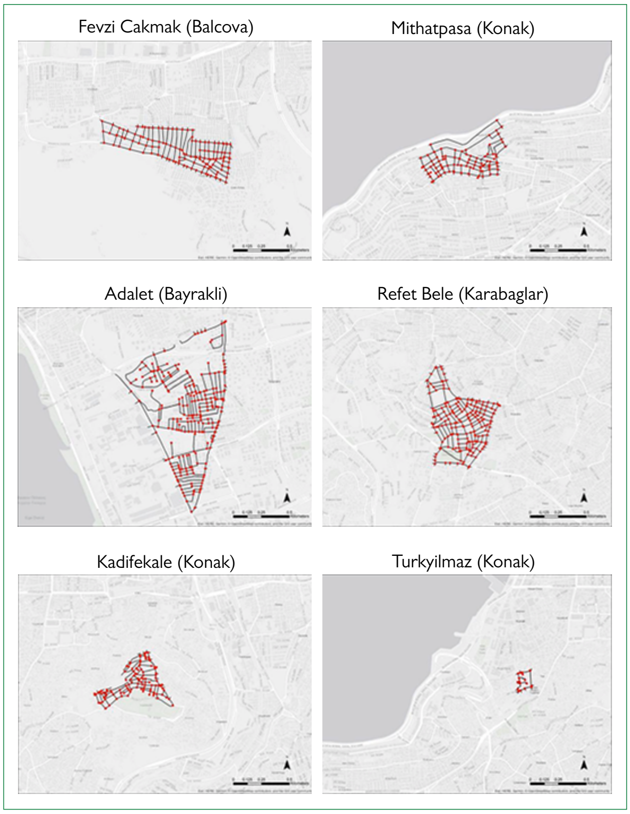

Figure 8. Street layouts with nodes and edges for the representative neighborhoods (residential areas only) (n=6) (The base maps are created using the ArcGIS® software by Esri. ArcGIS® and ArcMap™ are the intellectual property of Esri and are used herein under license).

actual length (Hammond and McCullagh, 1978). *Order of a node* is the number of edges intersecting at this particular node. Finally, *beta index* is the average number of edges per node, derived by dividing the total number of edges to the total number of nodes (Kansky and Danscoine, 1989). The index values for the representative neighborhoods are presented in Table 5.

Table 5 shows that Kadifekale (Konak) and Turkyilmaz (Konak) have significantly higher node and edge densities accompanied by lower eta index (average street segment length) values. The order of a node and beta index values for these two neighborhoods are also among the lowest. These index values reveal that there are more nodes and edges per area in these neighborhoods compared to the other representative neighborhoods, but these nodes and edges provide less connectivity. The sinuosity values for these two neighborhoods are also among the lowest indicating less direct connections between node pairs. All these indicate to less developed network topology. Remark that these two neighborhoods, namely Kadifekale (Konak) and Turkyilmaz (Konak), are the representative neighborhoods of *Cluster 5 and Cluster 6*, which have the lowest education scores. Also, *Cluster 5* has the highest density of unemployed people with no occupation, and *Cluster 6* has the highest density of unpaid family workers (Table 3, Fig. 5). These results alone indicate that more developed network characteristics are associated with more developed social and economic conditions.

Table 5 reveals that Fevzi Cakmak (Balcova) and Mithatpasa (Konak), the representative neighborhoods for *Cluster 1 and Cluster 2* respectively, show more developed network characteristics. For example, they provide more direct links between the pairs of nodes as evident from higher sinuosity values. Although the densities of nodes and edges are among the lowest, there are more edges per node and higher connectivity (with a higher order of a node values) indicating the presence of a more efficient network. Remark that *Cluster 1 and Cluster 2* are characterized by high education scores. Also, *Cluster 2* has the lowest density of unpaid family workers, and *Cluster 1* has a significantly low density of unemployment. These finding also supports the notion that more developed social and economic conditions are associated with more developed network characteristics or that is to say better urban spatial organizations.

Since the eta index (street segment length), order of a node, and edge sinuosity indices can be calculated at the edge or at the node level, these indices can be further examined by

Table 4. Descriptive statistics for the nodes and edges for the representative neighborhoods

Representative neighborhood	Cluster	Residential area (ha)	Number of nodes	Number of edges	Total length of edges
Fevzi Cakmak (Balcova)	1	33.96	133	242	11644
Mithatpasa (Konak)	2	27.05	97	170	8149
Adalet (Bayrakli)	3	91.38	237	344	20355
Refet Bele (Karabaglar)	4	35.48	192	328	13284
Kadifekale (Konak)	5	15.67	116	184	6767
Turkyilmaz (Konak)	6	2.79	18	29	972
Total		206.31	793	1297	61171

Table 5. Graph theory indice values for the representative neighborhoods

Neighborhood	Cluster	Node density (per ha)	Edge density (per ha)	Eta index (m)	Edge sinuosity	Order of nodes	Beta index
Fevzi Cakmak (Balcova)	1	3.916	7.126	48.116	0.999	3.286	1.820
Mithatpasa (Konak)	2	3.586	6.285	47.935	0.990	3.216	1.753
Adalet (Bayrakli)	3	2.594	3.764	59.172	0.981	2.734	1.451
Refet Bele (Karabaglar)	4	5.411	9.245	40.500	0.995	3.188	1.708
Kadifekale (Konak)	5	7.403	11.742	36.777	0.983	2.845	1.586
Turkyilmaz (Konak)	6	6.452	10.394	33.534	0.967	2.611	1.611

some statistical tests. The descriptive statistics for these three indices pertaining to the 6 cluster representative neighborhoods are shown in Table 6. The mean values for each of the three indices are analyzed using ANOVA (analysis of variance). Here the null hypothesis is that the means values for a particular index are the same for all the representative neighborhoods. The F statistic for the eta index is 10.436, edge sinuosity 6.843, and order of a node index 16.758. Relaxing the assumption of equal variances, Welch's Test for ANOVA is also applied. The Welch-statistic for the eta index, edge sinuosity, and order of a node index are 10.410, 9.409, and 15.114, respectively. These results reveal that the null hypotheses are rejected for all of the three indices, and the results are statistically significant at the 0.0001 level. These findings indicate that neighborhoods with different social and economic characteristics also differ in terms of the organization of urban space.

Applying post hoc tests, one can determine whether a given pair of representative neighborhoods differ in mean index values. The results from Levene's test of homogeneity of variances indicate that the assumption of homogeneity of variances does not hold. Tamhane's T2, which does not assume equal variances, is applied as a multiple comparison proce-

Table 6. Index values for the representative neighborhoods

Index	Descriptive	Fevzi Cakmak (Balcova)	Mithatpasa (Konak)	Adalet (Bayrakli)	Refet Bele (Karabaglar)	Kadifekale (Konak)	Turkyilmaz (Konak)
Eta Index (Edge Length)							
	n	242	170	344	328	184	29
	Minimum	0.042	2.756	0.187	3.643	0.930	5.798
	Maximum	186.836	674.093	289.852	214.749	193.319	135.730
	Mean	48.116	47.935	59.172	40.500	36.777	33.534
	St. Dev.	33.529	57.369	52.881	27.492	29.983	28.060
Sinuosity							
	n	242	170	344	328	184	29
	Minimum	0.851	0.565	0.283	0.722	0.482	0.746
	Maximum	1.000	1.000	1.000	1.000	1.000	1.000
	Mean	0.999	0.990	0.981	0.995	0.983	0.967
	St. Dev.	0.010	0.045	0.072	0.023	0.055	0.068
Order of A Node							
	n	133	97	237	192	116	18
	Minimum	1	1	1	1	1	1
	Maximum	4	4	4	4	5	4
	Mean	3.286	3.216	2.734	3.188	2.845	2.611
	St. Dev.	0.724	0.544	0.884	0.430	0.861	0.916

dure for each of the three indices at the local level. The significancy levels regarding Tamhane's T2 tests are presented in Table 7, where the cells in black color indicate that the mean difference is significant at the 0.10 level.

The findings in Table 7 confirm that neighborhoods with different social and economic characteristics have different spatial organizations, and they are different in terms of the network accessibility levels. When the pairwise comparisons are considered, any pair of representative neighborhoods is different in at least one of the three indices. For example, Fevzi Cakmak (Balcova) is different from Kadifekale (Konak) in three of the indices. Remember that Fevzi Cakmak (Balcova) and Kadifekale (Konak), are the representative neighborhoods of Cluster 1 and Cluster 5 respectively, and they represent the most and the least advantageous neighborhoods regarding the social and economic characteristics. Whereas, Fevzi Cakmak (Balcova) is not different from Mithatpasa (Konak) in any of the three spatial indices. Remark that Mithatpasa (Konak) is the representative of Cluster 2, which has relatively similar social and economic characteristics to Cluster 1. Likewise, Turkyilmaz (Konak) and Kadifekale (Konak), as the representative neighborhoods of *Cluster 6 and Cluster 5*, do not differ in any of the spatial index. Recall that *Cluster 5 and Cluster 6* that have the lowest education scores. Aside from the education score, Cluster 1 and Cluster 4 have similar social and economic index values. Thus, Fevzi Cakmak (Konak) and Refet Bele (Konak), as the representative neighborhoods of *Cluster 1 and Cluster 4*, are different in just one spatial index.

Conclusion

This study aims to answer the question: Is the organization of urban space associated with social and economic characteristics? The results from the ANOVA performed at the global level (or at the neighborhood level) and the post hoc Fisher's least significant difference tests performed at the local level (or at the node or edge level) both reveal that neighborhoods with different social and economic characteristics have different spatial organizations, and they are different in terms of the network accessibility levels measured through graph theory indices. The findings clearly indicate more developed social and economic conditions co-exist with more developed network topologies.

Table 7. Significancy levels for Tamhane's T2 tests*

Eta Index	**Fevzi Cakmak**	**Adalet**	**Refet Bele**	**Kadifekale**	**Mithatpasa**	**Turkyilmaz**
Fevzi Cakmak		**0.03**	**0.06**	**0.00**	1.00	0.19
Adalet	**0.03**		**0.00**	**0.00**	0.39	**0.00**
Refet Bele	**0.06**	**0.00**		0.93	0.83	0.97
Kadifekale	**0.00**	**0.00**	0.93		0.31	1.00
Mithatpasa	1.00	0.39	0.83	0.31		0.44
Turkyilmaz	0.19	**0.00**	0.97	1.00	0.44	
Sinuosity	**Fevzi Cakmak**	**Adalet**	**Refet Bele**	**Kadifekale**	**Mithatpasa**	**Turkyilmaz**
Fevzi Cakmak		**0.00**	0.22	**0.00**	0.16	0.24
Adalet	**0.00**		**0.01**	1.00	0.72	1.00
Refet Bele	0.22	**0.01**		**0.06**	0.89	0.40
Kadifekale	**0.00**	1.00	**0.06**		0.96	0.98
Mithatpasa	0.16	0.72	0.89	0.96		0.75
Turkyilmaz	0.24	1.00	0.40	0.98	0.75	
Order of a Node	**Fevzi Cakmak**	**Adalet**	**Refet Bele**	**Kadifekale**	**Mithatpasa**	**Turkyilmaz**
Fevzi Cakmak		**0.00**	0.93	**0.00**	1.00	**0.10**
Adalet	**0.00**		**0.00**	0.99	**0.00**	1.00
Refet Bele	0.93	**0.00**		**0.00**	1.00	0.22
Kadifekale	**0.00**	0.99	**0.00**		**0.00**	1.00
Mithatpasa	1.00	**0.00**	1.00	**0.00**		0.19
Turkyilmaz	**0.10**	1.00	0.22	1.00	0.19	

*: The black cells indicate that the mean difference is significant at the 0.10 level.

These findings are extremely important for urban planning discipline. The cities are now shaped more through planning processes, compared to the past. And if there is one unquestionable aim in urban planning, that is to provide equal access to public amenities for all, and that is possible with an equitable organization of space. The empirical findings of the present study put forward that the planning process is far from providing similar spatial organizations for people that differ in social and economic characteristics. That is a major real-life problem, and there can be several reasons for that. One may argue that establishing equality in accessibility levels is sometimes not a major objective in the planning process, but in reality that is more often than not false. Aside from a minority of planning attempts, providing access to public amenities is among the main aims in practice. However, the urban settings subject to the planning processes have been mostly already built-up at a great extent. Thus, it not easy to elevate the accessibility to a standard level for all neighborhoods, as each neighborhood has a story behind. For example, a considerable number of neighborhoods in Izmir are shaped through redevelopment plans covering the former *gecekondu* neighborhoods characterized by small parcels and insufficient supply of public amenities, and this solid physical structure is highly resistant to change. Also, some neighborhoods are under strict legal historic preservation, where changing the urban texture is not a possibility. Nonetheless, all these explanations and assertions should not be an excuse for the observed social and economic segregation in the urban space.

Although these findings alone is a big step in uncovering the relationship between the social and spatial structures in urban areas, more studies are required to generalize the results. Further studies should undoubtedly consider access to other public amenities including parks, recreational areas, public transport, and health and service facilities regarding the spatial organization of the urban settings. Also, the reasons for this relationship should be examined and assessed thoroughly in further studies. Nonetheless, the results leading to the fact that inequality in accessibility levels in neighborhoods with different social and economic characteristics have not been overcome through the planning process appears to be the most striking outcome of the study. It is clear that we cannot and should not enforce similar spatial layouts in all neighborhoods, but we can work for achieving a heterogeneous social and economic structure within each neighborhood through urban policies and development plans. The method described in this study can then be used to assess the degree of success in achieving this aim.

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