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The Impact of Passages on Street Connectivity in Commercial Areas: The case of Besiktas market area in Istanbul

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Abstract

Passages, an important and conventional building typology of the urban fabric, are about to disappear in today's globalized cities. Previous researches theoretically assume that passages allow continuous flow of public spaces, support accessibility, and enhance street vitality. However, there is not enough evidence to prove their potential for improving connectivity. This study aims to investigate how passages affect street connectivity physically and visually and thus how they improve spatial integration in street networks. The field study was conducted in a small-scale commercial market area, in which there are many interconnected passages. The methodology consists of axial, segment and visibility graph analyses of space syntax, and a systematic observation of pedestrian volume and route choices. Our findings suggest that passages increase physical and visual connectivity and spatial integration by providing many diverse, short, and alternative routes for movement within the street network. However, the findings also showed that the effective use of the passages is predominantly associated with their spatial attributes. As long as passages have short and direct corridors, providing connections in different directions, they can contribute to the accessibility of streets and the vitality of cities.

Keywords: spatial integration; street connectivity; pedestrian volume; route choice

Citation

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El impacto de los pasajes en la conectividad de las calles de áreas comerciales: el caso del área del mercado de Besiktas en Estambul

Resumen

Los pasajes, entendidos como una tipología constructiva importante y convencional del tejido urbano están a punto de desaparecer en las actuales ciudades globalizadas. Investigaciones previas asumen teóricamente que los pasajes facilitan el flujo continuo en los espacios públicos, favorecen la accesibilidad y mejoran la vitalidad de la calle. Sin embargo, no hay evidencia suficiente que demuestre su potencial mejorando la conectividad de los espacios. Este estudio tiene como objetivo investigar cómo los pasajes afectan física y visualmente a la conectividad de las calles y, por lo tanto, cómo mejoran la integración espacial en las redes de las mismas. El estudio de campo se llevó a cabo a pequeña escala en el área de un mercado comercial en el que hay muchos pasajes interconectados. La metodología utilizada combina un análisis gráfico visual, axial y segmentario de la sintaxis espacial; con una observación sistemática del volumen de peatones y las opciones de ruta. Nuestros hallazgos sugieren que los pasajes aumentan tanto la conectividad física y visual como la integración espacial al proporcionar muchas rutas diversas, cortas y alternativas para el movimiento dentro de la red de calles. No obstante, los hallazgos también mostraron que el uso efectivo de los pasajes está predominantemente asociado a algunos de sus atributos espaciales. En este sentido, siempre que los pasajes cuenten con corredores cortos y directos que proporcionan conexiones en diferentes direcciones, contribuirán a la accesibilidad de las calles y a la vitalidad de las ciudades.

Palabras clave: integración espacial; conectividad de las calles; volumen peatonal; selección de ruta

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1. Introduction

Street connectivity, which is associated with the attributes of urban spaces such as accessibility and walkability (Ozbil, et al. 2015; Handy, et al. 2003), reveals the strength of the urban core (Correa, 2021) and promotes public health (Marshall, et al., 2014) along with the quality of urban life. At the same time, it causes many problems such as crime (Poole et al., 2018), congestion, and traffic exposure (Handy, et al. 2003) which stem from decreased street connectivity. Even though passages, which are an inherent part of urban space configuration in many of the conventional urban fabrics, provide the potential for solving these problems, they have been replaced by enclosed shopping malls and are about to disappear in today's globalized cities. The emergence of global pandemic conditions and the growing effects of global warming make nations think about sustainable mobility choices and redistribute urban spaces to make our cities more climate neutral, livable and inclusive for all citizens (Yalcin Usal and Evcil, 2022). Accordingly, it is likely that passages, with their semi-open character and spatial value in promoting street connectivity and walkability, will become even more important in the future. Thus, this study aims to investigate how passages in commercial areas improve spatial integration by examining the relations between physical and visual connectivity, and pedestrian volume.

There had been very limited studies in the literature on passages. They have been mostly studied with their historic and typological attributes (Geist, 1989; Plevoets and Cleempoel, 2011; Ozkan, 2008; Gulenaz, 2011; Kunzmann, 2015; Vera, 2019) and their public aspect that enhances urban life (Schaule, 1991). In Benjamin (1999)'s concept of flâneur, passages were discussed as the object of the city stroller's urban experience. Their role in the formation and development of traditional bazaars in Islamic cities (Nejad Ebrahimi, et al., 2013) and the thermal performance that they provide (Potvin, 1997) were other subjects in which passages were examined. However, their contribution to connectivity in street networks has not been investigated extensively. Few studies showed that passages allow the public to freely pass through by offering new paths and shortcuts (Maeder, 2008), which are alternatives to the existing streets; they also offer easy and convenient access to a variety of amenities (Yavuz, 2000) suggesting that passages enhance street vitality and promote public life. This study will contribute to the literature by examining passages in terms of their physical and visual connectivity, thereby revealing their potential as a solution to many of the urban problems facing cities in this century.

In this study, the passages as important commerce buildings will be evaluated regarding their connectivity features. The case study that will be employed is the Koyici market area in the Besiktas District of Istanbul. This small-scale market area includes many passages, as well as open and semi-open shopping streets in its urban fabric, which provide connectivity. The focus of the study is the passages' both physical and visual links to their surrounding street network and how people circulate through these passages. Thus, it has been discussed how to improve them by pointing out the weaknesses of their design. Our results show both the efficiencies and inefficiencies of passages, helping us to discuss the reasons for these inefficiencies. Based on the lessons learned from this case, we will put forward some suggestions for successful urban design. In the following section, the theory of connectivity and integration in a street network will be examined. Then, the methodological approach for evaluating the connectivity of passages will be stated. Finally, the analysis of the Besiktas passages will be given in the case study along with the results and discussion.

2. Literature Review

As a critical concept for organizing spatial relations of public spaces, theorists such as Maki (1964), Trancik (1986) and Ellin (2013) addressed the importance of linkages and connections in the urban structure. Connectivity, joining together two or more things, has been described through the concept of linkages by Maki (1964) and Trancik (1986). For understanding and explaining urban form, Maki (1964) described linkages as *"the glue of the city"*. Likewise, Trancik (1986) employed the linkage theory to explain the connectivity of a place, which involves the organization of streets that connect the parts of the city. Ellin (2013) explained connectivity with its role in facilitating pedestrian movement between urban nodes for shorter and more direct routes. She highlighted that connectivity works for bringing activities and people together instead of isolating and separating either objects or functions.

Connectivity refers to the interconnectedness and directness of links in an urban network, and it is measured by the number of connections between a given starting point and various destinations, which tells us the directness and multiplicity of the routes within an entire network (Tal and Handy, 2012). Well-established connectivity in a street network provides spatial integration by enabling short links, many diverse intersections, and very few dead-ends. The more route options become available, the more pedestrian routes are interconnected with each other and thus resulting in the less distance between the origin and destination. This naturally allows for a more direct and accessible pedestrian movement in an urban network (CI, 2015). In this context, accessibility is a function of connectivity.

There are diverse measures to evaluate connectivity in the literature such as measures based on space syntax theory, GIS and typological views of connectivity. Space syntax is a significant theoretical and methodological field that offers concepts and measures to understand the concept of connectivity. The axial maps of space syntax theory (Hillier and Hanson, 1984) represent street segments and intersections as lines and nodes to show the syntactic relationships in an urban system. Using two basic measurements: integration (mathematical closeness) and choice (mathematical betweenness), metric distance at a local and global level can be calculated (Hillier, 2012). In space syntax theory, connectivity is measured by the number of immediate neighbors or segments that are directly connected to a space, and integration, which is the measure of accessibility, describes the average depth of a street with regard to all other streets in the network. Choice is defined as the quantity of movement that passes through each spatial element on the shortest or simplest trips in a system (Hillier et al, 2012). While integration shows how close a street is to all other streets in the network, choice shows how busy a street is, that is how much movement passes through each segment. Thus, it has potential to describe routes through the segments (Hillier and Iida, 2005).

In addition to axial analysis, segment analysis which is a more detailed technique than axial one can also be useful for understanding connectivity and as Hillier and Iida (2005) stated it provides a better correlation with pedestrian movement. In segment analysis, axial lines were broken into the segments at the intersection of lines. Segment analyses include topological, angular and metric choice analyses. Topological choice is defined as the shortest routes provided by the least number of turns (means a nodes minimization); angular choice is defined as the shortest routes provided by the least angular deviation (means angular minimization, namely it is the straightest route); and finally, metric choice deals with only the metric distance, therefore it is called the least length analysis (means length minimization) (Turner, 2008).

Connectivity can be both physical and visual. Besides the metric characteristic of streets, which corresponds to physical connectivity, visual connectivity and the geometry of space are also essential in understanding pedestrian activity (Hajrasouliha and Yin, 2015). In the literature on space syntax, visibility is measured through isovists (Turner, 2001). Visibility graph analysis (VGA) is applied in many indoor and outdoor environments to predict the volume of pedestrians (Parvin et al, 2008) and to understand the relationship between permeability and social activities in outdoor in-between spaces (Zerouati and Bellal, 2020). VGA has been developed by new approaches such as a continuous stochastic analysis that includes measures of connectivity, covisibility, compactness, and occlusivity (Psarra and McElhinney, 2014); the mapping of the visual clustering coefficient, which is one of the parameters derived from the VGA of isovists (Clua et al, 2022); and finally, the model of three-dimensional visual relations (Culagovski et al., 2014; Varoudis and Psarra, 2014), which is different from what can be done on planar surfaces.

Other important and widely used connectivity measures are block-based measurements like block length, block size and block density (Dill, 2004). Block section (Stangl, 2015) is also used, where larger blocks mean obstruction on pedestrian movement (Kerr et al, 2007; Stangl and Guinn, 2011). Intersection density (the number of intersections per unit of area) (Kerr et al, 2007; CI, 2015; Dill,

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2004), street density (the number of linear miles of streets per square mile of land), the ratio of the links (street segments) to nodes (intersections) (CI, 2015; Dill, 2004), the average distance between intersections and the ratio of intersections to dead-ends (CI, 2015), directional and metric reach (Peponis et al, 2008) also indicate connectivity (Dill, 2004). Pedestrian route directness, which is the ratio of the street distance to straight-line distance between two points, and effective walking area, which is measured as a ratio of the number of parcels within a specified network distance from a destination, are two important measures for accessibility through direct routes and a segmented urban pattern (Randall and Baetz, 2001; Dill, 2004).

3. Methodology

The research questions posed in this study are as follows:

- How do passages affect street connectivity both physically and visually, and what kind of spatial attributes of passages are associated with their connectivity?
- Does physical and visual connectivity have an influence on pedestrian volume in the street network with passages?

The relationship between physical and visual connectivity and pedestrian volume will be investigated using the techniques of space syntax and observations. The observations were carried out during the spring. The following two techniques have been utilized in four major stages during the research process:

Axial and visual analyses of space syntax: Measures of integration, connectivity, and choice in the study area have been analyzed by employing space syntax techniques. In order to see what kind of benefits passages provide to existing street networks, in terms of integration and connectivity, these analyses were performed and then two different situations were compared: (1) the current street network and; (2) a hypothetical system in which there are no passages, as if the whole area was a compact urban block. The evaluation of connectivity from VGA was also employed to see visual connections between the passages. The syntactic analyses were performed based on both global integration (Rn), which shows the integration of passages within the whole street network, and local integration (Radius 3), which best eliminates the edge effect of an urban network (Hillier, 1996; Chang and Penn, 1998; Penn et al., 1998; Ratti, 2004). DepthmapX (5.0), the space syntax modeling software developed by UCL's Space Syntax Laboratory, has been used for the space syntax analysis.

The gate method of systematic observation: Pedestrian volume (the frequency of movement by pedestrians) was obtained using the gate method of observation. A total of 37 gates, which are located on the street segments of the axial mapping, were determined in the case study area. 19 of the 37 gates were located on open streets, and the other 18 gates were located on passage streets. The number of pedestrians passing through a particular gate was counted over three days, including two weekdays and one day of the weekend. The observation periods on the weekdays were: morning (9.00 am–10.30 am), noon (12.00 pm–1.30 pm), afternoon (2.30 pm–4.00 pm), and evening (5.30 pm–7.00 pm); observation periods on the weekend were: morning (10.00 am–11.30 am), noon (12.30 pm–2.00 pm), afternoon (3.30 pm–5.00 pm), and evening (6.00 pm–7.30 pm). Three observers counted the pedestrians passing through each gate in five-minute time. Each observation period lasted one and a half hours in total.

Correlational analyses: The data gathered from the systematic observations, syntactic measures of integration, and the visual connectivity of street segments were analyzed correlatively to understand the relationship between the syntactic features and pedestrian volume in the passages. SPSS (Statistical Package for the Social Sciences) was used for the correlational analyses of the obtained numeric data.

Following and observing pedestrians' route choices: Observational data is generally consulted in the studies focusing on the quality of the urban space to support space syntax results (Gümüş and Erdönmez, 2021). In addition to the gate method of systematic observation, it is aimed to record pedestrian behavior in using passages. Six major passage entrances to three passages: (1) Sinanpasa

Passage, (2) Buyuk Besiktas Passage, and (3) Koyici Passage, were selected, as they are located next to each other and have direct connections. The pedestrians who entered at these points were followed and observed to determine their route choices in the study area. Observation results were interpreted qualitatively with descriptive statistics.

4. Case Study

4.1 Study area

The historic Koyici market area of Besiktas, which is a neighborhood in Bosphorus, is selected as the case study area (Figure 1). Located on the European side of Istanbul, Koyici is a market area with lively streets and passages where there are many shops, restaurants and cafes. The reason that Koyici market area was chosen was because it has many passages that provide rich urban connections and a wide range of alternative pedestrian routes. These passages are clustered in the center of the market area, so they all have access to each other. Moreover, the market area is one of the most popular and crowded commercial centers in Istanbul where thousands of people pass by every day, and a large amount of them use the passages.

As one of the oldest settlements of Istanbul, the history of the Koyici district goes back to the 15th century, at that time the urban fabric and identity of the district mostly formed when the Ottoman villages started to sprawl along the Bosphorus (Akbayar, 1998). The present urban pattern of the area is the result of a series of implementations; commenced in the 1930s as reforming the urban grid by widening existing roads and proposing new avenues according to the urban policies of the time. Later in the 1960s and the 70s, the built environment was regenerated by demolishing the mansions and parks; and constructing new buildings to augment the retail occupation of the land (Gokyay, 2009). A big proportion of the new building typology was the passages that host various retail facilities and functions in the market area.

What is referred to as a 'passage' in this study is different from the 19th-century retail buildings, known in the literature as shopping arcades. These buildings use a similar concept to that of a galleria, with boutiques and shops being placed under the canopy of an iron and glass roof. Such passages offer sheltered public spaces and connections between streets. Here, the term 'passage' has been used to reflect a modern architectural style, which is generally accepted after the 1950s. Built between 1970 and 1985, they are contemporary buildings of one or more stories, encompassing small shops and enriching non-retail activities. The ground floor of a building could also be converted into a passage, as a simple pathway with shops along each side. Since they are not privately owned, they are freely accessed, like public streets, breathing a sense of public space into buildings, which is why they are more inviting.

Figure 1. **The location of the study area through the satellite views**

Source: Elaborated by the authors from Google Maps, 2023

In the study area, there are six passage buildings: (A) Sinanpasa Passage, (B) Buyuk Besiktas Passage, (C) Koyici Passage, (D) Guzel Passage, (E) Kuyumcular Passage, and (F) BKM: The Passage of Besiktas

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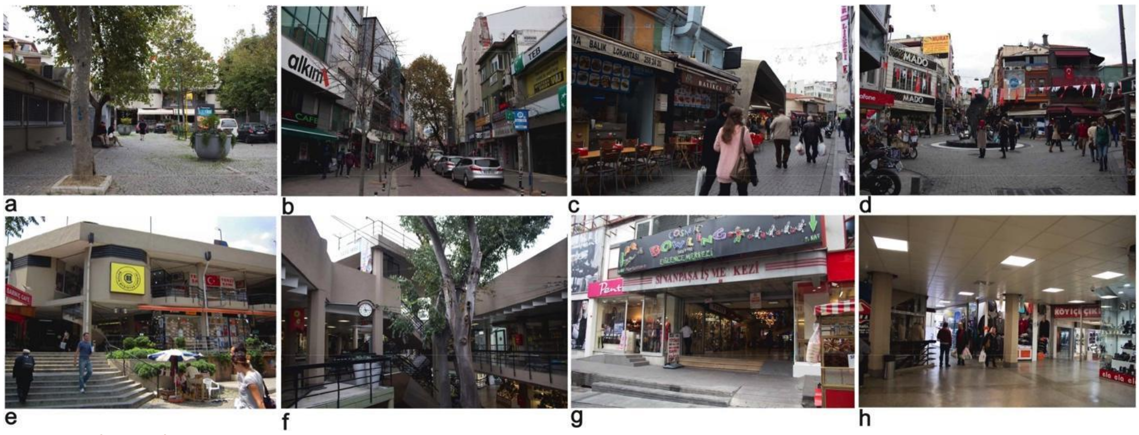
Cultural Center. Two of them are big and four of them are small-scale passages, which sprawl across eight thousand square meters of land and have walkways stretching to hundreds of meters inside. Figure 2 shows some views from these passages and the surrounding open streets. All of the passages are in commercial use, containing shops, cafes and restaurants, and one of them has additional facilities, such as an education center and a performance hall. The first three passages are interconnected; providing a long, enclosed walkway with interior access for market users. They all border the open streets and create semi-open connections with public spaces. Passages A and B are the biggest passages, which are as large as an ordinary mall in today's terms. Passage A faces the main market street and has three more gates on the street below. It has an atrium and a circular stairway that connects the different levels visually and physically. Passage B has a landscaped courtyard in the center that allows daylight and fresh air to enter the large walkways, creating a sense of being outdoors despite its size. It has many entrances in different directions. Passage C is a linear passage with a narrow corridor that connects Passage B to the main market street. Passage D mostly comprises shoe shops and has a similar plan to Passage C. Passages E and F contain specialized jewelry and fabric stores and its L-shaped plan loops back to the parallel main market street.

Figure 2. **(a) A view towards Passage B (b) Ortabahce Street (c) Koyici Street (d) Koyici Square (e) One of the entrances of Passage B (f) The interior courtyard of Passage B (g) The entrance of Passage A (h) The interior semi-open walkways of Passage B**



Source: The authors, 2023

4.2 Analyses of Findings

4.2.1 Axial and segment analyses of space syntax

The first analysis is performed by the space syntax axial measures of connectivity, integration and choice. Figure 3 shows the axial maps (R3) of the current street network with passages and a hypothetical street network where there are no passages as if the whole area was a compact urban block. The mean values for connectivity, integration, and choice of the market area for both networks are listed in Table 1. Accordingly, while there are 234 lines in the current street network, which incorporate all the public walkways in both the passages and streets, the hypothetical setup possesses 24 fewer lines, with 210 in total. From the current street network (with passages) to the hypothetical network (without passages), the mean connectivity and integration values decline slightly from 3.37 to 3.29 and 1.62 to 1.58. The space syntax axial measure of 'choice' also declines from 36.92 in the current condition to 35.89 in the hypothetical condition. As can be seen in space syntax axial analysis, the highly integrated lines that are the main streets of the market area are generally the same in both networks; however, the integration and connectivity values of these axial lines decrease slightly in the network without passages. For example, Koyici Street, which is the main street of the market area in the north, has a higher integration value (2.78 and 2.72) in the current network due to the connections provided by the passages compared to the network

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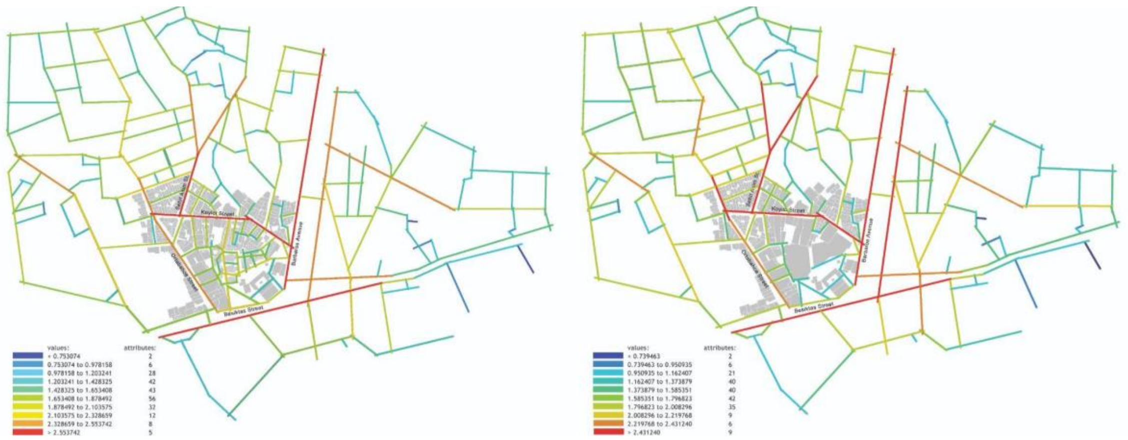
without passages (2.55 and 2.45). Similarly, the connectivity value of the same street also decreases from 12/9 to 9/7 for the street networks before and after. On the other hand, Ortabahce Street shows very slight changes in integration and no change in connectivity before and after compared to Koyici since it has no direct connections to the passages. The choice values of the first and second axial lines of Köyici Street decrease from 621/481 in the current network with passages to 326/263 in the street network without passages; which means there is nearly a reduction by half. Similarly, Ortabahce Street, which is not directly connected to the passages, exhibits very little difference between the before and after choice values.

Wilcoxon Signed Rank Test has also been applied to both street networks to compare axial mean values of connectivity, integration and choice measures. The comparison between these two street networks in axial analysis shows that there is not a significant difference between connectivity, integration, and choice values of the whole street network with and without passages ($p>0.01$), as is seen in Table 2. It is thought that the fact that the study area is relatively small in scale might be effective in obtaining these results in the axial analysis. At this point, considering that the area is not suitable for axial analysis, it is also to be analyzed with segment analysis to examine how the passages contribute to integration and route choices in the street network. Segment analyses (Rn) were made in an area centering the market within a diameter of 400 m. walking distance. The mean values for T4 integration, metric, angular, and topological choice of the market area for both layouts are listed in Table 1.

Figure 3. **The axial maps (R3) of the current street network with passages (left) and a hypothetical street network without passages (right)**



Source: Elaborated by the authors from DepthmapX, 2023

The Wilcoxon Signed Rank Test has been applied to compare the mean values of the street network with and without passages obtained from segment analyses. Significant differences have been found between the T4 integration of the street networks with passages and without passages ($p<0.01$), as well as between the metric and topological choice values ($p<0.01$) at the 99% confidence level. Also, a significant difference has been found at a 95% confidence level between the angular choice values of street networks with and without passage ($p<0.05$). In the results of the segment analysis, as shown in Table 2, more pronounced differences were found in the choice and integration values of the street network with and without passages. These results show that the passages make significant differences in the street networks in terms of connectivity. The street network in the hypothetical condition transforms the passages into a closed urban block and does not support access to the internal section, whereas the current layout provides more connections and supports higher accessibility throughout the market area. When the number of immediate connections that are provided by these passages disappears, it causes a decrease in integration and choice values of the street network, which means that the street network where there are no passages tends to be segregated in the whole street network. Thus, while the core of the market area is segregated dramatically in the hypothetical layout, the core of the current street network with its passages supports higher integration and accessibility in comparison. The differences in these two street networks, which are especially evident in the choice values, reveal that the passages connect the streets in different directions, and thus support the formation of alternative routes within the urban network. The six passages in the current layout create many diverse, short, and alternative movement routes within the system. These results also show that using segment analysis instead of axial analysis gives more accurate results in the analysis of small urban areas with space syntax.

Table 1. **Axial (R3) and segment (Rn) analyses of the current street network and a hypothetical street network through connectivity, integration and choice values**

Axial analyses (R3)	Street network with passages					Street network without passages				
	Min.	Max.	Mean	SD	Count	Min.	Max.	Mean	SD	Count
Connectivity	1	12	3.37	1.74	234	1	10	3.29	1.65	210
Integration	0.53	2.78	1.62	0.40	234	0.53	2.64	1.58	0.40	210
Choice	0	621	38.89	74.30	234	0	395	35.89	62.35	210
Segment analyses (Rn)										
T4 Integration	70.89	297.99	178.33	58.37	403	50.71	182.78	111.32	32.28	281
Metric choice	402	19094	2505.79	3318.9	403	280	11515	1545.84	2052.56	281
T4 Angular choice	0	65541	6164.43	12963.4	403	0	30694	3135.44	6155.64	281
Topological choice	402	26101	3259.03	4484.99	403	280	13919	2096.1	2618.22	281

Source: The authors, 2023

Table 2. **Wilcoxon Signed Rank Test results to compare axial and segment metrics of street networks with passages and without passages**

		Mean	N	SD	Z score	Sig.
Axial analyses	Integration (R3) with PSGs	1.63	210	0.38	-1.78	0.75
	Integration (R3) without PSGs	1.58	210	0.40		
	Connectivity (R3) with PSGs	3.35	210	1.67	0.45	0.65
	Connectivity (R3) without PSGs	3.29	210	1.65		
	Choice (R3) with PSGs	36.92	210	72.10	-0.82	0.41
	Choice (R3) without PSGs	35.89	210	62.50		
Segment analyses	T4 integration with PSGs	181.99	281	55.68	-13.02	0.000**
	T4 integration without PSGs	111.32	281	32.34		
	Angular choice with PSGs	6089.81	281	13316.85	-2.22	0.026*
	Angular choice without PSGs	3135.44	281	6166.62		
	Metric choice with PSGs	2546.44	281	3366.79	-4.42	0.000**
	Metric choice without PSGs	1545.84	281	2056.23		
	Topological choice with PSGs	2096.10	281	2622.89	-5.54	0.000**
	Topological choice without PSGs	3616.68	281	4960.96		

Note: ** The data presented are at a 99 % confidence interval and a significance level of 0.01. * The data presented are at a 95 % confidence interval and a significance level of 0.05. Source: The authors, 2023.

4.2.2 Visual analyses of space syntax

Connectivity, as a VGA-specific metric, is associated with the isovist area and is defined by the number of cells that are visible from a particular cell (Koutsolampros et al., 2018). It was employed to see the degree of direct visual connection or visibility between the passages. Visual connectivity helped us to understand how well people could see or perceive one location from another within the street network. As seen in the map in Figure 4, visibility converges at the intersection of the streets and the larger areas, such as the squares, including Passage Square 1, Koyici Square, and Cami Square. High visual connectivity often correlates with more direct and easily navigable paths between spaces. The highest visibility was recorded on the main market streets of Koyici and Ortabahce. The large walkways of Passage A and B and the atrium located in the middle of Passage B improve visual connectivity and provide a spacious environment for the visitors. The values decrease inside the closed loop structure of passages E and F and along the long corridor of Passage D. The streets at the rear of Passage B, which head towards Ortabahce Street, are not visually integrated with their immediate surroundings and are used by fewer people compared to other open streets. The connections between Passage A and B also have very low visibility values

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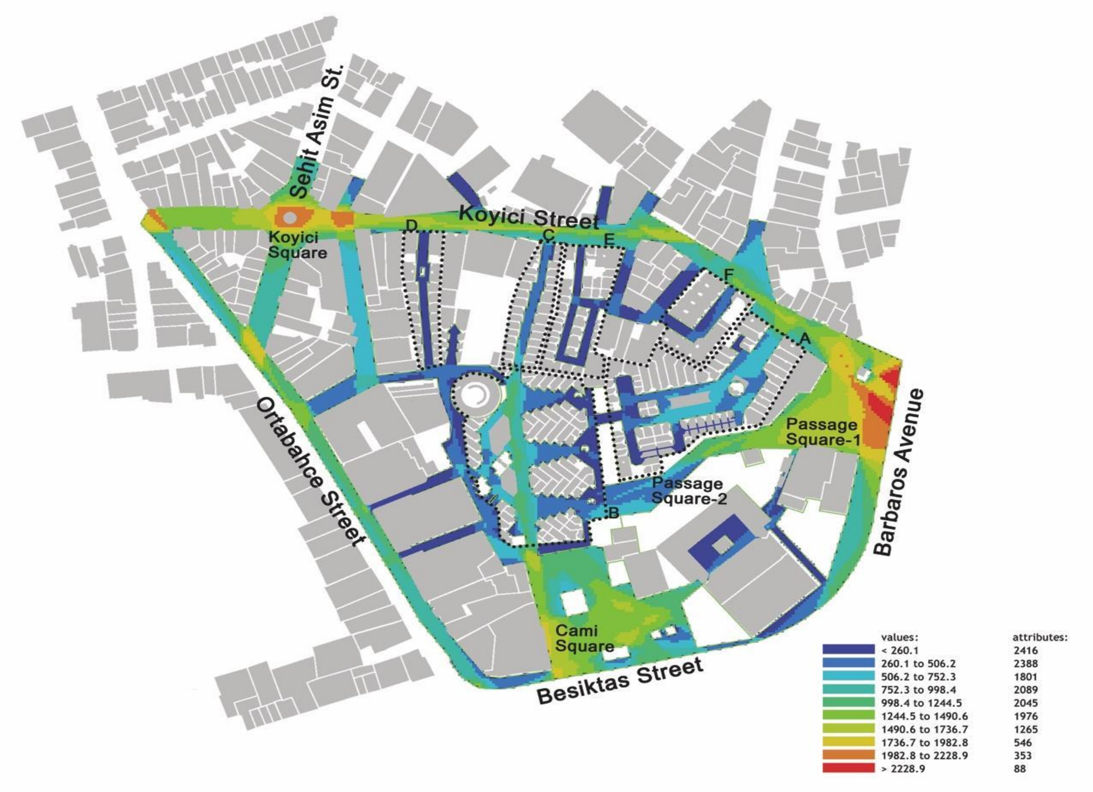
due to their very narrow corridors, which are connected by stairs. The narrow and long corridors in the passages and their connections to the open streets have very low visibility values. As the passage entrances become larger, light penetrates the semi-closed passageways. Visibility gradually diminishes when pedestrians move from the open streets to the long and narrow passageways. Compared to the integration values of the axial map, it can be seen that highly integrated street segments and spaces also have a higher degree of visibility.

Figure 4. **Visual connectivity values related the market area (by DepthmapX)**



Source: Elaborated by the authors from DepthmapX, 2023.

To widen our understanding related to the relation with visibility and street network, we conducted another analysis by using the Isovist _App (McElhinney, 2022), which is a free multi-platform software tool. It is based upon the spatial unit known as the ‘isovist’ (Benedikt, 1979). The Isovist_App can show isovists directly, compute inherent geometrical or relational properties of them as ‘measures’ and display spatial representations of how such measures are distributed in space as "fields”. Isovist area, which expresses the area of all space visible from a subject point in the plan, directly refers to ‘connectivity’ in visibility graph terminology -equivalent measure produced by depthmapX method. We performed a Vista Length analysis, seen in Figure 5, to determine the longest sightline achievable from various locations, accounting for obstacles and boundaries in the space. Vista length values identify regions of high axial view (McElhinney, 2022).

Longer vista lengths contribute to a more open and expansive perception of space, while shorter vista lengths may result in a more enclosed or confined atmosphere. Accordingly, the interiors of Buyuk Besiktas Passage (B) and Koyici Passage (C) feature the longest vista lengths, measured at the Passage Square-1 and the midpoints of Ortabahçe and Koyici Streets. The route cutting across the market area through the aforementioned passages offers an unobstructed view, promoting spatial continuity in the street network. Notable, the main streets with elevated vista length values align with pedestrian flows; aiding people in orienting themselves and comprehending the overall layout more easily.

Figure 5. **Vista length analysis**

Source: Elaborated by the authors from Isovist App., 2023.

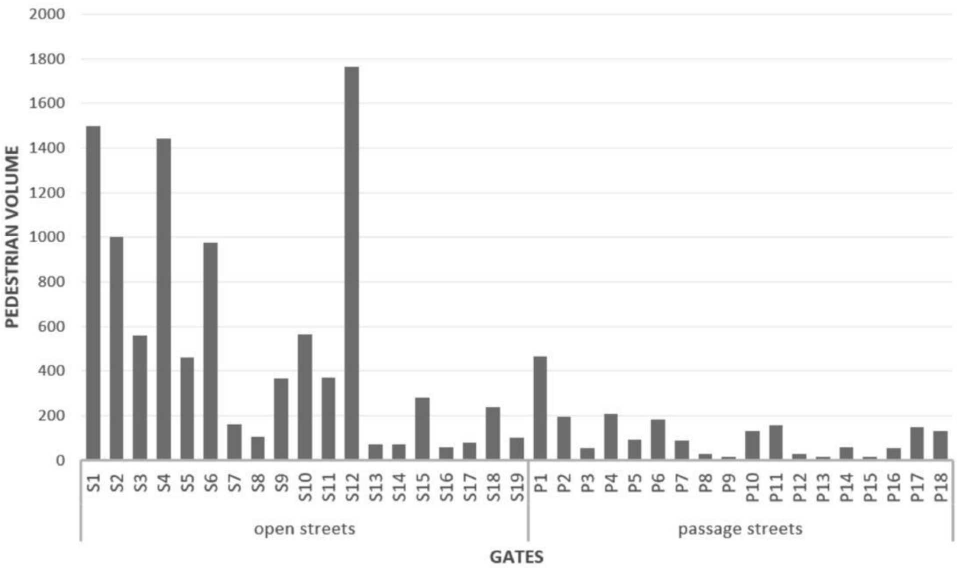
4.2.3 *The gate method of systematic observation*

The streets and passages were also monitored to determine the pedestrian volume. In total, 12.270 people were counted at the 37 gates within the study area. According to the data given in Figure 6, the volume of pedestrians on the open market streets is much higher than the passage streets. Thus, as seen in Figure 7, the highest pedestrian volumes were observed at the main open streets of the market area, such as S1, S2, S4, S6, and S12.

The main entrances of the passages P1, P2, P4, and P6 had a relatively higher volume of pedestrians in comparison to the passage streets. The loop-structured streets of the passages had the lowest counts, which were predominantly under 150 pedestrians.

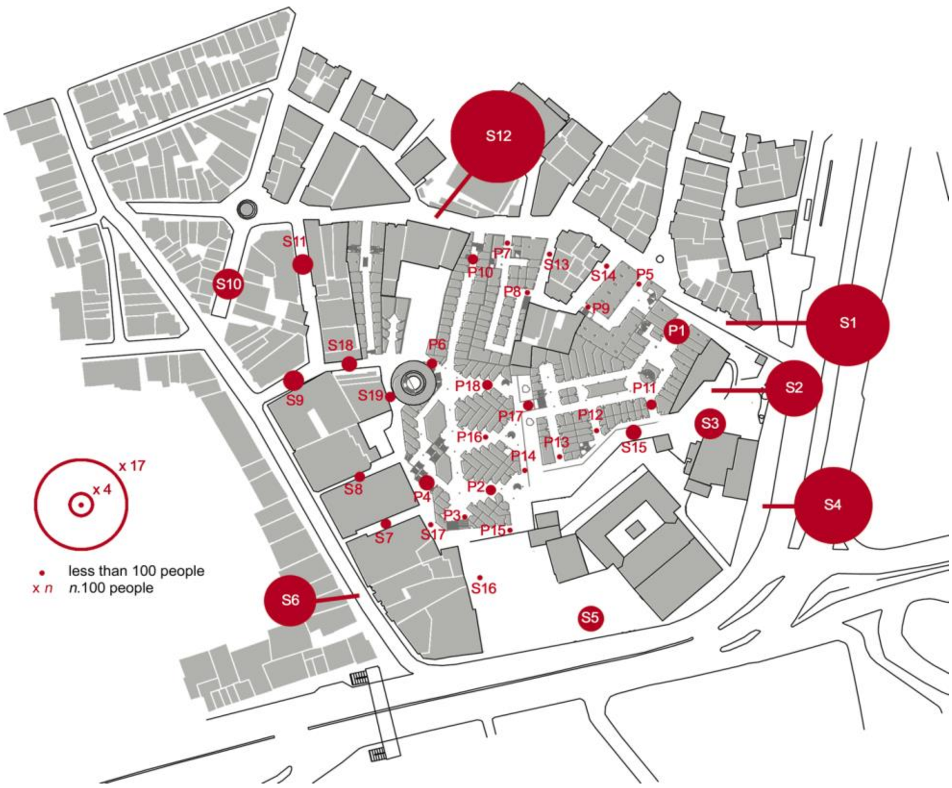
The non-parametric Mann-Whitney U test was applied to find out whether there is a significant difference between open streets and passage streets in terms of pedestrian volume. According to the results, the pedestrian volume between open streets and passage streets is significantly different (U=65, P=0.01) from each other. These results show that pedestrian volumes diminish gradually from open streets to passage streets. Thus, passage streets create a capillary vessel effect in the whole street network.

Figure 6. **The pedestrian volume at 37 gates within the study area**



Source: The authors, 2023.

Figure 7. **The location of the gates with their pedestrian volume in the study area (dot sizes show the frequency of pedestrian volume)**



Source: The authors, 2023

4.2.4 Correlational analyses

To further investigate whether the passages create a difference in street networks in terms of physical and visual connectivity, correlational analyses were performed. The correlational analyses of the pedestrian volumes with T4 integration, metric, angular and topological choices, and visual connectivity values of the streets were carried out in three groups: Pedestrian volumes at (1) all gates, (2) the gates of open streets, and (3) the gates of the passage streets (Table 3). These analyses not only show physical and visual connectivity's influence on pedestrian volume but also enable us to discuss the effects of passages in terms of physical and visual connectivity based on correlational differences among the groups.

Significant positive correlations have been found between T4 integration and pedestrian volumes for all of the groups (r=0.61, P=0.000 for all gates; r=0.59, P=0.007 for open streets and r=0.60, P=0.009 for passage streets). These findings show that pedestrian volume can be predicted by the variations in integration. As integration increases, so does the pedestrian volume. The comparison of the correlation values of open streets and passage streets shows that the contribution of passage streets to integration compared to open streets is not much different from each other. Angular, metric, and topological choices also show positive significant correlations with pedestrian volume. The correlations between angular, metric, and topological choice values with pedestrian volume at all gates reveal significant relationships at the 99% confidence level (r is 0.68 for angular choice, r is 0.52 for metric choice and r is 0.53 for topological choice). That is to say, pedestrian volume confirms how busy a street is for the shortest routes. However, there are a few differences in the comparison of choice correlations between open streets and passage streets. The angular choice positively correlates with pedestrian volume at both open streets and passage streets, but the correlation between pedestrian volume at open streets and angular choice is much higher than the correlation between pedestrian volume at passage streets. It is very clear that open streets have the least angular deviation, but passage streets in the study area mostly do not provide the straightest routes compared to open streets, instead, they branch and extend the existing street lines. The comparison of the correlations of metric choice with pedestrian volume in open streets and passage streets shows that the correlation between passage streets and pedestrian volume is much higher than the correlation between open streets and pedestrian volume, which verifies the passages provide the shortest route. However, there is not a significant difference between passage streets and open streets related to the correlation of topological choice and pedestrian volumes.

Finally, visual connectivity shows a consistent relationship with pedestrian volume. As visual connectivity increases, so does the pedestrian volume. By increasing the visibility of the streets, especially with their wide entrances, the passages also contribute to an increase in pedestrian volume. The correlation between visibility and integration decreases in open streets but increases when passageways are included.

Table 3. **The correlational analysis of pedestrian volume with integration, choice and VGA at all gates**

Spearman correlations	Pedestrian volume (All gates)			Pedestrian volume (Gates at open streets)			Pedestrian volume (Gates at passage streets)		
	N	r	Sig.	N	r	Sig.	N	r	Sig.
T4 integration	37	0.61	0.000**	19	0.59	0.007**	18	0.60	0.009**
Angular choice	37	0.68	0.000**	19	0.81	0.000**	18	0.57	0.013*
Metric choice	37	0.52	0.001**	19	0.53	0.19*	18	0.68	0.002**
Topological choice	37	0.53	0.001**	19	0.49	0.035*	18	0.53	0.025*
VGA	37	0.66	0.001**	19	0.52	0.024*	18	0.53	0.024*

Note: * Correlation is significant at 0.05 level (2-tailed) ** Correlation is significant at 0.01 level (2-tailed)
Source: The authors, 2023

4.2.5 Following and observing pedestrians' routes

To learn how people are using the passages, a total of 210 people who entered the passages at six passage entries (35 people per entry) were followed and their route choices were observed in three interconnected passages (passages A, B, and C). Figure 8 illustrates the observed pedestrians' routes including entrance/exit points, and how frequently these routes were used on the ground floor of the passages. Since the upper and lower floors of the passages are used very rarely (for specific purposes such as visiting the post office, tax office, or public toilet), those routes are dismissed. Table 4 shows the circulation patterns of pedestrians as follows: Direct passing by, which refers to a direct walk without stopping for any activity (in this category, pedestrians use the passages as a shortcut); shopping behavior, which is a purposeful activity carried out while walking; and flâneur behavior, which is a non-purposeful idle walk in the passage streets without shopping. The findings are summarized as follows:

Table 4. **Observed circulation patterns through the interconnected passages of A, B, and C**

Circulation Patterns	Total	Percentage (%)
People who make loops	24	11.4
People who go out from different exits	186	88.6
People who shop	85	40.5
People who do not shop	125	59.5
Direct passing behavior	103	49
Idle walk/ Flaneur behavior	22	10.5

Source: The authors, 2023

Most of the observed pedestrians (88.6%) came out of a different entrance than the one they entered through, following a total of 75 different circulation routes. 11.4% of the observed pedestrians who walked through the passages made a loop circulation, which means that they went into the passages through one entrance and then exited from the same point. 49% of the pedestrians passed by through the passage, which is a direct walk without stopping for any kind of activity, 40.5% of the observed pedestrians were doing shopping, and 10.5% of them were engaged in flâneur-like behavior. It has been shown that the total ratio of flâneurs and direct passers-by is more than the shoppers, and those who exit from different points are more than those who make a loop, which suggests that these passages have been mostly used for connection purposes.

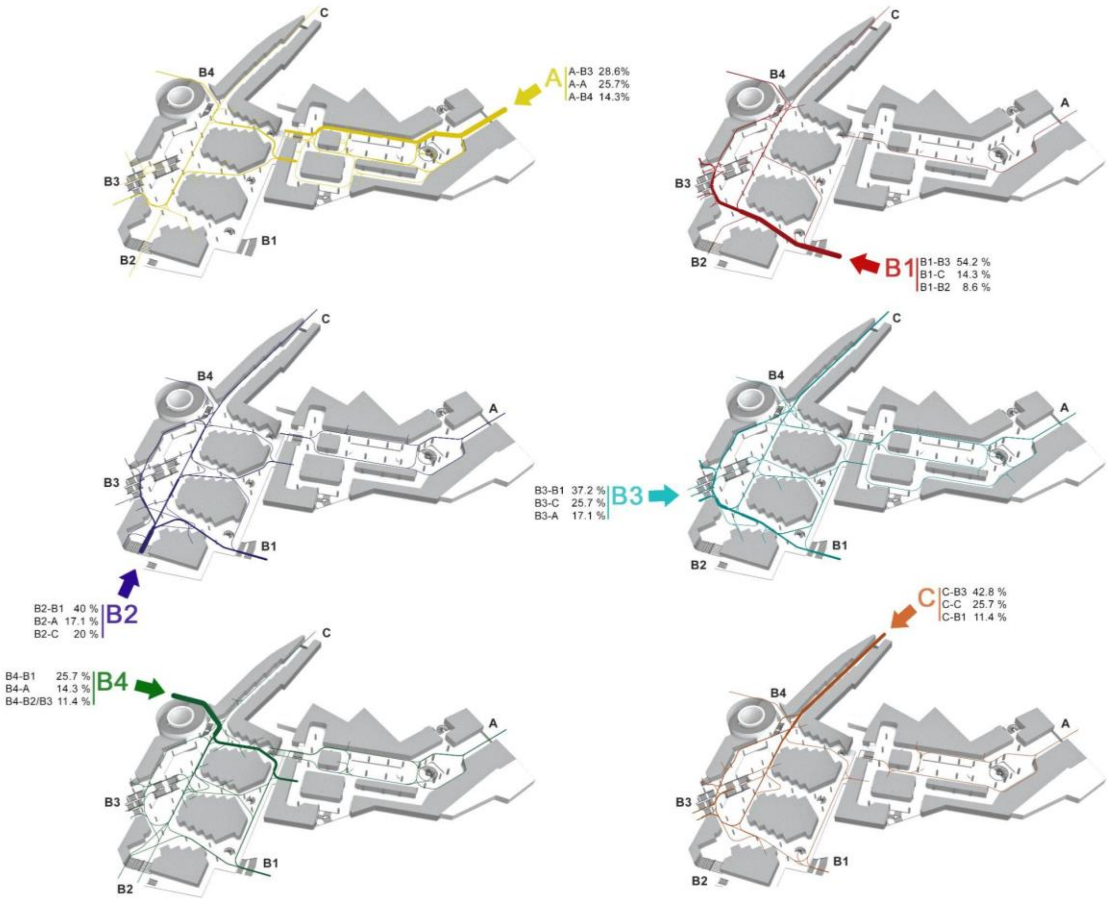
Three of the passages with a total of ten entrances create a total of 39 different connections. The observed pedestrians mostly used the routes: B1-B3 (54.2%), C-B3 (42.8 %), B2-B1 (40%), and B3-B1 (37.2%). These routes are the most direct and shortest ones, as they connect the roads in different directions. In particular, the direct route between B1 and B3 provides a perfect shortcut for passage users. Moreover, the entrances of B1, B2, and B3 are wide enough to provide visibility and invite pedestrians, which supports more transit flow. B1 as the main entrance of Passage B with a public square in front, collects and directs many pedestrians to the interior spaces of the passages, and splits the pedestrian volume towards the exit points in different directions, such as B3, B4, and C. Thus, it is seen that the heavily-used routes are mainly the shortcuts and the routes that provide connections between roads in different directions.

The routes between A-B3 (28.6%), B3-A (17.1%) and B2-C (20%) are moderately used routes in the whole market area. The reason why they are not used very intensively despite providing cross-connections is that they are also very long and include level changes, which implies that they are more complex and difficult to navigate, especially for those who are not familiar with the market area. The least used routes such as B1-B2 (8.6%), B2-B3 (5.6%), B3-B4 (5.6%), and B4-C (5.6%), do not connect roads in different directions, even though they are very short. The entrance B4 is narrow and has less visibility, and thus it is an uninviting entrance and only chosen by those who directly visit certain shops. The routes of A-B2 (5.6%) and B1-A (2.9%) which are among the least used ones are the longest and most indirect routes in the whole market area.

When all of the findings are evaluated together, the observations reveal the following results:

- The passages provide very diverse routes for pedestrian movement.
- Most of the pedestrians walk through the passages for a direct pass.
- Entrance and exit patterns in the passages generally depend on connecting movement in the opposite directions, which create alternative routes in the street network.
- Spatial attributes of the passages are very influential for holding pedestrian movement. While direct and short-cut routes with wide and inviting entrances, which provide connections towards opposite directions are the most heavily used ones; long and indirect routes which include level changes and less visible, narrow corridors and entrances are the least used ones.
- The majority of the pedestrian movement occurs on the ground floor of the passages, which also proves the connectivity feature of the passages.

Figure 8. **The most used pedestrian routes in the passages with their entrance-exit points on the ground floor**



Source: Authors, 2023

5. Results and Discussion

The axial analysis data does not cover differences in terms of the urban connections of the street network with passages and without passages, as it looks at the area on a larger scale, and is insufficient to explain the connections in such a small urban area. At this stage, segment analyses and observations allowed us to make a detailed analysis by zooming in the study area. The results of the observation allowed us to understand how and in what way the different spatial qualities of the passages contribute to the connections.

According to the results based on the segment analyses and observations, it has been seen that the passages increase connectivity and spatial integration by providing many diverse, short, and alternative routes within the street network. The findings show that street connectivity affects the distribution of pedestrians. It has also been observed that most of the pedestrians used the passages as a shortcut, rather than for shopping purposes. Thus, the passages mostly serve as a connector within a street network, rather than a place to carry out an activity, such as shopping. Furthermore, the effective use of the passages is mostly associated with their spatial attributes. In other words, as long as they are short, direct, and provide connections to opposite/different directions, the passages can be used effectively. If passages do not provide any connections to the surrounding street network, making a loop circulation, only the users who use the passage for a specific purpose or activity go there. As it is only used by very few people, a loop typology loses its efficiency. The interconnecting passages create shortcuts and numerous alternative routes that connect different directions within the market area.

In terms of the visibility of the passages, the findings show that the passages contribute to a rise in the visibility value of the street network. In particular, the passages with wide entrances cause both high visibility and high integration values in the street segments where they are located. It has been seen that the higher the integration of the streets, the higher their visibility. However, spatial features such as 90-degree turns, long and narrow corridors, and level changes reduce the visibility of passageways, causing them to be used by fewer people.

As the findings suggest, passages enable street networks to be more accessible. The results support previous research findings and confirm the relationships between (1) the impact of integration on pedestrian volume (Hajrasouliha and Yin, 2015; Ozbil et al, 2011); (2) the effect of visibility on pedestrian volume (Parvin et al, 2008; Desyllas, and Duxbury, 2001); and (3) the effect of visibility on the integrated street network (Desyllas, and Duxbury, 2001). The results also give attention to the fact that the spatial qualities of the passages have an impact on their connectivity and visibility.

6. Conclusion

Understanding how passages contribute to physical and visual connectivity and pedestrian movement in street networks is essential for creating successful and livable urban spaces. In this study, the movement and routes of pedestrians in a market area of a city connected by passages have been examined to reveal the connectivity of passages. After the analyses of axial and segment integration, visibility, and pedestrian volume, the results of the study can be summarized as follows:

- Passages increase the connectivity and integration of the street network in which they are located. Since passages increase the integration of a street network, they also contribute to an increase in pedestrian volume. Passages provide shortcuts, different routes, and alternative paths for users. In other words, the areas where passages are located in an urban layout will be much more accessible. However, the findings also showed that the effective use of the passages is predominantly associated with their spatial attributes. The more alternative routes the passages provide, the more pedestrians use them, and thus, the more successful they become in the urban layout. Passages with long and narrow corridors, different levels, and loop circulations result in a lower volume of pedestrians. As long as passages are short and direct, providing connections in opposite and differing directions, they can contribute not only to the accessibility of streets but also to the vitality of our cities.
- Physical and visual connectivity are in mutual interaction with each other. Visual connectivity has an important influence on pedestrian flow. As their visibility value increases, the passages attract more pedestrians to the street network. Higher visual connectivity in street segments leads to a more integrated street network.

Overall, passages provide a well-connected and integrated street network by offering different connections and alternative routes within the street layout. Well-connected street networks provide pedestrians with easy access to key destinations. This integration also increases accessibility by continuing pedestrian flow, thus increasing the livability of public spaces by attracting more people. As shown, passages that contribute to visual and physical connectivity are significant building types in terms of enhancing the livability of public spaces. It is also essential to recognize the impact of the market on the vitality of streets. The market serves as a crucial attraction point, potentially transforming isolated passages into visited ones. The absence of the market would lead to the neglect of the passages since it plays a key role in activating the place, rather than just remaining at the center of through movements. It is noteworthy that space syntax analysis, which focuses mainly on the spatial and topological relations of the streets, does not consider the impact of attraction points; therefore, they are generally supported by various analysis techniques such as observations and other functional analysis. Given this limitation, an investigation of how attraction points can be integrated into space syntax analysis may yield valuable findings for future research. The present research provided insights to urban designers and architects by demonstrating the importance of passages, which are decreasing day by day in contemporary cities, in terms of providing connectivity in a street network. Further research is needed to confirm the connectivity of passages in different cases, which will also contribute to obtaining generalizable results. Future research will ensure that the passages deserve more attention, both in theory and in practice.

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