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THE EFFECT OF BRIDGES ON THE SPATIAL CONFIGURATION OF CITIES:

The Golden Horn, Istanbul case

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ABSTRACT

Throughout history, transportation projects have attempted to offer full accessibility for their users. In terms of the overall street pattern, bridges are considered to be components which shape the urban form and affect the spatial configuration of cities.

Transportation projects especially subways, bridges and new transportation modes such as tube tunnel, gained importance in İstanbul in the last decades. One of the projects; the Golden Horn Metro Bridge, which connects two parts of the European side of İstanbul (Sarıyer district in the north to Yenikapı, a major transport hub in the south) and has a station on the bridge, has caused major criticisms not just because of having these unique and significant characteristics but also because of the effects of the bridge on the silhouette of Historical Peninsula.

The main aim of this paper is to analyze the impact of bridges on their surrounding environments and to explore the different influences of metro and vehicular bridges. Within this scope, three bridges located over the Golden Horn (the Atatürk, Galata and Golden Horn Metro bridges) which created connections between historical site of İstanbul and the newly developed CBD are chosen as case study. Area within 1km (0.6 mile) zones around the three bridges were analysed, and GIS-based urban pattern (street pattern, block size and building utilization) and Space Syntax (angular segment based integration and choice implemented in Depthmap) analyses were conducted for demonstrating the changes in the spatial organization of the area before and after the construction of the bridges and for explaining the different effects of metro and vehicular bridges.

The findings of the study indicate that after the construction of the bridges spatial values of the surrounding urban form have increased and the area has become more intelligible. Additionally, the study area has transformed into more divided streets and urban blocks and the number of buildings increased through time. On the other hand, it is observed that the metro-rail bridge system has less impact on the pattern and spatial configuration of the settlements when it is compared with the impact of the vehicular bridges. This study contributes to urban planning and design not only by making an analysis of the impact of different kinds of bridges on the spatial character of cities, but also by analyzing the effects of bridges in a historical city and by drawing comparisons between the pre- and post-construction processes.

KEYWORDS

Urban morphology, spatial configuration, space syntax, the Golden Horn Metro Bridge, İstanbul

1. INTRODUCTION

The Golden Horn region of Istanbul constitutes an important historical part of the city. This area has changed dramatically during its long history and the bridges which have been constructed along the Golden Horn are significant examples of these changes. Due to the effect of these bridges, the form of the settlements on the Golden Horn has changed, and by examining this change, this study analyzes the major effects of bridges on the form and spatial structure of cities.

This study can be considered important because it analyzes not only vehicular-pedestrian bridges, but also a newly-constructed metro-pedestrian bridge over the Golden Horn of Istanbul. To analyze the effects of bridges on spatial configuration, pattern analyses prepared in GIS (Geographic Information Systems) for different periods were examined. Space Syntax, the methodology of which measures the connectivity and accessibility values of a street network, was utilized to support the morphological results.

Space Syntax is a methodology that was developed by a team led by Bill Hillier (Hillier, 1996). This methodology is important as it gives consistent results based on the mathematical data created according to the open spaces within cities. It provides unique evidence-based learning by creating a systematic framework that allows comparisons between environments to be made (Peponis, 1990). Therefore, in this study a comparison between close surroundings of bridges are made by the help of syntactic measures and pattern analysis.

The main goals of the study are:

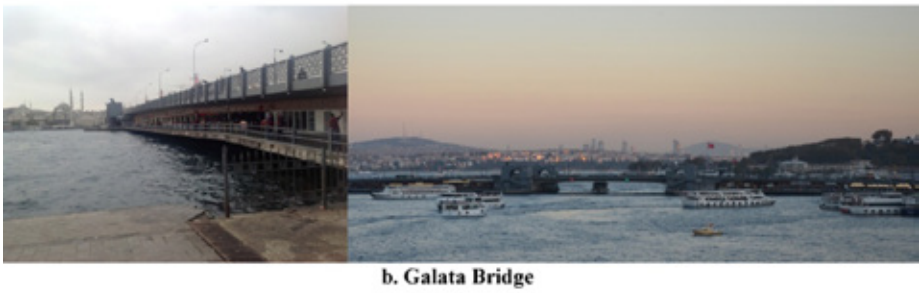
- to explore and analyze the pattern of settlements of the Golden Horn and determine its level of transformation
- to analyze the spatial structure of the area by using Space Syntax and pattern analysis
- to discover the relationship between the urban pattern and changes in its syntactic measurements
- to discover the different effects of vehicular-pedestrian bridges and metro-pedestrian bridges on the urban form

2. METHODS

Within the context of this study, three bridges which span the Golden Horn; the Atatürk, Galata and Golden Horn Metro bridges (Figure 1) were selected to facilitate an analysis of the impact of bridges on settlements. These three bridges were selected since they make a connection between the neighborhoods of the Historical Peninsula, which is well-known for its historical background, and the newly developed CBD.

As a part of this study, not only the pre-, post- construction process of bridges but also two time periods, which urban pattern changed dramatically, were also analyzed. During the first – 1922 – the Islamic city image changed to that of a more cosmopolitan city; the organic pattern started to shift toward a grid pattern and the Republic was about to be proclaimed. In addition to this, a tram line was added to the Galata bridge. During the second – 1996 – several planning decisions were implemented in the study area, thus the patterns of the settlements were changed.

a. Atatürk Bridge



b. Galata Bridge

c. Golden Horn Metro Bridge

Figure 1 - Silhoutte and sidewalks of the bridges

Empirical evidence was used to determine 1km as a distance that people can, and do, walk (Lee and Moudon, 2006). To determine the specific study area, 1km zones around the bridges were created and the road segments at the edge of these zones were selected as the boundaries of the study area. Natural borders and boulevards were also considered to specify certain borders. Thus, this area can be described as;

- a region with a focus on bridges
- a pedestrian-scaled urban space
- a border that allows the effect of bridges on urban pattern to be observed more easily, and
- Divanyolu boulevard (the Mese, or main street of Constantinople) as the southern border of the study area (Figure 2).

Following this, morphological analyses such as:

- street patterns
- urban blocks
- building level land use were conducted in ArcMap 10.3.1.

To support this data, Space Syntax methodology was integrated into the study to allow angular analyses such as connectivity, integration r12, choice r3 and choice within 500 meters values by using UCL Depthmap 10 software (these measures are selected since these values show more significant results). Finally, these analyses were added to a table to allow comparisons to be made.

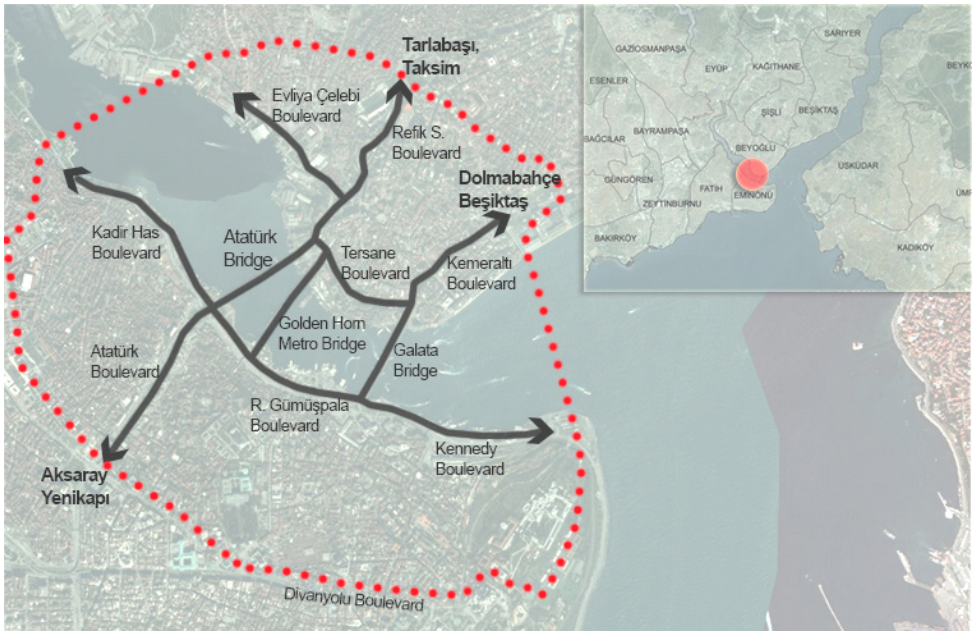


Figure 2 - Location and the borders of the case area.

3. ANALYSIS

3.1. HISTORICAL PROCESS OF THE BRIDGES

Historical background of the bridges over the Golden Horn dates to 1830s (Figure 3). Both the Galata and Atatürk bridges were originally constructed during the Ottoman period, while the Golden Horn Metro Bridge was constructed during the Republican period. These bridges are of great importance because they are located on the Historical Peninsula, which is listed as a World Heritage Site.

In 1836, the first historically-verifiable bridge was built across the Golden Horn. The bridge connected Azapkapı and Unkapanı, and was about 600m in length and 10m in width. The main reason for the construction of the bridge was the location of the imperial shipyards in Azapkapı. In addition to this, Pera(Beyoğlu) and Beşiktaş were not developed enough in the 1830s to support a connection between Karaköy and Eminönü, and Karaköy was not yet a busy trade centre, though it became so after 1838 (Celik, 1993).

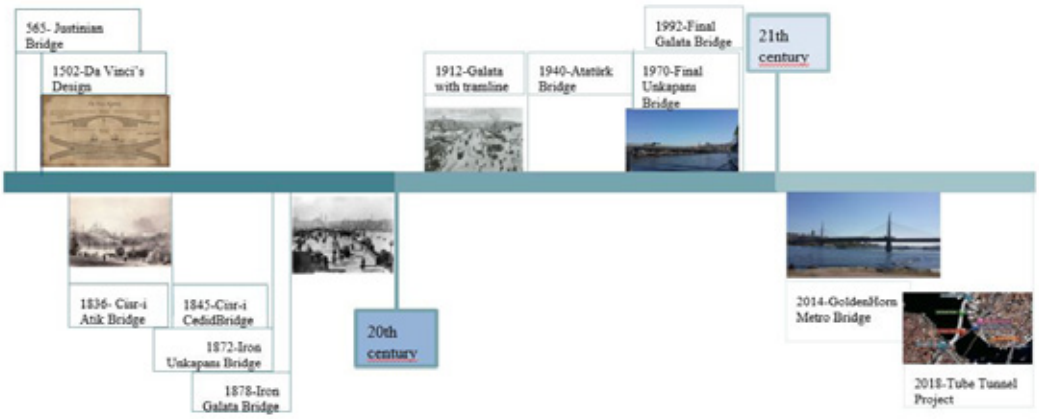


Figure 3 - Historical development of bridges over the Golden Horn

After this period, with the effect of increased transportation system between Karaköy and Eminönü the Sultan began to reside in a palace at Beşiktaş, known today as Dolmabahçe Palace. The population of Beşiktaş and Beyoğlu increased, and horse carts imported from Europe became more widespread. Therefore, the "Cisr-i Cedid" bridge, now known as the Galata Bridge, was built in 1845 (Cekmis Gorgulu and Hacihasanoglu, 2012). The original bridge served Istanbul for about 12 years, but discussions about replacing its wooden structure with one of iron began in 1869. The new bridge design was planned by an English company; it was to have been about 460m long and 18m wide, with 1.5m wide pedestrian sidewalks on both sides. The government agreed to the construction of the project, but the bridge plans underwent some changes (Celik, 1993).

A new Galata bridge was built in 1912 and the old bridge was moved to a place between Unkapanı and Azapkapı. The new bridge had more advanced technology that allowed a tram line. Following this, replacement and reconstruction of the bridges continued during different periods. In 1936 Unkapanı bridge broke into pieces as a result of a powerful storm. Therefore, in 1940 Atatürk Bridge was constructed between Unkapanı and Azapkapı. In the 1970s an agreement was made for a new bridge with Japanese-German company. The bridge which is still in use having had much extension work carried out at several times has become a very important and busy highway. In 1987, construction work for the Galata Bridge of today started. This bridge has a drawbridge-style opening at its centre which allows ships to sail through an 80m gap (Cekmis Gorgulu and Hacihasanoglu, 2012).

3.2. CONSTRUCTION PROCESS OF THE GOLDEN HORN METRO BRIDGE

The construction process of the Golden Horn Metro Bridge first started with an announcement by the mayor of metropolitan Istanbul, Kadir Topbaş, in 2004. He announced that there would be a new metro bridge, and that it would become a new landmark for İstanbul (Vardar, 2014). With the construction of the metro bridge, the underground line from Hacıosman, (passing through 4th Levent, Taksim and Şişhane), would reach the Yenikapı terminal and transfer station after crossing the Golden Horn (Cekmis Gorgulu and Hacihasanoglu, 2012). The project was approved in 2009 by the Conservation Board. Although the Historical Peninsula, where an abutment of the bridge is located, had been on the World Heritage Site list since 1985, the bridge project was not reported to UNESCO (Vardar, 2014). In 2009, when the construction of the project began, UNESCO stated that this project would damage the silhouette of Suleymaniye and the Historical Peninsula and warned that the area could be added to the World Heritage in Danger category (Bilgehan, 2015). After this warning, the project was revised and the height was decreased from 82 meters to 65 meters and construction work was halted until 2011 (Vardar, 2014). In 2012, the revised design of the project was approved and construction started again. The bridge eventually entered service in February 2014 (Figure 4).

Figure 4 - Entrance to the metro bridge (on left) and the link of the bridge to the Historical Peninsula (on right)

3.3 PATTERN ANALYSIS

In the 1830's, the Historical Peninsula was the center of the settlement and the Galata region was limited by its old borders. Outside these borders, however, there were newly developing settlements (Figure 5).

During this period, as shown in the figure below, the continuous street segments along the Golden Horn shoreline were notable. The street pattern of the time was usually organic, except at the north side of the Golden Horn and the south-western side of the study area.

Also during this period, the number of street segments totalled 437, while the average length of the streets was 152 meters. Additionally, the number of dead-end streets totalled 35 and the number of urban blocks totalled 148.

After the construction of the two bridges (in 1850), there were some changes to the morphological characteristic of the area. The number of street segments increased from 437 to 479, and the number of urban blocks increased from 148 to 185. Furthermore, some parts of organic street pattern located between the two bridges on the Galata side were rebuilt according to a grid pattern.

In addition to these impacts, the Galata Bridge became a part of the urban identity and the region around the bridge became known as Galata. The bridge became a symbol of the connection between the European and Turkish cultures as well as a physical connection between the two shores (Kuban, 1996).

During the 20th century, there were many different processes underway in the study area. Therefore, it was constructive to conduct an analysis across two different time periods. First, in 1922, when the Republic was about to be proclaimed and a tram lane was added to the Galata Bridge, the number of street segments increased from 479 to 2454, and the number of urban blocks increased from 185 to 828. The average area of the urban blocks decreased from 27177 to 5732 square meters and the number of buildings increased from 721 to 811. The most important buildings were the Sirkeci railway terminal (on the Historical Peninsula), two hospitals (Beyoğlu and Sankt Georgs) and the town hall (located in Galata). Additionally, after the establishment of the Republic of Turkey, Topkapı Palace was transformed into a museum at the date April 1924 and it was also the first museum of the Republic of Turkey. Ministry of war was transformed into a university building in 1923.

Second, in 1996, after the planning processes around the Golden Horn, the number of street segments increased to 2568 and the average area of the urban blocks decreased to 5449 square meters. The number of dead-end streets decreased from 127 to 107.

In 2006, before the construction of the third bridge (the Golden Horn Metro Bridge), the number of urban blocks increased from 876 to 1088 while the average area of the urban blocks decreased from 5450 to 4526 square meters. In addition, the number of street segments increased from 2568 to 3654 and the average length of the streets decreased from 58 to 48 meters. In addition to this, the study area now contains Istanbul Ticaret University and Kadir Has University.

In 2016, after the construction of the bridge, the number of street segments decreased from 3654 to 3648 due to the changing function of the shoreline. Additionally, the number of urban blocks decreased from 1088 to 1064, and the number of dead-end streets increased from 232 to 237.

Figure 5 - Changes in the urban form of the Golden Horn (only pre- and post- construction processes of bridges are shown in the figure)

3.4 SYNTACTIC ANALYSIS

In 1831, the highest value for choice (R3) was on the shoreline of the Golden Horn (Figure 6). On the other hand, the choice within 500 meters value was significant in both the Galata and the Historical Peninsula regions while the integration (R12) value was high in the Historical Peninsula. The integration (R12) and choice (R3) analyses emphasized three roads, the Ragıp Gümüşpala, Kadir Has and Atatürk boulevards. Galata Tower and its surroundings were defined as having high choice values. Unlike the integration analysis, the choice within 500 meters values do not show a hierarchical order. In 1831, the intelligibility value of the area was 0.196.

In 1850, connectivity measures moved towards the new bridge, and the highest integration value for R12 and choice value of radius 3 were recorded for Ragıp Gümüşpala Boulevard and the Galata Bridge. Additionally, high integration (R12) values continued through the south side of the Galata Bridge area. Moreover, the choice within 500 meters value was higher around the Galata Bridge, the Spice Bazaar and Galata Tower. It can be said with the effect of new bridge, the higher choice within 500 meters values moved from the Unkapanı Bridge to the Galata Bridge.

The street network configuration in 1922 showed significant changes and an increase of the values for choice (R3) (from 3.14 to 3.28), connectivity (from 3.25 to 3.31) and integration (R12) (from 7.29 to 7.61). Accessibility of the area increased dramatically in this period due to the urban form changes, and both the Galata and Unkapanı bridges recorded the highest integration (R12) values. The Atatürk, Tersane, Ragıp Gümüşpala and Kadir Has boulevards were also defined by having the highest integration values. The choice (R3) value and choice within 500 meters value did not show any hierarchical order during this period. The intelligibility value was 0.223.

In 1996, street connectivity measures; connectivity increased from 3.31 to 3.41, the choice (R3) value increased from 3.28 to 3.30, and the integration within 500 meters value increased from 7.60 to 7.65.

The integration analysis of the area verified the significance of the Atatürk Bridge, as well as the Atatürk and Şehzadebaşı boulevards. Choice (R3) values were high for the Atatürk, Ragıp Gümüşpala and Banks boulevards.

In 2006, the most integrated space was still the Atatürk Bridge and its connection to the Kasımpaşa neighborhood. The choice (R3) value increased from 3.30 to 7.15 and the choice within 500 meters value increased from 3.34 to 6.97. Additionally the integration (R12) value increased from 7.45 to 7.57. In terms of choice (R3) and choice within 500 meters, Evliya Çelebi and Refik Paşa Boulevard have higher values. The intelligibility value dramatically increased to 0.347 in this time period.

The choice(R3) value and choice within 500 meters value were same before and after the construction. The integration (R12) value increased from 7.57 to 7.59 in 2016. This analysis emphasized the importance of the Atatürk Bridge, and the Refik Saydam and Evliya Çelebi boulevards. Furthermore, the Tersane, Ragıp Gümüşpala boulevards and Atatürk Bridge are distinguished by their high integration values, as are the Galata and Golden Horn Metro bridges. The choice (R3) value and choice within 500 meters value verified the significance of the Refik Saydam, Evliya Çelebi, Tersane boulevards and the Atatürk Bridge. The intelligibility value increased to 0.372 in 2016.

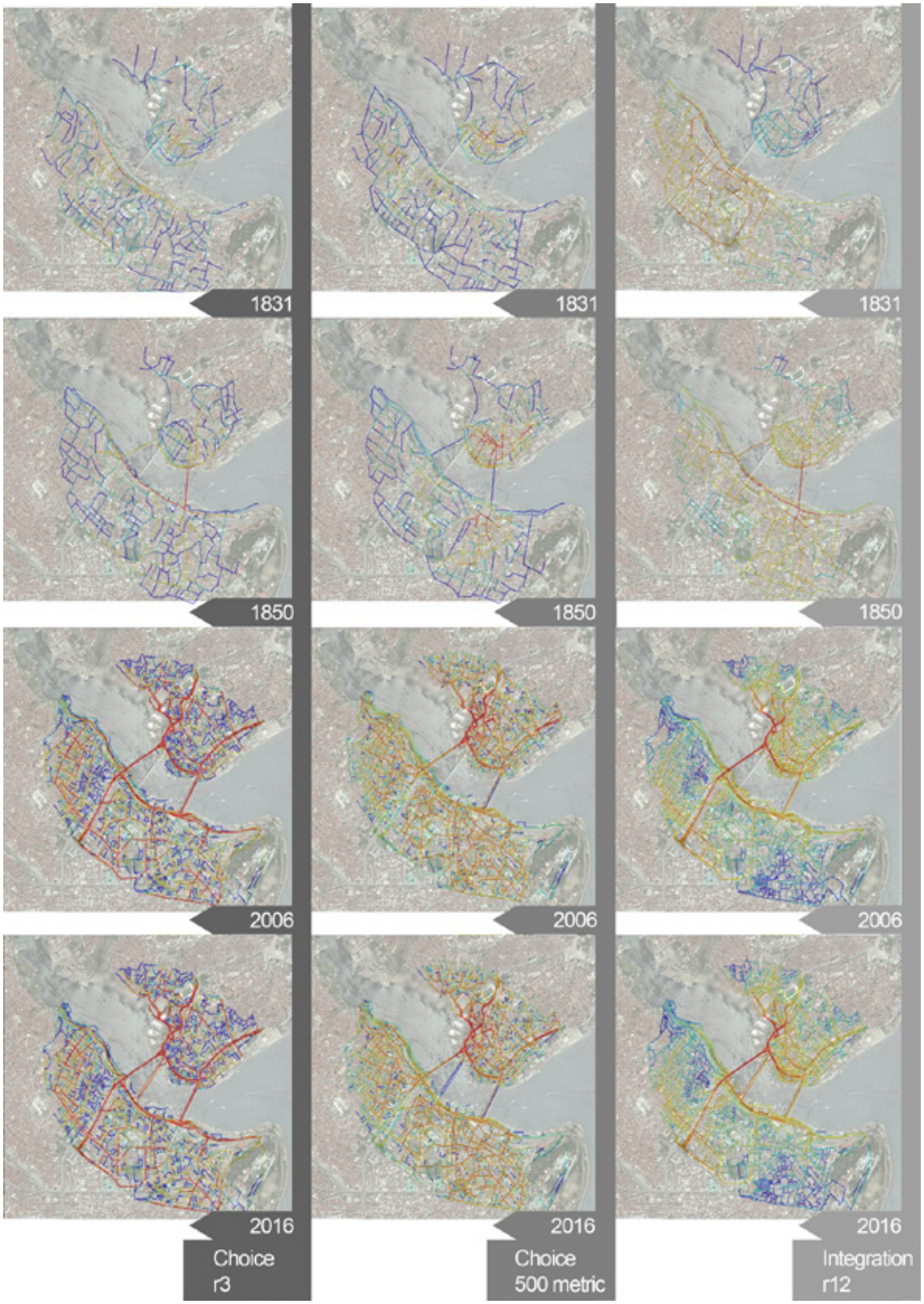


Figure 6 - Changes in the spatial values of the Golden Horn (only pre- and post- construction processes of bridges are shown in the figure)

4. RESULTS

Results of the study demonstrated that with construction of new bridges:

- number of urban blocks increased and blocks are divided by new streets or boulevards (Table 1)
- as the number of urban blocks increased, the average area of the urban blocks decreased
- syntactic measures; choice and integration values increased after the construction of the vehicular bridges (Table 2)
- especially after the construction of the second bridge, the number of buildings and new functions have increased (Table 3).
- intelligibility of the study area increased after the construction of the bridges.

Date		2016	2006	1996	1922	1850	1831
Street Pattern	Number of Street Segment	3648	3654	2568	2454	479	437
	Average Length of Streets(m)	49	48	59	56	154	152
	Number of Deadends	237	232	107	127	12	35
Urban Blocks	Number of Blocks	1064	1088	876	828	185	148
	Average Area of Blocks(m2)	4578	4526	5450	5733	27177	31611
Buildings	Number of Buildings	858	858	812	811	721	685

Table 1 - Urban form characteristic of the area around the bridges

Date		2016	2006	1996	1922	1850	1831
Syntactic Values	Connectivity	2,40	2,40	3,41	3,31	3,25	3,23
	Choice R3	7,15	7,15	3,3	3,28	3,14	2,91
	Choice 500 metric	6,97	6,97	3,34	3,46	2,45	2,32
	Integration R12	7,59	7,57	7,45	7,61	7,29	7,52

Table 2 - Average syntactic values of the area around the bridges

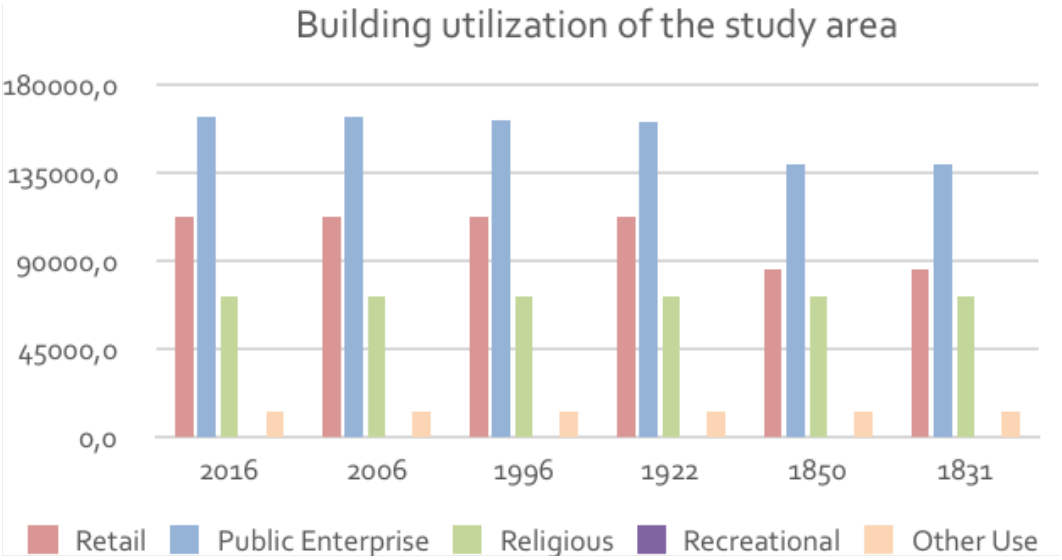


Table 3 - Building utilization of the area (m²)

Date	1831	1850	1922	1996	2006	2016
R^2	0.196	0.144	0.223	0.137	0.347	0.372
Significance	0.01	0.01	0.01	0.01	0.01	0.01
N	917	1100	4656	4665	22558	22500

Table 4 - Correlation of bivariate connectivity and integration(n) data for different time periods

**. Correlation is significant at the 0.01 level (2-tailed).

Finally, intelligibility is a value which is derived from the correlation between connectivity and integration. A high correlation between two factors means that the spatial structure is intelligible, and low correlation means that the spatial structure is not intelligible. Kubat (1997), discovered that the intelligibility value of the Anatolian towns she analyzed was 0.350, while that of the Islington area of London has been reported at 0.61-0.26 (Hillier, 1989), and that of Athens has been reported at 0.790 (Peponis et al., 1989). Also Pinho and his colleagues determined that global intelligibility value of Oporto (Portugal) was about 0,076 in 2005 (Pinho and Oliveira, 2009). Therefore, it can be said that the intelligibility value of the study area (Table 3) remained weak until 2006, and that this value then became similar to the finding of Kubat's Anatolian towns. As an overall assessment, the intelligibility value of the area has increased, and it has become a place where people can learn about its large patterns from their experience of its smaller parts.

5. CONCLUSIONS

As a result of these analyses, it is possible to state that the study area has transformed into more divided streets and urban blocks, and the number of buildings increased after the construction of the bridges. Therefore, as planned, Galata and Karaköy regions have become more accessible and more preferred areas; thus, new functions and buildings have been constructed. Although it is not possible to claim that the bridges are the only factors behind these changes, it can be stated that the bridges have created more accessible spaces. Although the bridges generate more accessible spaces on both sides of the Golden Horn, they created more complicated and crowded districts.

This study is an attempt to contribute to the literature by explaining the influences of bridges on urban morphological characteristics and street network configurations. Furthermore, it is clear that the metro bridge-rail system of the Golden Horn Metro Bridge has had less impact on the pattern of the settlements when it is compared with the impact of the vehicular bridges. The primary reason for this lower values is that there is no distinct, continuous pedestrian route in the north-west direction. Golden Horn metro bridge was built as a separated metro bridge which passes through the existent urban blocks and has only a pedestrian connection with the coastal area. Since it creates no significant change in the existing urban pattern, it shows low spatial values. There is no concern on the linkage of the pedestrian activities. However, just as with the Galata and Atatürk bridges, it is expected that with some new planning decisions (new routes connected to the main sidewalks and new functions around the Golden Horn Metro Bridge), the settlements around the bridge will become more accessible and integrated spaces.

In conclusion, it is possible to state that bridges create more intelligible and accessible spaces, and because of the increases in choice values that they produce, they affect preference rates within nearby settlements. Furthermore, new buildings with different functions can be integrated into neighborhoods which are close to bridges. Finally, the increased accessibility provided by bridges allows city development to be better organized.

6. NEXT STEPS

There should be future studies to analyze the new tube tunnel project planned for the Golden Horn. This tube tunnel project, which was announced by the mayor of the Istanbul Metropolitan Municipality, is intended to connect the Unkapanı region and the Kasımpaşa neighborhood. It is currently expected that this project will go into service in 2018, and will include the removal of the Unkapanı Bridge, thereby triggering a new series of transformations (Istanbul Metropolitan Municipality, 2016). It is expected that this study will be a beneficial source for future studies into the historical process and spatial changes that affect the neighborhoods which develop around bridges.

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