ISSN 1309-6915

MEGARON

Megaron is indexed in Web of Science, Emerging Sources Citation Index (ESCI), Avery Index to Architectural Periodicals (AIAP), TUBITAK TR Index, EBSCO Host Art & Architecture Complete, Arts Premium Collection, ProQuest, SciTech Premium, ERIH Plus, DOAJ, Gale/Cengage Learning and Ulrich's.

Volume 18
Number 1
Year 2023

YTU PRESS

www.megaronjournal.com

ISSN 1309-6915

MEGARON

Volume 18 Number 1 Year 2023 - March

ISSN 1309-6915

MIMARON

Volume 18 Number 1 Year 2023 - March

ISSN 1309-6915

MEGARON

Volume 18 Number 1 Year 2023 - March

Abstracting and Indexing: Indexed in Web of Science, Emerging Sources Citation Index (ESCI), Avery Index to Architectural Periodicals (AIAP), TUBITAK ULAKBIM, EBSCO Host Art & Architecture Complete, DOAJ, Gale/Cengage Learning, ASOS Index, DRJI, and Ulrich's.

Journal Description: The journal is supported by Yildiz Technical University officially, and is a blind peer-reviewed free open-access journal, published bimontly (March-June-September-December).

Publisher: Yildiz Technical University

Owner: Gülay Zorer Gedik

Managing Director: Gülay Zorer Gedik

Editors: Ayşen Ciravoğlu, Sırma Turgut

Co-Editors: Gökçe Tuna Taygun, Esin Özlem Aktuğlu Aktan

Language of Publication: English

Frequency: 4 Issues

Publication Type: Online e-version

Publisher: Kare Yayıncılık

Correnspondence Address: Yıldız Teknik Üniversitesi, Mimarlık Fakültesi, Merkez Yerleşim, Beşiktaş, 34349 İstanbul, Türkiye

Tel: +90 (0)212 383 25 85

Fax: +90 (0)212 383 26 50

E-mail: megaron@yildiz.edu.tr

Web: www.megaronjournal.com

Free full-text articles in Turkish and English are available at www.megaronjournal.com.

MEGARON | YILDIZ TEKNİK ÜNİVERSİTESİ 1911 | KARE

ISSN 1309-6915

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Megaron, Vol. 18, No. 1, pp. 1–14, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2023.70437

Article

Investigation of old water supply system in the historic town of Beypazarı

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ARTICLE INFO

Article history
Received: 21 December 2021
Revised: 16 March 2023
Accepted: 20 March 2023

Key words:
Beypazarı; historical water structures; urbanization; water supply system; water network

ABSTRACT

Throughout history, civilizations have improved water supply and management systems depending on new needs and innovations. Anatolia, home to many civilizations, showcases the development of water systems from the Neolithic period to the present. Beypazarı, located in Central Anatolia, demonstrates an advanced Ottoman-era water supply system with 19th and 20th-century water structures, such as fountains and riverbeds, despite many drying up today. However, infrastructure works have disrupted connections between water sources, fountains, and agricultural lands. Fountains have lost their function due to river drying, global warming, and man-made interventions. This study aims to understand Beypazarı's historical water supply system between the 19th and 20th centuries and the effect of interventions on increasing floods. Visible components, including natural water sources and fountains, were analyzed through site surveys, literature data, and unstructured interviews with locals. Lost components were examined using locals' narratives, old cadastral maps, and aerial photos. The whole system was determined by overlapping data and land slope using GIS. Results show that Beypazarı's historic water supply system during the Ottoman period was tailored to the purpose of water usage. Specific stream branches and springs provided drinking water, transported to fountain reservoirs via a closed pipe system for hygiene. All stream branches were distributed to agricultural lands through open runnels using gravity. The abandonment of this system has caused stream beds to exceed their capacity in winter, leading to floods.

Cite this article as: Eken Güney E, Şahin Güçhan Ş. Investigation of old water supply system in the historic town of Beypazarı. Megaron 2023;18(1):1–14.

INTRODUCTION

Water has always become the primary need of every civilization throughout history. While many have preferred to settle near the water sources, this brought along requirements such as the distribution, transportation, and use of water or control of the water level. Thus, each civilization has given significance to developing a water supply and a management system to use water efficiently. Even the techniques and materials change according to technological innovations, and all historical systems and structures that have been transferred from the past reflect characteristics of the previous culture. Thus, historical water management systems generate the basis of current systems.

Anatolia, which has hosted many civilizations throughout

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history, makes it possible to investigate the development of water management systems inherited from the various former cultures until today. In Çatalhöyük, one of the oldest settlements in Anatolia, traces of irrigation channels and water wells were found during recent excavations (Baykan and Baykan 2015, 144).

In addition to biological needs, water had sacred significance for civilizations like the Hittites in Anatolia. They established settlements near a water source and sacred pools, called *pınar*, to collect water from these sources. Before entering their gods' presence, they used it for bodily and spiritual purification and created reliefs symbolizing rituals on the pool walls (Murat 2012, 126). While the water was transferred to the pools through underground channels with a triangular cross-section supported by stones, underground earthen pipes can also be dated back to the Hittite period (Uçar 2016, 74).

Urartians have a significant place in the history of Anatolia, especially with the advanced water systems they have established. They settled in the Eastern Anatolian Region of Turkey and ensured the region was called the "Region of Dams" (Kalmış 2017, 570). They also have built cisterns and wells to store and collect water in addition to dams. The collected water was used for various purposes like drinking and irrigation of the lands. Depending on the multifunctional purpose of the dams, Urartians have also built castles near the dams for their protection (Kalmış 2017, 572).

In addition to being the pioneer in the construction of dams, Urartians are also considered to be the founders of the piped irrigation system thanks to their advanced mining industry (Baykan and Baykan 2015, 148; Kalmış 2017, 571). While this system is called *kehriz* in some regions, like the East Anatolian Region of Turkey, it is also known as *kanat* (qanat) in the areas around Iran. The main purpose of this system was to transfer the underground water to the plains from the higher elevation with the principle of gravity. In this system, the well reaching the groundwater level is called the main well. Then, wells are drilled every 25 to 50 meters toward where the water will be transported. These wells are connected horizontally with a slight slope from the elevation where the main well reaches the groundwater level (Figure 1, left; Uçar 2016, 77). The underground water tunnel that connected wells is called *livas* in Anatolia (Figure 1, right; Uçar 2016, 82). While the water may be for public use, there is also the distribution of water to houses or agricultural areas (Uçar 2016, 78). *Kehriz* or qanat system and dams are still used for irrigation of some lands in Anatolia (Kalmış 2017, 571).

During the Hellenistic and Roman Periods, more developed water structures started to be built. While water has been transported between the valleys by aqueducts above the ground, and earthen pipes, have been used underground (Figures 2 and 3). In these systems, the main principle for the transportation of the water was gravity which allowed water to flow from a higher altitude to a lower altitude. On the other hand, a reverse siphon system has been developed to raise it from the lowest point of the valley to the top of the valley. The reverse siphon system was a method that worked as a result of bringing the waterway to the bottom of the valley by stone or lead pipes, continuing horizontally along the bottom of the valley, and bringing it to the top of the valley at the other end. In the operation of this system, two water reservoirs were built at the beginning and end of the valley. As a result of the fact that the reservoir located at the beginning was higher than the reservoir located at the end of the valley, the water flow was provided continuously (Yılmaz 2015, 200). In addition to these advanced water transportation systems, new water structures like baths, fountains, cisterns, and wells were built for public usage, and an advanced sewage system was established during Roman Period (Uçar 2016, 74).

In the Seljuk and Ottoman Periods, water structures like

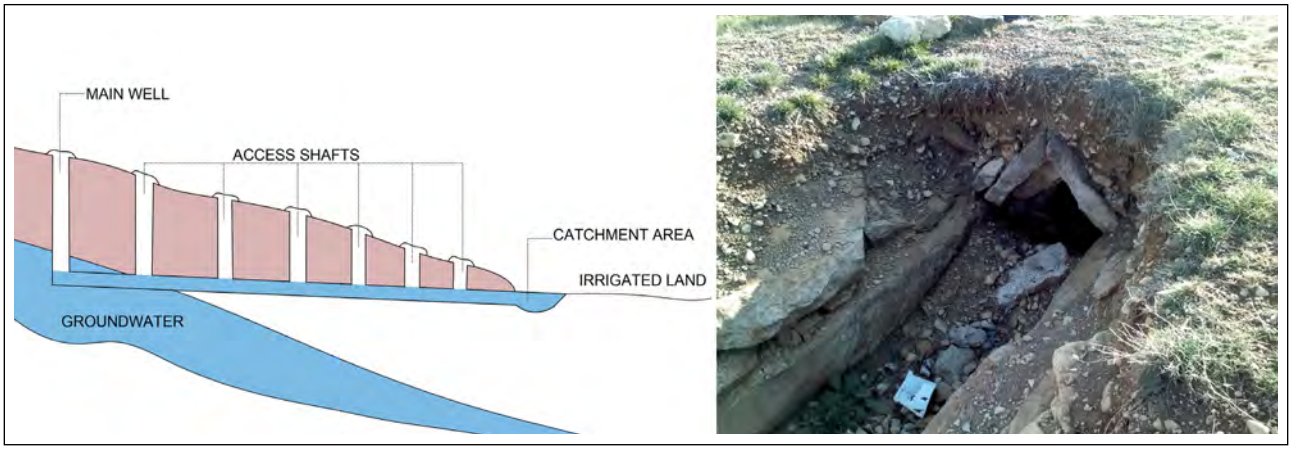

Figure 1. Schema of the qanat system (left, drawn by author after Uçar 2018, 27) and A livas in Gaziantep, Turkey (right, Uçar 2016, 82).

Figure 2. Akvadük Aqueducts in İzmir, Turkey (Eken Güney, 2020).

Figure 4. Ahmet Çelebi Kasteli in Gaziantep, Turkey (Uçar 2016, 91).

fountains, *sebil*, and *şadırvan* came to the forefront in addition to the existing structures of previous civilizations in Anatolia. After the 15th century, fountains started to build new types depending on the rise in population in Anatolia (Tekeli 2011, 227; Uçar 2016, 75). One of these types was based on establishing a fountain in front of the water storage and this storage was connected to a water source (Uçar 2016, 75).

Transportation tradition through earthen pipes continued during the Seljuk and Ottoman Periods. However, using lead pipes was also determined in the Ottoman Period in addition to earthen pipes (Uçar 2016, 75). Additionally, there were rock-cut underground water channel systems in Anatolia like the ones in Kayakapı district in Ürgüp, Cappadocia, kastels, and channels of Gaziantep city (Figure 4; Uçar 2016, 76).

At the beginning of the 16th century, the heyday period of the Ottoman Empire, Mimar Sinan, the most famous architect of the period, designed lots of waterways in Anatolia, especially in Edirne and İstanbul, through unique water structures that connected with established water ways (Diri Akyıldız 2018, 41). In underground systems, stone masonry water channels that collected the water from the various main streams finally joined to the water structures, called *maksem*, used for collecting and distributing water (Figure 5; Diri Akyıldız 2018, 42). In later periods, these structures developed containing separate underground pools, one collecting the water and the other distributing purified water to the city (Diri Akyıldız 2018, 43).

Although a water network has been established generally compatible with the land to advance by gravity, some cases require the transportation of water from a valley to the valley at an equal or higher height. In these cases, an inverted siphon system is operated by air pressure. Additionally, aqueducts were constructed between separated wider

Figure 3. Earthen water supply pipes in Ephesus, Turkey (Eken Güney, 2020).

Figure 5. Taksim Maksemi in İstanbul, Turkey (Source: SALT Research Kayıhan Türköz Archive).

valleys. These stone masonry structures included arches, narrow upward to allow only the transportation of water (Diri Akyıldız 2018, 43).

The fact that the Ottoman settlements were generally located on sloping lands at the foot of the mountain made it convenient for the surface waters to flow throughout the stone-covered streets. Water ditches were formed to control the flow of water, creating a triangular section in the middle of the streets. Although the pavement material of the roads has generally changed, this system can be seen in old photographs of historic settlements (Figure 6). While these surface waters were especially used for cooling, irrigation of the gardens and agricultural fields was provided through runnels located on one or two sides of the streets (Figure 7).

When all water management systems that continued to evolve and were used up to the Ottoman Period are evaluated, accumulated water in rivers, lake, barrages, or water wells were transported through water pipes, closed water channels, aqueducts, open water channels, and the surface of streets covered with stones (Figure 8). In most of these systems, the main principle is gravity as the sloping topography allows. Depending on the purpose of the usage, water was transported to lands or water structures like fountains, basins, pools, baths, etc. In the end, water accumulates again in the underground or sewage system and takes part in the natural hydrological cycle. This water network can be determined in lots of Ottoman Towns like Sa,franbolu, Cumalıkızık, and Beypazarı in Anatolia.

Situated northwest of the capital Ankara in the inner Anatolian region (Figure 9a), Beypazarı is a typical Ottoman town with its naturally sheltered location on the mountainside (Figure 9b), urbanization around the religious buildings and commercial center, and introverted housing structures (Cerasi, 1999, 120; Figure 9c). Even the current settlement was mostly shaped during the 19th and 20th centuries, the history of the Beypazarı settlement dates to 3000 BC through the first occupation of the Luwi

Figure 6. Water ditch that allows surface water to flow in historic streets of Beypazarı (Source: Beypazarı Municipality).

Figure 7. A historic water runnel in Safranbolu (Source: Haberts.com).

community, and the settlement was called "Lagania" in that period [1]. After the Luwi people, the region was respectively dominated by the Hittites, Phrygians, Galatians, Romans, Byzantines, Germiyanoğulları Principality, and Ottoman Empire. Considering developing a water network through various civilizations in Anatolia from the Neolithic Period until the Ottoman Period, such a network should also exist in Beypazarı as well. In addition to riverbeds around the settlement, many fountains, a few bridges, and bathes built between the 18th and 20th centuries also provide a clue about the existence of an improved water network during this period.

Although residents claimed that the water, the source of which was the streams in the vicinity, also flowed along the roads of Beypazarı through open channels and irrigated the agricultural lands in the past, there is no evidence of this information in the physical environment due to infrastructural interventions in the settlement until today. Although these studies have been carried out to prevent the increasing flood disasters in the region in recent years, the region is still exposed to flood disasters despite all the efforts.

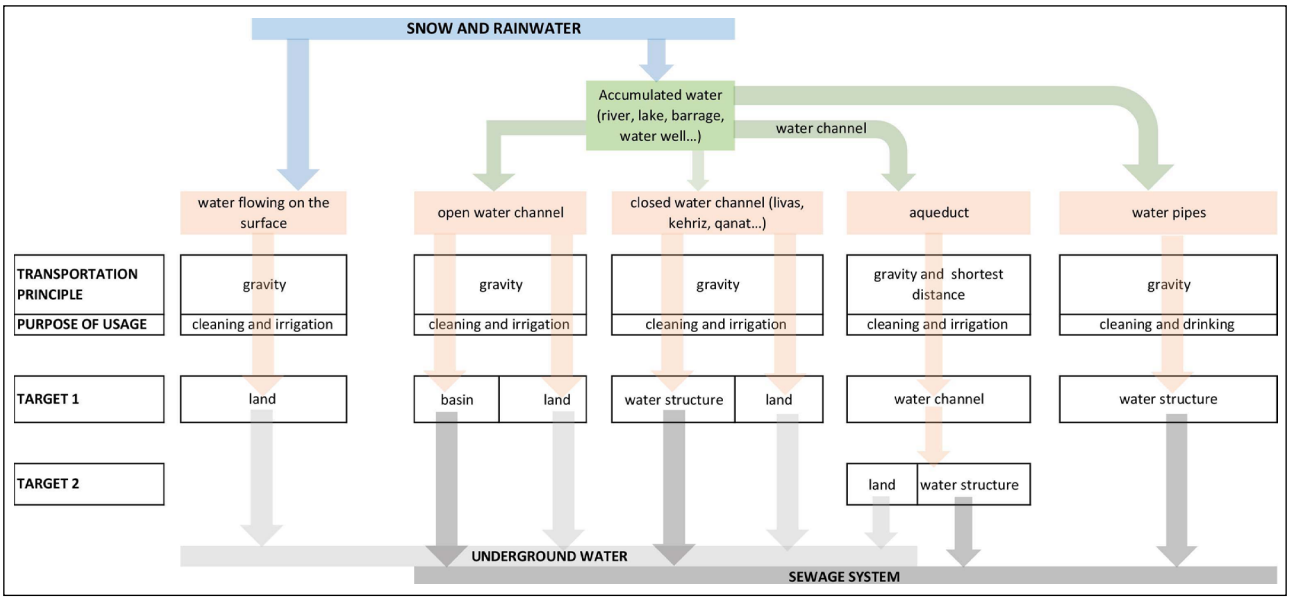

Figure 8. Type of historic water management system in Anatolia including transportation principle (prepared by the authors).

Even though all stream beds around the settlement, which are completely dry in summer, overflow with precipitation in winter and cause floods on the roads of the settlement. Thus, this article proposes to understand the water supply system and water structures in Beypazarı during the Ottoman Period, when the settlement was largely shaped, and the effect of the abandonment of the historic system on the floods. Thus, the article will seek answers to the following questions:

- What were the main sources of water to meet people's needs and the main principles of the water supply system in Beypazarı during the Ottoman Period?
- How did these resources reach people in Beypazarı during Ottoman Period?
- What are the main reasons behind the loss of some components of the historical water system today, and what is their role in flood disasters?

Depending on the aim and research questions, the article begins with the methodology that will be used to decipher the visible and invisible parts of the historic water supply system. Following, visible components of the system, including natural water sources and fountains, as the prominent water structures, were analyzed, focusing on the function, location, and architectural features of the fountains. Then, the study examines the lost components of the system that provided connections between water sources and fountains and the

Figure 9. **(a)** Location of historic Beypazarı town in Turkey (base map data © 2021 Google) **(b)** View of historic Beypazarı town from Hıdırlık Hill (Eken Güney, 2021) **(c)** View of a street of Beypazarı town (Eken Güney, 2021).

purpose of their usage of them. Lastly, the outputs of the study are discussed holistically with both visible and invisible elements of the historical water system and the effects of the reclamation of this system on floods. The study ends with a conclusion part.

METHODOLOGY

The article investigates the historic water supply system and water structures to serve the water to people in Beypazarı during Ottoman Period through a qualitative research method. To achieve this, a site survey was conducted in 2020, but this survey was limited to observations because of COVID-19 pandemic conditions. During the site survey, visible components of the historic water supply system, including natural water sources and water structures like bridges, fountains, and bathes, were mapped on the current cadastral map of Beypazarı. Additionally, their architectural features and physical conditions were analyzed. On the other hand, the book of Ethem Torun (2004), a local historian, was used as the main source to determine the system's invisible components and their relations with the water sources and water structures in the settlement. Additionally, impromptu interviews were conducted with a limited number of existing locals through phone calls in April 2019. Unstructured interviews were made with three people, MÜ (1947), HÇ (1960), and HA (1953). Although they were able to convey the situation of the settlement during the 1970s especially, they conveyed its previous situation through the memories of their ancestors.

Within the light of the gathered data, the aerial photos of Beypazarı from 1944 until today were superposed through GIS (Geographic Information System) to decipher all the streams that feed the water structures from the past to the present. Following, the branches of these streams that reached Beypazarı urban settlement were determined, and the altitudes of these branches and points where the water structures are located have been checked through Google Earth. Then, physical connections between the water sources and fountains in the settlement were determined according to narratives of locals and sources, traces from aerial photos, and the rule of gravity that was determined as the main water transportation principle during the Ottoman Period in Anatolia.

THE VISIBLE HISTORIC WATER COMPONENTS IN BEYPAZARI: MAIN STREAMS AND FOUNTAINS

Beypazarı is surrounded by Işık, Aladağ, and Köroğlu mountains and Teke Hill at the north, and Sündiken Mountains at the south. The area that lies between the northeast-southwest direction is called Beypazarı Plain. Within this large plain, the historic Beypazarı settlement is located at the foot of the northern mountains. Depending on tectonic movements in the north, limestone hills that detached from the movements created a mountainous region up to the historic settlement. Even though the altitude gradually decreases within the historic settlement from north to south, limestone hills like Hıdırlık, Karcıkaya, and Salihler, located in the city center, cause a sudden change in altitude (Figure 9b).

In addition to the north being covered with forests, the mountains in the north are also the source of many streams in Beypazarı and its surrounding area (Figure 10). Among them, the Koca River creates a natural border with Nallıhan at the west and feeds Sarıyer Barrage at the south. Lots of branches of the Koca River and other streams flow throughout the settlements and converge with the Kirmir River in the south. Additionally, some streams feed Çamlıdere Barrage, located northeast of Beypazarı.

Tributaries between these main streams starting from the north and pouring into the Kirmir River in the south form the main water resources of the Beypazarı settlement. Among these tributaries, İnözü Stream, which merges with Sabagoz, and Mundarcı Stream, which is a branch of Ilıman reaches the Beypazarı urban site (Figure 10, no. 1-6).

Depending on the existence of stream beds within the historic site, water structures like bridges and fountains stand out in number. Even though locals state that there were more than ten bridges in the past, at present, only two of them are still standing in their location. While one of them is located above Mundarcı Stream, the other, Hacılar Bridge, is located above İnözü Stream (Figure 11, no.18 and 19). Hacılar Bridge is the most historical stone bridge, and it is dated to the 17th century. According to narratives of locals and official records, there were also 29-grain mills throughout İnözü Stream in the past (Ankara Enstitüsü Vakfı 1995, 112). However, remaining of only one of them can be observed at present.

Fountains are significant structures that represent the direction of development in Ottoman towns. Especially during the 18th century, fountain construction in many Anatolian cities accelerated to attract immigrants in

Figure 10. Main streams, their branches, and location of Beypazarı historic urban site on a macro scale (base map data © 2020 Google).

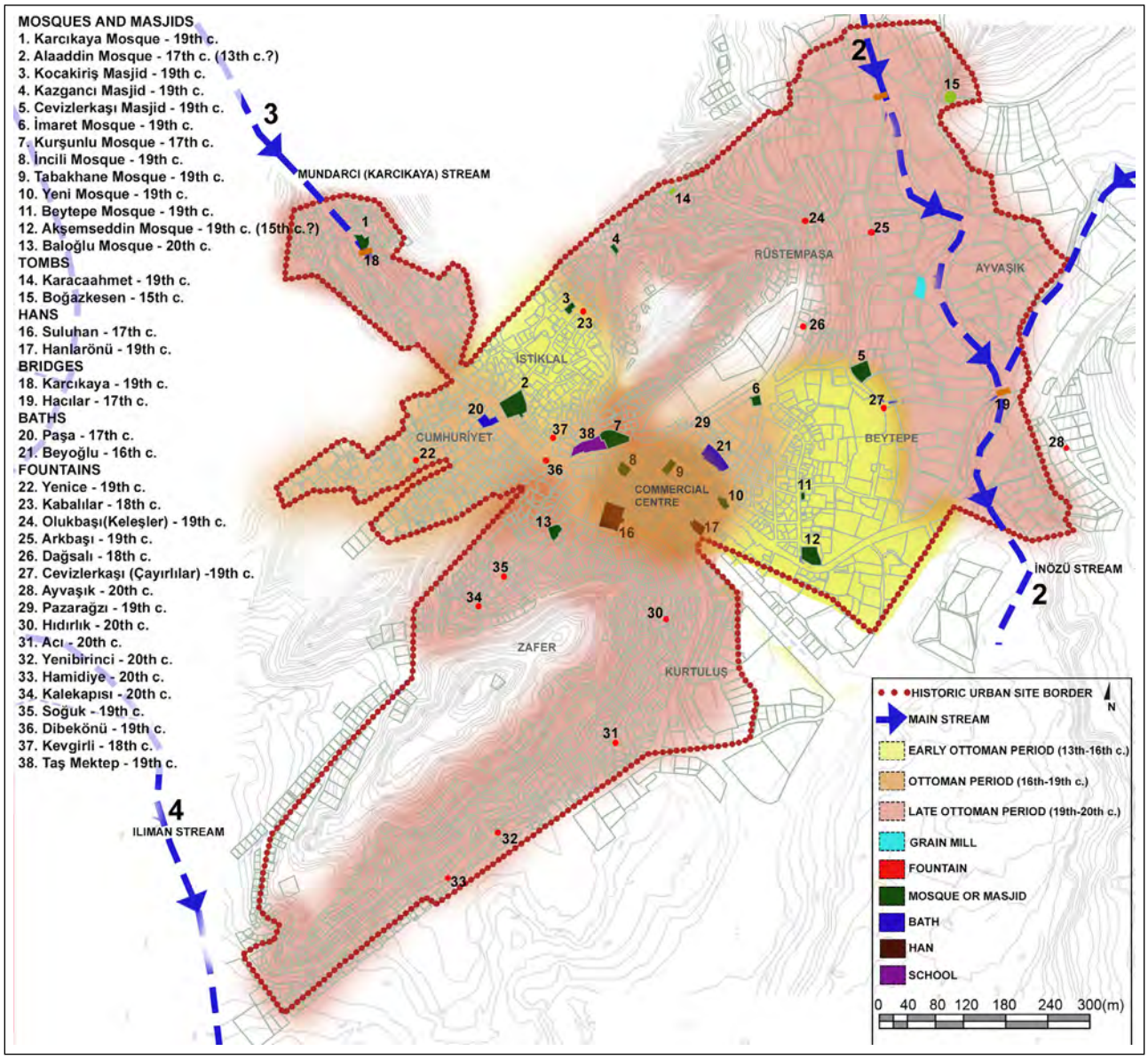

Figure 11. Historic development of Beypazarı in the Ottoman Period including current neighbourhood borders and monumental buildings with their construction period (on the cadastral map obtained from the Beypazarı Municipality).

addition to the supply demands of the existing locals (Cerasi 1999, 191). Within Beypazarı Urban Site, although some fountains are in bad condition at present, 15 fountains are still standing in their location (Bozkurt 2004, 193-234). While most of them were built in the 19th and 20th centuries, only three of them date back to the 18th century [4]. Thus, the location of these fountains, Kabalılar, Dağsalı, and Kevgirli, is an indication that the first residential settlements in the Ottoman period were formed around the commercial center (Figure 11).

In terms of the construction technique of fountains, apart from three fountains, all of them have been constructed as stone masonry rectangular reservoirs (Figures 12 and 13). The main construction material is rubble stone, and lime mortar was used as binding material. Earthen pipes that provide water supply are still observed within the walls of some reservoirs at present. Additionally, a wall of each reservoir has sight windows to control the level of water (Figure 14). However, these windows are closed with metal sheets in some fountains at present (Bozkurt 2004, 224). Although the exterior facades are not plastered, the inner facades of the reservoirs have been covered with Horasan plaster (Bozkurt 2004, 195). Even though the tops of reservoirs are seen as cement-based flat roofs today, they were originally covered with a barrel vault inside (Figure 13).

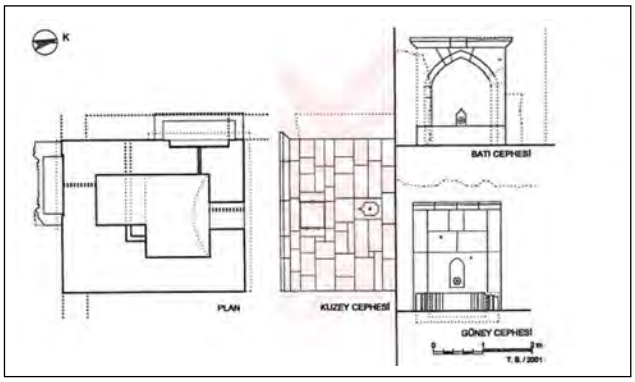

Figure 12. Plan and facades of Dağsalı Fountain (Bozkurt 2002, 357).

Depending on the location of the fountains, they can have more than one street facade to serve each street. Street facades differ from the reservoir by using cut stone (Table 1). The main hole where water is served is located on *ayna taşı*, which has been nearly placed in the middle of the facade. *Ayna taşı* can differ from other stones through ornamentations created as reliefs (Figure 15). Apart from the hole on this stone, there is also a *taşkan hole* on the upper level and a *tahliye* hole at the bottom level. While the *taşkan hole* prevents the water level from rising after a point, the *tahliye* hole provides the discharge of stored water for a long time (Bozkurt 2004, 193). All fountains have stone basins along the street facades. However, most of them are lost at present due to the elevation of the street level (Bozkurt 2004, 203).

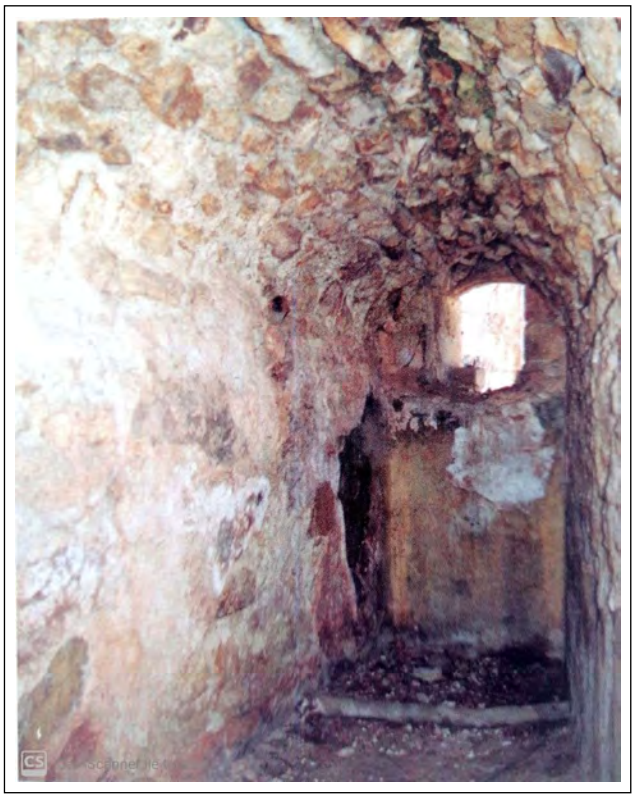

Figure 13. Reservoir of Cevizlerkaşı Fountain (Bozkurt 2004, 200).

Figure 14. Pazarağzı Fountain and Its Sight Window (Eken Güney, 2021).

Even though all fountains have lost their function today, large reservoirs behind the street facade and the earthen pipes embedded in the walls of reservoirs indicate that water came to these fountains from a source for a while. However, in the current situation, it is impossible to determine the water source for each fountain through observation.

While Torun claims that drinking water was transferred from Sabagoz Branch to all fountains located north of the main axis, all interviewees emphasize that drinking water was provided from Kozalan Village in the north of Beypazarı between 1950 and 1970 (Figure 16).

Transported drinking water from Kozalan was stored in two cisterns (more modest water collection and distribution structures than *maksem*) located in the Tepedelen region,

Figure 15. Ayna Taşı of Kevgirli Fountain (Eken Güney, 2021).

Table 1. Main characteristics of fountains within the historic urban site (location of the fountains can be seen in figure 11 through fountain numbers; Bozkurt 2004, 246; images are copyright of the authors)

No	Fountain Name	Construction Period	Location	Existence of reservoir	Number of façades	Current situation
22	Yenice	19th century	Cornet lot	+	2	
23	Kabalılar	18th century	Separated lot	+	1	
24	Olukbaşı (Keleşler)	19th century	Embedded in the garden wall	-	1	
25	Arkbaşı	19th century	Embedded in the garden wall	+	1	
26	Dağsalı	18th century	Separated lot	+	3	Could not be observed
27	Cevizlerkaşı (Çayırlılar)	19th century	Embedded in the garden wall	+	1	
28	Ayvaşık	20th century	Separated lot	+	1	
29	Pazarağzı	19th century	Corner lot	+	1	
30	Hıdırlık	20th century	Separated lot	+	1	Could not be observed
31	Acı	20th century	Corner lot	+	1	
32	Yenibirinci	20th century	Separated lot	+	1	Could not be observed
33	Hamidiye	20th	Separated lot	+	2	Could not be observed
34	Kalekapısı	20th (1916)	Corner lot	+	1	
35	Soğuk	19th century	Separated lot	+	1	
36	Dibekönü	19th century	Corner lot	-	1	
37	Kevgirli	18th century	Corner lot	-	1	

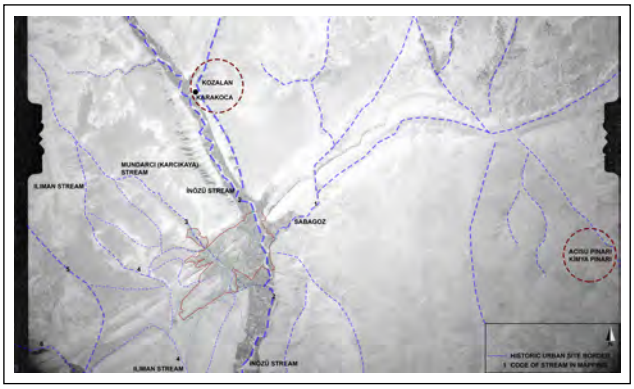

Figure 16. 1944 dated aerial photo of Beypazarı with the border of the historic urban site, main streams around, and significant water sources (1944 dated base map data © Archive of General Directorate of Maps).

within the border of Rüstempaşa Neighbourhood (Figure 11; MÜ, 15/04/2019). Then, it was transferred to fountains through earthen pipes with a diameter of 0.10 meters (Bozkurt 2004, 199). Then, residents of the settlement carried their drinking water from the fountains to their homes with copper jugs (Torun 2004, 436).

Karakoca District within Kozalan Village was also a significant mineral water source for the whole country (Figure 16). As HÇ stated (15/04/2019): *"Karakoca Water was also a branch of İnözü. Picnics were held around this water source and the children were bathed. When mixed with sugar and lemon salt, it would be 'soda'."* This mineral water is still distributed to the whole country by the factory that was established in the Karakoca district in 1957.

In addition to the natural water source in Kozalan Village, Kimya Spring was also a significant drinking water source for wealthy families in the settlement (Torun 2004, 436). This spring was located nearly 3 km east of the settlement around the Derbentçik and Acı locations (Figure 16). HÇ noted (15/04/2019): "*Our drinking water was Kimya Spring. We used to carry it with our knuckles. An uncle used to bring them in copper jars. The prominent people of Beypazarı drank from that water. It was bought with money*." At present, some families still use this source as drinking water, according to narratives of locals.

After the 1970s, depending on the increase in population and the number of houses, water that was transported from Kozalan became inadequate to meet all needs. Thus, after the 1980s, caisson wells were drilled around İnözü Valley, and new cisterns were constructed around the neighborhoods (Torun 2004, 222). Additionally, water from the Uşakgöl Region, located north of Kozalan, was also transferred to the settlement. The water carried by the underground pipe system from all these sources around the settlement is served to the houses with the modern pipe system after being treated in the treatment plants at present.

Although the historical earthen pipe systems embedded in the fountain walls still exist today, the water flow in these systems has stopped. Accordingly, the fountains are no longer used, and their structural integrity is being damaged day by day. Since 1984 all residences have been connected to the city water network (Torun 2004, 222).

THE LOST HISTORIC WATER COMPONENTS IN BEYPAZARI: WATER RUNNELS

Since agriculture was the main source of livelihood in the historical settlement of Beypazarı, as in many Ottoman settlements, the fact that agricultural lands could be irrigated with natural water sources had been one the main factors in the formation of the settlement. Tributaries between Koca and Kirmir Rivers were used as the main water source for irrigation of the lands throughout the history of the settlement.

According to the land use analysis prepared within the scope of the Conservation Aimed Development Plan in 2014, residential courtyards of houses cover the majority part of the traditional urban pattern (Beypazarı Municipality 2014, 43). Historic houses are located within large courtyards and gardens. Although the streets are covered with cobblestone, old photographs of the settlement show that the streets were covered with slate stone and included a water ditch that allowed surface water to follow.

In addition to residential courtyards and gardens, large gardens and vineyards without residences were generally located around the İnözü River. This positioning suggests that the gardens were irrigated directly from the river through gravity. However, the level of the stream bed is lower than the level of the gardens. Although an inverted siphon system was the common solution in that case since Roman Period, locals state that irrigation of gardens was provided thanks to runnels that transported water from the north side of the settlement to the streets during the 20th century. As MÜ stated (15/04/2019):

"Water weirs were kept on both sides of the İnözü Stream at the north of the settlement. Those weirs formed runnel groups. These runnel groups were divided into two and three, and they were poured into the İnözü Stream by stopping by the orchards. In the past, there were watermen, and those watermen used to give water to vineyards and gardens in turns."

Although these runnels are lost at present, they were open-top channels that received their sources from surface water depending on the presence of nearby streams. The flow of water was controlled by large stone blocks on both sides, and water was allowed to pass through any garden by opening the metal cover between the garden and the runnel. Additionally, this system would pass directly through private gardens to reach another street.

Depending on aerial photos, topographical characteristics, and narratives of locals, the runnel system that was fed by the İnözü Stream started from two points at the north of the settlement with an altitude of nearly 750 meters according to the hypothetical map prepared to illustrate the existing and possible streams, runnel beds and their altitudes (Figure 17). One of them proceeded to the south towards the commercial center, and it was divided into two branches. Then, they joined another wide runnel, which originated from the Mundarcı Stream, on the main axis within the settlement. Likewise, the other would proceed to the east, giving water to the street called Arkbaşı Street, move around the limestone hill called *Dinazor Sırtı* by locals, and merge with İnözü Stream at an altitude of nearly 650 meters [5].

Additionally, this runnel was divided into branches towards the east to provide water to gardens, and these runnel branches reached İnözü at an altitude of around 670 meters. Fountains like Keleşler, Arkbaşı, Pazarağzı, Cevizlerkaşı, and Kabalılar were located on branches of these two runnels (Figure 18, no. 23-24-25-27-29), and all of them had stone basins even though some of them are lost at present (Bozkurt 2004, 193-234).

Current locals emphasize that these basins were also used for washing clothes by the people who do not have a fountain in their residences. As MÜ noted (15/04/2019): "*Women used to go to the edge of İnözü Stream on Sundays to do laundry. Or there would be large areas made of stone in front of the neighborhood fountains. Laundry was also done there.*"

Mundarcı Stream reached the urban site at the northwest point and arrived at the main axis of the settlement flowing throughout Karcıkaya Neighbourhood and merging with a branch of Ilıman Stream at the west (Figure 17, stream no. 3). A wide runnel continues along the main axis where the historic commercial center is located, and water was finally poured into İnözü Stream at the eastern end. Although the main benefit of this wide runnel was transferring water from Mundarcı Stream to agricultural lands at the southeast

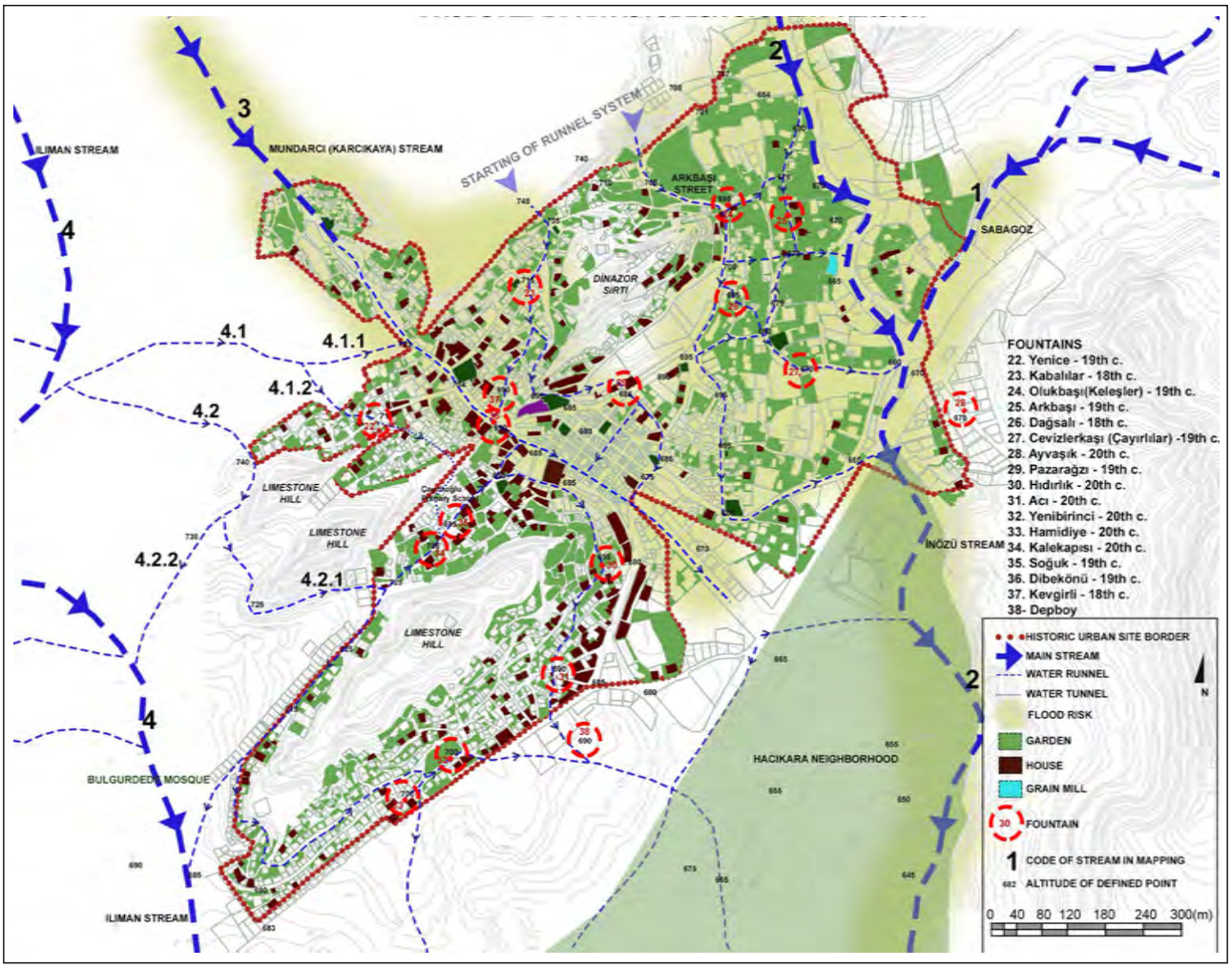

Figure 17. Map of the historic urban site with main streams, runnel system, and fountains (prepared by the authors on the cadastral map obtained from the Beypazarı Municipality).

of the settlement, it also provided coolness during summers for people in the commercial center. MÜ (15/04/2019) emphasized: "*One of those runnels flowed from the bazaar (the commercial center). To cool off, shopkeepers would sprinkle water in front of the shops with a stove shovel.*" Even though Dibekönü Fountain was located on this runnel, including a basin, it was used for cooling purposes only instead of washing clothes due to its positioning in the commercial zone.

Although Ilıman Stream flowed in the northwest-southeast direction outside of the historic urban site, this stream provided water to Hamidiye, Depboy, Soğuksu, Kalekapısı, and Hıdırlık Fountains (Figure 17, fountains no. 30, 33, 34, 35 and 38; Torun 2004, 219). Additionally, depending on the existence of gardens around limestone hills and stream bed traces observed in the aerial photo of 1944, there should be also a runnel system that transported water from Ilıman Stream (Figures 17, stream no:4). According to the narrative of Torun (2004, 219), Ilıman Stream was divided into two branches at the west of the settlement (Figure 17, branches no. 4.1 and 4.2).

One of these branches proceeded towards the main axis and was divided into two branches. While one of them merged with the wide runnel in the main axis, the other arrived at Yenice Fountain (Figure 17, fountain no.22 and branch no. 4.1.2). Then, the water transferred to the street where Kalekapısı and Soğuk Fountains located, through a water tunnel between two limestone hills (Figure 17). This branch continued to flow in the direction of the southeast from an altitude of 700 m and combined with the second branch of Ilıman Stream after providing water to Hıdırlık and Acı Fountains [6] (Figure 17, fountains no. 30 and 31).

The second branch of Ilıman Street was also divided into two branches. While one of them merged with Ilıman Street directly, the other transferred water to Kalekapısı and Soğuk Fountains (Figure 17, fountains no. 34 and 35). This branch also arrived at Yenibirinci and Hamidiye Fountains at the southwest point of the settlement flowing around the limestone hill (Figure 17, fountains no. 32 and 33). All branches of Mundarcı and Ilıman Streams arrived at Hacıkara Neighbourhood and joined with İnözü Stream after transporting water to agricultural lands and basins of fountains (Figure 17).

In addition to runnels that transport water from streams to the gardens, some houses located far from runnels had wells in their gardens. While winding wheels were being used for water extraction, then water pumps replaced these wheels (Torun 2004, 436). According to Torun (2004, 436), water in the wells was not used as drinking water [7]. However, MÜ (15/04/2019) stated that about fifty percent of the houses had their wells in the vineyard orchard houses along the İnözü Valley, and this water was drinkable.

Even though this system, organized for basic needs and irrigation of agricultural lands, was used for a long time in the settlement, it has become insufficient as water resources start to dry up with the effect of climate change. Additionally, water damns constructed between 1951 and 1985, Sarıyer at the southwest and Çamlıdere at the northeast of Beypazarı, may have caused the stream branches reaching the settlements around to dry up by diverting the stream beds in the north. Thus, especially during summer months, locals have started to irrigate their gardens and lands from the public water main and the wells they drilled. This situation led to the uncontrolled use of city water and groundwater. On the other hand, the runnels that lost their function were closed by the municipality, and the roads originally covered with slate stone were covered with cement-based stones.

In addition to the drought in the summer months, another negative effect of climate change on Beypazarı is the floods that occur because the precipitation in the winter months is above the seasonal normal. Although, while the structuring was in the center of the settlement during Ottoman Period, further away from the rivers, in time the structuring progressed towards the rivers and today continues in all directions, crossing the rivers. Heavy rains in winter cause the streams to overflow and the waters, which cannot find a place to flow due to rapid urbanization and closed runnels, fill the inside of the houses. As a solution to these disasters, which are frequently experienced, remediation works towards riverbeds have been ongoing since 2011 by the municipality. Although the stream improvements provide a temporary solution for floods, on the other hand, it eliminates the opportunity to benefit from natural water resources. Additionally, they have caused the waterway networks, which were a part of the historical water system, to be completely lost today.

DISCUSSION ON OUTPUTS OF THE STUDY AND CONCLUSION

Natural water sources have always been the most significant factor for people to settle in a region throughout history. Each civilization has developed water systems inherited from previous civilizations to use natural water resources efficiently.

This study focused on the investigation of the historic water supply system and distribution of water through water structures in Beypazarı, a historic town in Anatolia that was mostly shaped during the Ottoman Period. One of the main motivations for choosing Beypazarı as a case for this study is that the settlement reflects the traces of an improved water supply system by hosting various civilizations throughout history. The existence of agricultural production tradition, lots of water sources around, and many fountains in the settlement are the visible physical traces of this system. On the other hand, physical connections between the water

sources, gardens, and fountains are lost at present due to infrastructural interventions in the settlement until today.

The water supply system in Beypazarı during the Ottoman period was based on the distribution of river waters to the whole area with the gravity principle. However, in addition to the water source, distribution type also changes according to the purpose of the usage of water.

Supply of Drinking Water from The Fountains

Results of the study show that the spring water source in Kozalan Village at the north of the settlement was the main drinking water source until the 1970s. Water was transported through a pipe system and firstly stored in cisterns within the settlement, and then, it was delivered to the storage of fountains through earthen pipes that were embedded in the walls. In order not to pollute the water, the fountains that reach the water carried by a completely closed system were built, reconsidering the circulation of water. While the stored water is made available to people through the hole in the middle of the special stone called *ayna taşı* on the street façade of the fountain, the excess water in the tank is discharged through another hole at a higher level.

Water wells were also the drinking water source for the residents who settled close to İnözü Stream. Additionally, the springs around the settlement, like Kimya Spring, have also been a special source of drinking water that was generally used by wealthy families.

Supply of Water for Cleaning and Irrigation of The Lands Through Runnel Groups

On the other hand, tributaries around the settlement, like İnözü, Mundarcı, Ilıman, and Sabagoz, were the main water sources for the settlement for the cleaning activities and irrigation of the lands. There was a network of runnel that were constructed as open channels and carried water to all the gardens and fountains. While Mundarcı Stream flowed through a wide runnel along the main axis, runnels that were separated from İnözü and Ilıman Streams would transport water to the courtyards in the north and south of the main axis. Then, all of them were combined with İnözü Stream in Hacıkara Neighbourhood at the southeast of the settlement. In this system, gravity is the main water transportation principle in Beypazarı, like in lots of Ottoman towns. For the gardens of the houses far from the runnels, the main source is the wells.

While many fountains were located on the runnel network, water that was transported through the runnels was not stored in the reservoir of the fountains because of hygiene problems. It was used only for washing the clothes within the basins of these fountains. Thus, it can be said that the locations of the fountains were determined consciously to accumulate water in the basin.

Significance of The Historical Water Supply System Through Water Structures in Beypazarı and Its Current Condition

Although Beypazarı is dated to the Ottoman period with its monumental and civil architectural structures existing today and there is no structure dating from the previous periods, it is possible to see the traces of pre-Ottoman civilizations in Beypazarı through water distribution principles in the historical water system. Using wells for drinking water, seen even in Neolithic settlements, or distribution of the water to reservoirs or fountains through earthen pipes seen in lots of Roman settlements are the reflections of the regular development in the water supply system in Beypazarı. However, this ever-evolving system, which took its most developed form in the Ottoman period, lost its function at present with the decrease of water resources and infrastructural interventions over time.

In addition to the effects of global warming, the rivers have dried up by constructing dams close to the settlement and changing the flow direction of the river branches. Due to the drying of the rivers, infrastructural works such as the closing of runnels and changes of street coverings were carried out in the settlement. Unfortunately, these works caused the existing stream beds to increase their capacity after the rains and flooding in the region, especially in the winter months. With the effect of rapid urbanization across the riverbeds, citizens who live around stream beds or have a garden are adversely affected by this situation.

Even though this study is limited to understanding the historic water supply system in Beypazarı during the Ottoman Period, it can be an example to decipher the historic water supply system in the other settlements. By deciphering the historical waterways, which are invisible today, this study gives an idea about the regions in Beypazarı where there is a flood risk at present.

Notes

1. The meaning of "Lagania" is "rock peak country" in the Luwian language (Torun 2004, 16).
2. According to notes of Evliya Çelebi, there were twenty neighborhoods during the 17th century. There was Kebir Pasha Mosque in the commercial center. There were 3060 two-storied houses with mudbrick walls and exterior walls covered with wood. Madrasa, Darülhadis, Darülkurra, 70 schools, seven khans, baths, 600 shops. A khan was burned in the commercial center. A bazaar was established once a week by the stream in the bazaar. This stream flowed into Sakarya below the city (Torun 2004, 57-58).
3. The construction dates of the monumental structures range from the 15th to the 20th centuries. However, Şener (1997, 29) emphasizes that Alaaddin Mosque, dated to the 17th century, was first constructed during

the 13th century within a timber post and lintel system. Thus, this oldest mosque can be considered the Friday Mosque located in the commercial center according to Ottoman settlement tradition (Cerasi 1999, 103).

4. Some fountains have stone on the street façade that shows the construction date of the fountain. However, construction periods of the fountains that do not have inscription panels were assumed according to closed monumental buildings whose construction date is known and have similar construction techniques (Bozkurt 2004, 193-234).
5. "*Arkbaşı*" means "the beginning of runnel" in English. The name of the street also confirms that there was a runnel in the past. On the other hand, "*dinozor sırtı*" means "dinasour ridge". Limestone hills protruding from the settlement are likened to this by locals.
6. Torun states that the entrance of this tunnel is located behind Çayırlıoğlu Primary School at present, and it is dated to the Roman Period. However, there is no scientific data related existence of a tunnel yet (Torun 2004, 219).
7. Wells were also used to cool foods and beverages. These foods and beverages were dropped into the well with buckets or jugs, and after a while, it was pulled up again (Torun 2004, 436).

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 15–28, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2023.59376

Article

From crossover road to underpass: Examining the large-scale projects over their uncertainties

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ARTICLE INFO

Article history
Received: 04 April 2022
Revised: 10 March 2023
Accepted: 10 March 2023

Key words:
Kaşüstü junction project in Trabzon; large-scale projects; mid-sized city; uncertainties

ABSTRACT

Large-scale projects are among the characteristics of the current globalisation pattern. This phenomenological urban space changer (the large-scale project) has samples mostly in and around the megacities and urban regions, yet not limited to those areas. Besides the conventional aspects of large-scale projects which are mainly high cost, complexity, multi-actor collaboration, long duration, and great impact, some other identifiers are also apparent such as having high risks and specific types of uncertainties. The process should be analysed detailed and systematically to control the problems caused by uncertainties. An analytical perspective is required as it is very difficult to comprehend the nature of large-scale projects with conventional tools. In the study, the conceptual framework of uncertainties, which was adapted to large-scale projects by Hall (1981), was used to examine the selected case study. In mid-size cities, reveals some other projects, which do not totally meet the definitive criteria of large-scale projects but resemble the content and impact of such projects to a certain level. In the study, it is argued that such projects can and must be evaluated in terms of large-scale projects, even if they do not have an impact on a national or international scale. From this perspective, the Kaşüstü junction project in Trabzon city, which is an implemented sample of such relatively large-scale projects, was examined. By using archival research and in-depth interview methods, the process of the "Kaşüstü Junction" project was analysed. The characteristics of the junction project and the uncertainties that it contains show that a mid-sized city can also be exposed to the impact of large-scale projects.

Cite this article as: Tatlı P, Erkan GH. From crossover road to underpass: Examining the large-scale projects over their uncertainties. Megaron 2023;18(1):15–28.

INTRODUCTION

For the last decades, urban projects have been built in the urban space in such a manner that considerably differs from the past. These projects with significantly high-cost attract a high level of public attention or political interest because their direct and indirect impacts contribute to national growth at a great magnitude (Patanakul et al., 2016; Pagliarin et al., 2020). These urban projects are named with multiple terms, such as mega projects (Flyvbjerg, 2014,

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Mok et al., 2015), urban strategic spatial projects (Monclus, 2003), urban development projects (Pagliarin et al., 2020), large-scale urban projects (Penpecioğlu, 2013; Leick, 2015). In this study, they are named "large-scale projects". Implemented examples of the large-scale projects that are visible in the cities are the central business areas, tourism centres, housing and shopping centre projects (Penpecioğlu, 2013), urban renewal/regeneration projects, (Taşan Kok, 2010; Köksal ve Öztürk, 2017), Olympic structures (Monclus, 2003; Erten, 2005), museums, exhibition halls, international landmarks events (Swyngedouw et al., 2002), transportation and infrastructure projects (Mok et al., 2015; Pagliarin et al., 2020).

Large-scale projects are seen as powerful landmarks to direct development at national, regional, and even local levels (Leick, 2015). The reasons for the rising number of large-scale projects that have become an urban policy mechanism are associated with the rise of neo-liberalism by the drive for great economic gain (Penpecioğlu, 2013). Large-scale projects are defined as a substantial capital project, which requires concerted efforts from major participants in terms of resources, skills and expertise (Mok et al., 2015). In addition to their political appeal; the ease of construction of the projects with technological developments, and the size of the amount of gain caused an increase in the number of large-scale projects (Flyvbjerg, 2014; Leick, 2015).

When the implemented projects are examined in terms of their types, effects and impact areas, it would be appropriate to say that the projects have different scopes and scales. In the study of Erten (2005) which was prepared in this context, the terms of small-scale and large-scale were used to define project differentiations. However, it was found that there is no clear consensus as a result of the literature review.

There are some common criteria for defining large-scale projects. Projects in urban areas have begun to differentiate depending on factors such as cost, impact area, duration of project and technology used. Youcef et al. (2013) defined the change in urban projects as the popular working form of modern cities. The phenomenon behind this definition is "megaprojects". Researchers consider megaprojects as wild projects of project world because of their complexity, long duration of construction and extremely high costs. On the other hand, Tekeli (2014) emphasises that the definition of these projects should be based on large-scale investment, large impact/change on the environment and the government budget, and the impact on the lives of the people in the region.

Large-scale projects are very high-cost projects that serve on a national and international scales. These projects differ from other projects in terms of decision-making, implementation and monitoring. Regardless of the scale, each project inevitably produces effects on the existing spatial texture to some degree. However, large-scale projects are inherently risky because of the construction techniques and engineering applications. This risk is generated by the lack of knowledge and its resulting uncertainty (Regev et al., 2006; Hetemi et al., 2020). The involvement of different stakeholders and rapidly developing technology increase the complexity of these projects. Therefore, risk identification, risk elimination, risk reduction, and risk control in such projects are also critical success factors (Regev et al., 2006; Kimiagari and Keivanpour, 2019). Large-scale projects should be analysed in detail and systematically because of these characteristics. In academic studies on the subject, risks and uncertainties in large-scale projects are pointed out (Hall, 1981; Sutterfield et al., 2006; Leick, 2015). Unforeseen results may be encountered in the decision-making, implementation or monitoring process of large-scale projects. An acceptable level of uncertainty may occur in many projects with a wide impact area (Regev et al., 2006; Türk and Erkan, 2018). The experiences gained from the applied projects can be a guide to eliminate, reduce or control the risks for the following projects (Sutterfield et al., 2006; Türk and Erkan, 2018). Thus, the aim of the study is to propose effective risk elimination policies for large-scale project management processes by analytically investigating and learning from a sample case.

Large-scale projects are different from other projects implemented in cities. An analytical perspective is required, as it is very difficult to comprehend the nature of large-scale projects with conventional tools. Hall (1981) used such a conceptual framework that identifies and classifies the problems and deficiencies experienced in the process as "*uncertainties*". Hall (1981) adapted the analytical framework for uncertainties introduced by Friend and Jessop (1969) to large-scale planning projects which constitutes the underlying concern of this article. The analytical framework introduced by Friend and Jessop (1969) has been used, modified, adapted and improved by several scholars since its first introduction. Hall (1981) adapted this framework to large-scale urban projects. Couclelis (2005) added a fourth category of uncertainty related to the reliability of planning support models (UM). Abbott (2012) added another fourth type (UVS) which reads as uncertainty in community values. Recent studies using, modifying, adapting and applying Friend and Jessop's analytical framework show that it is actually and potentially a working model. An elaborate application of this framework on uncertainties by Hall (1981) on large-scale projects can potentially be effective to eliminate, reduce or control the risks for large-scale projects.

Political discourses with criticism of large-scale projects and academic studies with technical reviews are common (Flyvbjerg et al., 2003; Sutterfield et al., 2006; Dooms et

al., 2013). Leick (2015) pointed out that existing research shows a certain bias toward studying projects in large metropolitan regions. The key argument of this study is the idea that many cities besides metropolitan cities can have large-scale projects within the scope of their own dynamics and financial budget, even if they do not have an impact on a national or international scale. Large-scale projects growing, differentiating and spreading worldwide, and their locations are not limited to broad regions or metropolitan areas. There are also several other projects which do not cover all the characteristics of this phenomenon but have a similar impact on their physical, economic or political environment.

Large-scale projects have started to become a phenomenon in Turkey, especially after 1980 with the effect of neoliberal policies. However, many projects similar to the projects that were described as large-scale projects 10 years ago build in many cities today. It may be an appropriate approach to include the size criterion among the definitions due to its effect on the relevant urban geography rather than mentioning the size due to the scope of the project. There are different opinions in the literature about whether large-scale projects should be considered in terms of scope, cost or results (Flyvbjerg et al., 2003; Tekeli, 2014; Leick, 2015). Sometimes, projects that do not have an international impact and do not fully meet large-scale project criteria, but significantly exceed the city's budget considerably are built. Flyvbjerg et al. (2003) also tried to explain the size of the project by emphasising that large-scale projects of a metropolitan city and a town will be different from each other. This is also an indication that a project cannot be defined independently of the region in which it is built. In this context, the process of the "Kaşüstü Junction", which is a transportation infrastructure project implemented in Trabzon, a mid-sized city[1], was examined in this study. Kaşüstü junction project is similar in size with constructed large-scale projects, and has high-cost. Even if it is not a project on a national scale, it is a project with a wide impact area in terms of transportation. The project was on the public agenda for many years with the involvement of many different actors in the process. Thus, Kaşüstü junction project largely meets large-scale project features. Actor-based chronology of the project process was identified. Hall's (1981) framework was used to examine the uncertainties involved in this project. As a contribution to the literature on the subject matter, the sample case investigated in the study was defined as a "relatively large-scale project" in a mid-sized city.

Characteristics of Large-Scale Projects

Competitive projects are being developed to create city brand strategies, to be included in international indexes, to attract global capital or to increase recognition in cities. Their visible implementations are large-scale projects. Large-scale projects are defined as a substantial capital project which requires concerted efforts from major participants in terms of resources, skills and expertise. Therefore, the main characteristics which differentiate large-scale projects from other projects in the cities are budget, the technology used and collaboration of stakeholders. In addition to the key characteristics, other common characteristics of large-scale projects are listed by examining other features identified in the literature (Table 1).

The most remarkable characteristic of these projects is the cost. Flyvbjerg (2014) explained the "extremely high-cost" in the "project cost" line in Table 1, with very high dollar figures by giving an example of the size of external debts of the states to each other. On the other hand, Youcef et al. (2013) expressed this situation with a cost criterion exceeding one billion dollars. These explanations help to understand the high-cost of large-scale projects.

Table 1. Characteristics of large-scale projects (compiled from Flyvbjerg et al., 2003; Youcef et al., 2013; Flyvbjerg, 2014; Patanakul et al., 2016)

Characteristics of large-scale projects				
Project cost	High-cost	Extremely high-cost		
Project duration	Long-duration			
Technology used in the project	High-technology	New Technology		
Impact area	Urban	National	International	
Scale of the project	Generally large-scale (may vary according to project type)			
Singularity of the project	Rare	Unique		
Stakeholders	Generally central government, public institutions beyond local	Public institutions beyond local + private company		
Uncertainties in the project	About Duration	About cost	About other estimations	High-risk

Another characteristic that makes large-scale projects different is the technology used. In such projects, either the latest technological developments or the new technology developed especially for that project are utilised. At this point, it is expected to encounter difficulties in terms of technology and logistics (Regev et al., 2006; Youcef et al., 2013; Hetemi et al. 2020). Increasing project scale and complexity also includes interdependencies between different actors at different points in time (Hetemi et al., 2020). Working with a partner or a contractor that has better knowledge of the technology can absorb the probable risks (Regev et al., 2006).

Although it varies according to the type of project, the impact area of the project is large as well as the size of the project itself. Due to this situation, the difficulties that may be experienced with the technology used can be tolerated. Because of all these characteristics, projects are rare or unique (or few). It is also expected that such projects will have long-duration. Youcef et al. (2013) also used the criterion of having a time frame of 5 years or longer for the duration of the project.

Large-scale projects often do not have a single actor. Because of the technology used, scope and scale of the projects, the implementation of such projects entails building governance regimes at the city or regional level (Taşan Kok, 2010). More than one public institution is involved in the decision-making process, and multi-partner models are established and project-based collaborations are carried out between private companies in the implementation process (Flyvbjerg, 2014). However, it is known that many projects fail because the project manager is sometimes unable to effectively manage the agendas of the various project stakeholders. Collaborations established between stakeholders also enable minimise the loss in case of failure of the project (Sutterfield et al., 2006). Therefore, the complex and uncertain nature of large-scale projects requires an effective stakeholder management approach to accommodate conflicting stakeholder interests (Sutterfield et al., 2006; Mok et al., 2015).

Uncertainties in Large-Scale Projects

Several kinds of problems occur in such projects because of the characteristics of large-scale projects. In the literature, researchers associate these problems with the terms of risk and uncertainty. Hall's (1981) framework [which was originally introduced by Friend and Jessop (1969)] in which the uncertainties encountered in large-scale project processes are classified, was taken as the basis for the study. In addition, recent studies using, modifying, adapting and applying Friend and Jessop's analytical framework show that it is actually and potentially a working model.

In the analysis of some large-scale projects seen as planning disasters, uncertainties are explained under 3 categories (Hall, 1981):

a) Uncertainty about the relevant planning environment:

It is a type of uncertainty that can be related to everything outside the decision-making systems such as project preparation, project duration, incorrect forecasting and unpredictability of human behaviour in society.

b) Uncertainty about decisions in related decision areas:

There are different actors who are decision-makers or practitioners in a project. However, these actors need to work in harmony and depend on each other. Any problem originating from one of the actors can cause the project to be disrupted and uncertainties to occur. For this reason, all actors involved in the project should consider each other's actions at all stages of the project.

c) Uncertainty about value judgment:

Generally, society does not have a homogeneous structure and includes different subgroups from each other. As a result of any project, not every group can benefit equally from the project. The positive or negative impacts of the project will also affect all groups differently. Therefore, uncertainty about value judgment arises during the questioning of values in the later stages of the project.

METHOD

Large-scale projects have a high level of complexity and uncertainty. In the literature, there are many studies exploring different dimensions of the phenomenon such as the risks of these projects, reducing/eliminating the risks, and management of the large-scale projects. Large-scale projects are different from other projects implemented in cities. It is very difficult to understand and manage these projects with conventional tools. The aim of this study is to propose effective risk elimination policies for large-scale project management processes by analytically investigating and learning from a sample case. To this aim, two crucial points were considered. Firstly, the literature review on large-scale projects has shown that in-depth analysis of large-scale projects requires an appropriate framework on its own rather than conventional analysis methods. The threefold analytical framework of "uncertainties" by Peter Hall was employed as a working model. Secondly, the range of large-scale projects is so wide and variable. There are also several other projects which do not cover all the characteristics of large-scale projects but have similar impacts on their physical, economic or political environment. In order to distinguish these highly influential projects from the classical understanding of large-scale projects, a notion of relativity is recommended in the article. In this manner,

as a contribution to the literature on the subject matter, the sample case that was defined as a relatively large-scale project in a mid-sized city was selected.

The uncertainties defined by Hall (1981) for large-scale projects were examined in the context of a transportation project implemented in Trabzon, a mid-sized city . Trabzon's "Kaşüstü Junction Project" was selected for the case study because of these reasons:

- The total area of the underpass project built is approximately 5500 m^2 as seen in Figure 1. It is similar in size to many projects defined as a large-scale projects.
- It is not a national or international project. However, it is a project with a wide impact area in terms of transportation, since it is built on a road that provides intercity and even international access.
- The junction project is a large-scale project in terms of the financial budget of Trabzon city.
- The project was on the city's agenda for a long period of time, and numerous different actors were involved in the process.

The project, which was originally designed as a crossover road, was later changed to an underpass project. After starting the construction of the underpass project, the route was changed because of an incomplete database (physical terrain data, topography, ground conditions, etc.) and problems with decision-making issues (e.g., lack of inter-institutional integration, and the hierarchy of authority). The high-cost project was realised in partnership with public and private entrepreneurs. Kaşüstü junction project largely meets the large-scale project criteria in literature, due to high-cost, long-duration, multi-actor, technologically challenging construction, and impact on an urban scale (Table 1). In this context, a case study was carried out.

In the study, archival research (bulletins, official records, minutes, media scanning, etc.) and in-depth interviews with key person methods were conducted and used together to complement each other. An in-depth interview was made with two civil engineers (E1, E2) from the Trabzon Branch of the Chamber of Civil Engineers which as an institute, raised objections to the project and suggested a new project; an academic (E3), who made a detailed technical analysis of the traffic in the area and based at Karadeniz Technical University Department of Civil Engineering; another academic (E4) specialising in geotechnical; a civil engineer (E5) who worked directly in the field as a leading personnel in the contractor company of the project. An actor-based chronological history of the project was created with the help of interviews and findings from archival research. The uncertainties experienced during the process were classified, and the risks of the project were examined by evaluating the opinions of the experts with whom in-depth interviews were conducted.

Figure 1. Location and features of the project area (It was produced from maps obtained from OpenStreetMap which is a geographic database).

KAŞÜSTÜ JUNCTION PROJECT

The most important road providing access on the east-west axis in Trabzon is Blacksea Highway (D 010), which was opened in 2007. It is an international road that starts from the Sarp Border Gate of Georgia-Turkey in the east to Samsun Province in the Central Black Sea Region. Although it is a highway according to the road hierarchy, it is frequently used for daily trip by local people in Trabzon, as in many cities in the region. This situation causes traffic congestion, especially during peak hours along the highway (Tatlı and Ünlü, 2015). Kaşüstü junction project, which was selected as the case study, is within the borders of the district Yomra, located in the east of the city. As seen in Figure 2, it was designed to be located on Blacksea Highway.

- To reduce traffic congestion caused by urban mobility on the highway
- To provide the connection of the district Yomra to

Figure 2. Project area in Kaşüstü neighborhood and pre-project situation.

Trabzon Southern Peripheral Road, which is still under construction

- To facilitate access to the hospital, which provides services at the regional level, located in the south of the project area.

The junction project, which had a high-cost and longer duration than estimated, provides services on a city scale today. Although it has a mid-sized content compared to many large-scale projects, the former mayor had once explained that the underpass project is one of the rare projects in Turkey in terms of construction technology (Milliyet, 2016). The project carried out in public-private cooperation included uncertainties and risks regarding duration, cost, etc. When the project process was examined in order to explore uncertainties, 4 different stages were distinguished (Figure 3). (1) design as a crossover road project, (2) downsizing of the project because of the roadside licensing works, (3) changing the crossover road project to an underpass and (4) starting the implementation and changing the route direction and length because of the physical constraints.

In 2008, the preparation of the crossover road project for the Kaşüstü region was started. Municipalities were informed so that the project will be taken into account in preparing development plans and managing construction activities. Yet, no activity related to the project was carried out until 2014. When the project preparation was given started in 2014, it was observed that roadside licensing works were carried out without taking into account the notifications made to the municipalities in previous years. It was very difficult to implement the designed project while new construction was being licensed alongside the direction. Thus, according to the information received from the Trabzon Branch of the Chamber of Civil Engineers (CCE) and media (Altıntaş, 2016), the crossover road project was downsized. However, the initial technical drawings of the project could not be obtained from the institutions. Therefore, it was not identified to what extent a change was made in the project. The contractor company won a tender for the crossover road project with a cost of 55,000,000 TL and started working. This process is the first stage identified in the study.

In 2014, Trabzon city was appointed to the status of a metropolitan municipality and the Kaşüstü region, where the project area is located, transformed into a neighbourhood of the district Yomra in terms of local administration. The crossover road project was approved by the Trabzon Metropolitan Municipality on the 14th of December 2015 and announced to the public. Local people were informed about the final version of the project for the first time (Table 2). However, non-governmental organisations, professional chambers and local people did not want the crossover road project. Local people preferred an underpass project for the area instead of a crossover road. Although many petitions of objection were submitted to the municipality for the project, the objections were rejected by a majority of votes at the council meeting. A meeting was arranged, consisting of the Trabzon Metropolitan Municipality Commission, representatives of the 10th Regional Directorate of Highways (RDH), relevant professional chambers and non-governmental organisations. The Trabzon Branch of CCE presented an underpass project proposal at the meeting. However, RDH found the proposed projects as a draft and claimed that it includes problems in terms of security. If the Trabzon Branch of CCE brought a new proposal until the completion of the expropriation process in the project area, RDH would re-evaluate the new project proposal (İHA, 2016). In summary, the second stage includes the

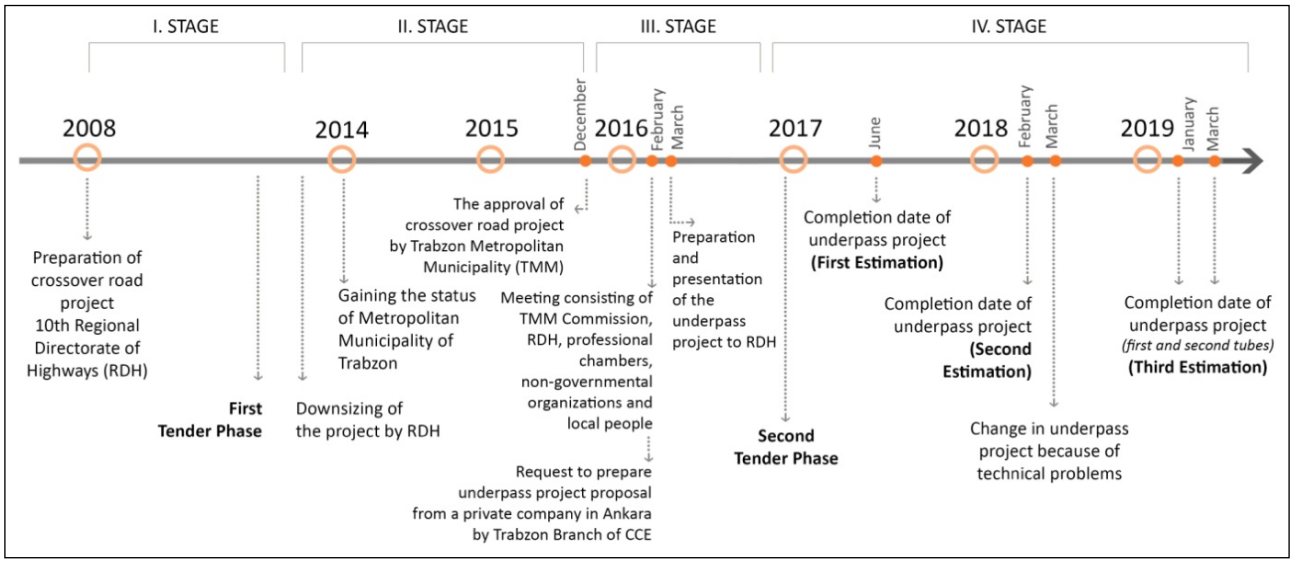

Figure 3. Process of Kaşüstü junction project (Compiled from URL-1-URL-13).

Table 2. Actor-based chronology of Kaşüstü Junction project process (compiled from compiled from Açkı Ulusoy, 2016; Altıntaş, 2016; Haber61, 2016; İHA, 2016; İMO, 2016; Milliyet, 2016; Sinop, 2016; Taka, 2016; Haber61, 2017; İHA, 2017; Haber61, 2018; Lakot and Paça, 2018; Öztürk, 2018).

	10th Regional Directorate of Highways (RDH)	**Trabzon Metropolitan Municipality**	**Local people + Professional chambers + Non-governmental organisations**	**Contractor company**
1st Stage				
2008	Design of crossover road Notification to municipalities that the project should be taken into account in construction activities	-	-	-
2014	Downsizing of the project because of the roadside licensing works	Gaining the status of metropolitan municipality of Trabzon The Trabzon Metropolitan Municipality became the responsible institution for the approval of projects prepared for the area	-	Winning the tender for downsized crossover road project with a cost of 55,000,000 TL and starting to work by contractor company
2nd Stage				
2015	-	The approval of crossover road project by the majority of votes in the Trabzon Metropolitan Municipality Council dated the 14th of December 2015 and numbered 598	-	-
	-	Announcement of the project to the public on the 26th of December 2015	Informed about the final version of project. Objection to crossover road project by the Trabzon branch of CCE and local people	-
2016	-	Rejection of the objections by a majority of votes at the council meeting on the 12th of February 2016	-	-
	-	-	Notification to the press of local people's demand by non-governmental organisations without having technical knowledge	-
	10th Regional Directorate of Highways (RDH)	**Trabzon Metropolitan Municipality**	**Local people + Professional chambers + Non-governmental organisations**	**Contractor company**
			Explaining that such projects for the benefit of society should be carried out by taking the local people' the opinion Discussion on the situation by Trabzon branches of relevant professional chambers such as the Chamber of Civil Engineers, City Planners and Architects and consensus on an underpass project	
	Having a meeting consisting of the Trabzon Metropolitan Municipality Commission, representatives of the 10th Regional Directorate of Highways (RDH), relevant professional chambers and non-governmental organisations			
	-	Requesting geometric study for the intersection from the Trabzon branch of CCE, stating that a re-evaluation will be made if the requested study is submitted	-	-

Table 2. CONT.

	10th Regional Directorate of Highways (RDH), Trabzon Metropolitan Municipality and Local People + Professional Chambers + Non-governmental organisations	Yomra Municipality	Contractor Company
3rd Stage			
2016	Starting expropriation process for crossover road project	-	-
	Request to prepare the underpass project proposal from a private company in Ankara, which prepares transportation projects throughout the country by the Trabzon Branch of CCE	-	-
	Starting to work by contacting RDH and the Trabzon Metropolitan Municipality of company	-	-
	Completion the project and presentation to the Trabzon Metropolitan Municipality on the 25th of March 2016 by company	-	Reaching the final point in drawings of the implementation project. Notification that the existing road would be raised 1.70 m
	Approval of the underpass project by RDH and the Trabzon Metropolitan Municipality	-	-
	Putting junction project out to tender for the second time as an underpass project in late 2016	-	Winning the tender for underpass project with a cost of 117,000,000 TL by same contractor company and starting to work
4th Stage			
2017	-	The mayor's explanation to the local press that they do not prefer crossover road themselves, and that underpass project will be the first for Turkey Announcement the date of June 2017 for project completion	-
	-	-	Incorrect measurement of depth for solid ground and prolongation of the project
	-	Announcement the date of January or February 2018 for project completion because of the technical problems	-
2018	-	Closure of some trade units in the vicinity because of ongoing work	Presence of dangerous high -voltage power lines in the area Unwillingness of operators and site managers to work because of the danger
	-	Encountering traffic problem of road users and people that live in the area	Determining that the solid ground on which the foundation can be laid is at a depth of 54 m. The need of different construction equipments than the company's own to excavate at this depth
	-	-	Establishing business partnership with another company because of the increased cost Increasing the length of underpass from 750 m. to 1200 m. Announcement of completion date (first tube– January 2019, second tube – March 2019)

announcement of the crossover road project and the rejection of the project by local people, non-governmental organisations and professional chambers.

In the third stage of the project, the Trabzon Branch of CCE contacted a private company in Ankara, which prepares transportation projects throughout the country, to prepare a proposal for the underpass project. The company started working by contacting RDH and the Trabzon Metropolitan Municipality. While the contractor company was about to achieve the final point in the drawings of the implementation project, it announced that the existing road would be raised by 1.70 m. according to the project. Immediately after the announcement, the company in Ankara completed the underpass project and presented it to the Trabzon Metropolitan Municipality on the 25th of March 2016 (IMO, 2016). The underpass project was approved by RDH and the Trabzon Metropolitan Municipality. Kaşüstü Junction Project was put out to tender for the second time in late 2016 as an underpass project. The same contractor company won the tender for the underpass project with a cost of 117,000,000 TL and started working (Açkı Ulusoy, 2016).

The last stage includes issues such as starting of the construction, problems experienced in the project because of technical and physical constraints, and incorrect estimations for the deadline. The Mayor of Yomra Municipality announced to the press that he did not want the crossover road. They would favour an underpass project which would be the first model of its kind for Turkey. It was announced that the project would be completed within 5 months (in June 2017) (Altıntaş, 2016). By August 2017 construction activities continued in the area. Construction activities were prolonged as a result of stones coming out in the area close to the surface because of incorrect measurements on the ground. February 2018 was announced as the extended deadline (Haber61, 2017).

The presence of high-voltage power lines in the area during the construction endangered the lives of the employees. Power lines had to be temporarily removed from the area. RDH had no authority to remove power lines. However, this work was costly and the electricity distribution company could not implement this temporary work. Operators and site managers stopped working because of this life-threatening situation. The problem was reported to the Minister of Energy and Natural Resources and the process of moving power lines was accelerated (Açkı Ulusoy, 2016).

A civil engineer who worked in the contractor company explained some incorrect estimations. The company which made the measurements of the ground determined the solid ground to be laid at a depth of 22 m, but in practice, it was realised that the solid ground was 54 m deep. Construction equipment different from the company's own instruments was needed to excavate at this depth. The number of such construction machines is few in Turkey and it is necessary to queue to use them. The civil engineer stated that the company waited for a long time and the cost doubled. Therefore, the contractor company established a business partnership with another company.

In August 2018, RDH announced that construction activities were continuing in line with the currently approved project, and there was no change in the project (Haber61, 2018). However, the company stated in March 2018 that some changes were made and the length of the underpass was increased from 750 m to 1200 m. A third ending date was on the agenda for the project that could not be completed because of technical problems. The underpass was designed as a round-trip 2 tubes model. The company announced that the first tube of the underpass will be opened in January 2019, and the second tube in March 2019. Nevertheless, the proposed time was exceeded, and the first and second tubes were opened in 2020, respectively.

As a result; the crossover road project was not accepted by local people and was changed over time. The project type was changed to an underpass project and started to be implemented in March 2016. The duration was prolonged and the cost was increased because of the reasons such as constraints caused by other relevant institutions authorised in the field and inaccuracies in technical measurements. The tradesmen in the vicinity started to lose money because of the continuing work and some tradesmen closed their workplaces (Haber61, 2017).

FINDINGS AND EVALUATION

It was determined that the Kaşüstü junction project, which largely meets the large-scale project criteria, contains uncertainty types stated by Hall (1981). In this context, uncertainty types examined for the junction project were (1) uncertainty about the relevant planning environment, (2) uncertainty about decisions in related decision areas and (3) uncertainty about value judgment.

Uncertainty About the Relevant Planning Environment

Issues such as project preparation, estimation for the duration, incorrect technical measurements, and unpredictability of human behaviour in society appear to be the representatives of uncertainty about the relevant planning environment. The crossover road project was decided in 2008, but the work started in 2014. This situation caused uncertainty about project preparation. Although the relevant municipalities were informed about the project, roadside licensing works were carried out in the project area. Therefore, the crossover road project was downsized.

During the project timeline, human behaviour in society was not appropriately taken into consideration. The crossover road project was not accepted by local people and non-governmental organisations. Several objections were made against the project. The fact that the requested project was different from the prepared project was an unpredictable situation for RDH. As a result, the crossover road project, which began operating, was changed to an underpass project, and it caused the prolongation of the process.

In the process, incorrect estimations were made about both technical measurements and the timeline of related operations. Developing a project with an incomplete database is one of the main reasons that create risks in large-scale projects. One of the situations that result in uncertainty regarding this issue in the junction project was the rainwater lines and irregular sewer lines, which were not included in the maps taken from the Trabzon Metropolitan Municipality, but were encountered in the field. Another incorrect estimate that created uncertainty was the depth of solid ground measured for the underpass foundation. Therefore, higher level technical equipment was needed and the difficulty in obtaining technical equipment resulted in exceeding the proposed deadline of the project.

The change in the type of the junction project, physical constraints and incorrect technical measurements not only caused incorrect estimations of project duration but also increased the cost of the project (Table 3). Cost estimation in the initial phases of the project did not consider such risks and incompatibilities thoroughly.

In summary, incorrect estimations in project preparation, project duration prediction, and technical measurements in the project process have led to uncertainties about the relevant planning environment.

Uncertainty About Decisions in Related Decision Areas

Since there are different actors as decision-makers or practitioners in a project, these actors must need to work in harmony and depend on each other. The actors directly involved in the Kaşüstü junction project were RDH and the contractor company. In the following process, the contractor company established a partnership with another private company as it could not cover the cost. The private company that made the technical measurements in the field, the Trabzon Branch of CCE, the private company that prepared the underpass project for the Trabzon Branch of CCE, the electricity distribution company and the 22nd Regional Directorate of State Hydraulic Works were indirectly involved in the process.

In the project, there were some uncertainties regarding the decision-making of the actors with each other. The first uncertainty determined on this issue was that the relevant municipalities were informed about the project by RDH, but roadside licensing works were carried out in the area. Therefore, changes were made to the project.

The project area is located in the sub-centre of the city. A participatory process was not carried out when the crossover road project, which will affect the silhouette of the city in the area, came to the agenda. Therefore, after the project was approved, many objections were made to the project by professional chambers, non-governmental organisations and local people. An underpass project was prepared by a private company upon the request of the Trabzon Branch of CCE to change the project type. However, RDH was not aware that the Trabzon Branch of CCE would prepare a different junction project and that the contractor company was preparing the implementation project at that time.

In the implementation stage of the underpass project, the power lines in the area posed a life threat to the operational work on the field. Power lines had to be temporarily removed from the area. However, the electricity distribution company had not been informed by the stakeholders about the project. There was no such project in the annual budget plan, thus the company could not perform the requested work.

The lack of coordination between the actors, the lack of information in the decision and implementation stages and the actors' ignorance of each other's jurisdictions caused in uncertainties.

Uncertainty About Value Judgment

The positive or negative impacts of the project affect all groups differently because of the heterogeneous structure of the society. Uncertainties about value judgment arise

Table 3. Cost of Kaşüstü Junction project (Açkı Ulusoy, 2016; Haber61, 2016; İHA, 2016; Sinop, 2016; Taka, 2016; Haber61, 2017; İHA, 2017; Haber61, 2018; Öztürk, 2018; Interview with expert 5 (E5), the 25th of November 2018)

Stages	Cost (TL)	Expropriated price (TL)
1st Stage (Crossover road project)	55.000.000	40.000.000
2nd Stage (Underpass project)	117.000.000	
3rd Stage (Changed underpass project)	80.000.000 (additional cost)	
Total cost	292.000.000	

during the questioning of values in the later stages of the project. Additionally, some uncertainties about value judgment emerged over time during the progress. There are different types of land uses and functions in the surroundings of the project area, mostly dominated by residential use and commercial uses, as well as some administrative facilities and leisure activities. The disruptions and uncertainties experienced in the process adversely affected the residents living in the area and its surroundings, the employers and employees in the area and road users.

The property owners living in the area did not leave their places for a long time, although they had been granted expropriation compensation at once by the administrations. That was unexpected social behaviour. On the other side, construction activities in the area and the prolonged project process negatively affected the daily life of the users (Figure 4). One of the reasons for the emergence of the junction project was to reduce traffic congestion. However, there was more traffic congestion than the existing traffic load during the construction process.

Another group that was adversely affected was project construction workers who were not permanent users of the project like those residents and business holders in the surroundings. Stream beds and high-voltage power lines in the project area were a risk for workers. Operators and site managers did not want to continue working unless necessary precautions were taken, thus they stopped the work occasionally.

The junction project affected different groups in different ways. The underpass project was opened to use in 2020 yet gradually. It is a project that has been finished regarding its total functioning, but technically not completed in March 2022. For this reason, uncertainties in value judgment can be determined more clearly in the following years.

CONCLUSION

Large-scale projects are among the characteristics of the current globalisation pattern. The necessary infrastructure for the operation of international economies, and developments in construction technologies are changing the physical structure of urban space rapidly and more drastically than ever. Numerous large-scale projects are under design, construction, revision or operation stages all around the world. The literature on large-scale projects, also known as mega projects, is also accumulating with special attention paid to their distinguishing characteristics. Besides the conventional aspects of large-scale projects which are mainly high-cost, high revenue, wide scope exceeding national boundaries, complexity, multi-actor collaboration, long duration, and great impact, some other identifiers are also apparent such as having high risks and specific types of uncertainties.

Large-scale projects are one-time undertakings. Consequently, they are performed under uncertainty and they are subject to risk (Regev et al., 2006). Unforeseen outcomes are highly likely to emerge in decision-making, implementation or monitoring processes of large-scale projects. Therefore, risk assessment techniques must be given special importance in project preparation and management processes. The aim of this article is to propose effective risk reduction/elimination policies for large-scale project management processes by examining a sample case.

The phenomenological urban space changer (the large-scale project) has samples mostly in and around the megacities and urban regions, yet not limited to those areas. Other projects that do not totally meet the definitive criteria of large-scale projects, but are similar to such projects in terms of content and impact, are constructed in mid-sized cities. In the study, it is argued that such projects can and must be evaluated in terms of large-scale projects, even if they do not have an impact on a national or international scale. These "relatively" large-scale projects embody most contents regarding large-scale projects. From this perspective, the Kaşüstü junction project in the city of Trabzon-Turkey which is an implemented sample of such relatively large-scale projects was examined.

The study employed Peter Hall's (1981) conceptual framework in dealing with the uncertainties in large-scale project processes. It was found that the three types of uncertainties defined by Friend and Jessop (1969) and applied by Hall (1981) were evident in the Kaşüstü junction project: 1) uncertainty about the relevant planning environment, (2) uncertainty about decisions in related decision areas and (3) uncertainty about value judgment. Basically; miscalculations, underestimation of important aspects, disharmonious actions of stakeholders, and wrong or incompetent choice of methodologies appeared as the sources for uncertainties about project revisions, budget extensions and time delays. In this context, the reasons for uncertainties and solutions can be discussed as follows:

- The uncertainties and risks identified for large-scale projects mainly originated from failures in project management (Regev et al., 2006; Taşan Kok, 2010). Even if large-scale projects are carried out in public-private cooperation, effective stakeholder management is required by the public sector (Mok et al., 2015). Although the projects have one or more than one executive institution, some other external institutions are likely to intervene directly or indirectly in the process. City management is a complex structure because there are several institutions authorised with

different powers for specialised service provisions. In the case of Kaşüstü junction, some institutions were different from the major actors such as the municipalities and the construction company involved in the process at certain phases. When they were required to make extra expenditures that were not included in their annual budget plans, problems emerged. These unexpected conditions can risk the project prolongation as happened in the Kaşüstü junction project sample.

- Monitoring all the necessary steps in the project can improve process management. In the Kaşüstü junction project, some fundamental steps were skipped in order to perform some type of result-oriented work. However, problems originating from the oversimplification were encountered frequently during the process and the project duration was prolonged.
- Large-scale projects should be approached more systematically and elaborately because of their high costs. Advanced studies should be carried out by groups that are specialised in the subject matter and calculations should be made delicately before as well as during the project. Incorrect calculations sometimes lead to increased costs sometimes to prolongation of the process, and sometimes to both. Incorrect calculations in the Kaşüstü junction project not only increased the cost but also prolonged the project duration by 270%.
- Projects are mostly constructed within the built-up area where people accommodate, work, etc. The prolongation of the project duration may also adversely affect the people living and working in the surrounding areas. Therefore, the project duration should be estimated correctly or at least within tolerable limits by considering all the steps. In addition, the public should be informed constantly about the progress. In the Kaşüstü junction project, the technical problems in the process were not always unknown or unpredicted. On most occasions, the project teams were aware of the potential problems long before they emerged. However, the public was not informed thoroughly, as it was not accurately estimated how long the technical problems would prolong.

The complexities of multi-actor governance influence the implementation of projects. Each city has its own particular experience with the implementation strategy (Taşan Kok, 2010). Problems, possibilities, uncertainties, and risks vary from city to city in accordance with the unique composition of local actors and their existing relations. Therefore, besides the common features of large-scale projects, there is always some level of uniqueness in the environment of large-scale projects. Kaşüstü junction project which was constructed in Trabzon, a mid-size city, is a significant example to understand the impact and authenticity of multi-actor governance mechanisms.

The uncertainties and failures as the results of project management in large-scale projects addressed in the literature have also been identified in the Kaşüstü Junction project. This experience showed similar results with others around the world that either megaprojects or large projects are home to uncertainties. It has been determined that not only mega projects or large-scale projects built in large-scale cities, but also relatively large-scale projects built in mid-sized cities have similar uncertainties. Every project contains uniqueness and uncertainties. Thus, project preparation teams should pay special attention to the concern of reducing uncertainties in their agendas. After several revisions, time delays, budget extensions, project shrinking / downsizings, organisational renewals, and corrosive public debates Kaşüstü junction project was finished with some degree of differentiation from the original project. It is suggested that learning from the analysis of the large-scale project experiences will contribute to efforts to reduce such negative effects of large-scale projects which show a worldwide tendency to become more expensive, more complex, more uncertain and riskier.

Figure 4. Construction activities of Kaşüstü junction project (Fieldwork photos of November 2018).

[1]*In Yazar's (2006) study, which includes the classification of the cities in Turkey according to population of their city center, Trabzon is considered as a mid-sized city.*

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 29–42, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: 10.14744/megaron.2023.98975

Article

Identifying the manufacturing industrial clusters in the districts of Türkiye

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ARTICLE INFO

Article history
Received: 02 September 2022
Revised: 20 March 2023
Accepted: 20 March 2023

Key words:
Cluster identification; cluster policy; industrial clusters; manufacturing industry; Türkiye

ABSTRACT

This article identifies the manufacturing industry clusters in Türkiye and contributes to the literature by identifying clusters at the district level. The literature background of this study is based on the concept of cluster and cluster identification. The study uses the sales and purchases between manufacturing industries via the input-output tables of 24 manufacturing industries and the number of employment and workplaces in each industry at the district level for 2019 as data. The methodology consists of three steps: the study first identifies the purchase and sales relations between industries, then groups related industries using principal component factor analysis, and lastly determines the spatial concentration of industries using the location quotient. The study's findings show manufacturing industries to be grouped into six cluster templates. The districts where industries are clustered are mostly located in the western Türkiye. The textile industry differs because it is clustered in southeast Türkiye. The geographical distributions of the furniture industry clusters and non-metallic industry clusters also differ due to having different location criteria. The packaged food industry is clustered in more districts compared to all other industries except the non-metallic industry, and the districts are located in highly populated provinces. These results place a comprehensive framework across the country and can enable policymakers to direct cluster policies.

Cite this article as: Sakarya A. Identifying the manufacturing industrial clusters in the districts of Türkiye. Megaron 2023;18(1):29–42.

INTRODUCTION

In Türkiye, industry clusters started becoming one of the main policies for regional development after the 2000s in relation to the application process for European Union (EU) membership (Bulu & Yalçıntaş, 2015; Dulupçu et al., 2015). This approach has been supported in the national development plans. The Ninth Development Plan (2007-2013) was the first national plan to use the concept of clusters and to support clustering as one of its strategies (State Planning Organization, 2007). The emphasis on cluster policies was increased in the Tenth Development Plan (2014-2018) and Eleventh Development Plan (2019-2023). The Tenth Development Plan supported clusters by aiming for innovation, competitiveness, collaboration, and better infrastructure (Ministry of Development, 2014), while the Eleventh Development Plan updated the previous aims, increased strategies regarding clusters, and also defined specific sectoral clusters (Presidency of the Republic of Turkey- Presidency of Strategy and

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Budget, 2019). These national strategies and global trends regarding clusters have directed regional and local policies. For example, development agencies have an important role in cluster policy (Bulu & Yalçıntaş, 2015; Dulupçu et al., 2015). Türkiye has 26 development agencies that were established within the EU membership process at the Nomenclature of Territorial Units for Statistics-2 (NUTS-2) level. These agencies' main objectives are to accelerate regional growth based on national aims and targets, organize economic development, develop the coordination of different agents, and diminish regional disparities. On the other hand, development agencies organize regional incentives (Official Gazette, 2006) and also make regional plans in line with the national development plans. Development agencies use these plans to define clusters in the region, determine objectives for clusters, and organize clusters. For example, supporting industrial clusters is one of the main objectives of the İstanbul Development Agency's (2014) regional plan for 2014-2023. The Bursa Eskişehir Bilecik Regional Plan for 2014-2023 also defines objectives for clusters regarding specific sectors (Bursa Eskişehir Bilecik Development Agency, 2014). In addition to regional plans defining clustering objectives, development agencies also organize and finance clusters. For example, the İzmir Development Agency is an agent in the İzmir organic food cluster, the İnoviz health cluster, the İzmir Atatürk Organize Sanayi Bölgesi (İAOSB) machinery metal cluster, and the aeronautics and space cluster (Günaydın, 2013). The Dicle Development Agency (2018) covers the provinces of Batman, Mardin, Siirt, and Şırnak and coordinates and designs the textile cluster project in Batman. Both in the regional plans and projects, development agencies focus on cluster policies, but these policies are bordered by region due to area of authority. Therefore, the need exists for a general framework across the country regarding clusters. Türkiye has some studies that have analyzed the manufacturing industry clusters across the country, and these are mentioned in the literature review. However, these studies analyzed clusters at the provincial level as the lowest unit of size. This study analyzes manufacturing clusters at the district level using updated data, which is the contribution this study makes to the practical aspect of the literature.

After the introduction, this paper presents information on the concept of cluster and both national and international studies on identifying clusters in the literature review in Section 2. Section 3 explains the three-stage methodology and data used in the study. Section 4, discusses the findings using the maps made in ArcGIS Pro. The last section makes general evaluations and provides suggestions for policymakers and further research.

LITERATURE REVIEW: CLUSTER AND CLUSTER IDENTIFICATION

The concept of cluster has a long historical background. Marshall (1920) asserted that firms agglomerate because of positive externalities that he called agglomeration. After the mass production crises in the 1970s, the spatial pattern of production changed (Harvey, 1990), and agglomeration started being discussed again, with the rapid growth of some districts compared to others increasing the interest in this concept. During this period, studies analyzed agglomeration in terms of industrial districts and industrial regions (Becattini, 1990; Lazzeretti et al., 2013). These studies focused on both the economic and non-economic dimensions (e.g., cultural, social, and institutional) of industrial districts (Scott, 2000; Cainelli, 2008; Becattini et al., 2009). Michael Porter (1990; 1998) developed another approach in the literature based on competitiveness and asserted competitive firms to be agglomerated, which he defined as a cluster. The diamond model has been used to describe the dimensions and relations of clusters (Martin & Sunley, 2003; Porter & Ketels, 2009), and this model makes clusters applicable for policies.

Different approaches and relatedly different definitions exist for the concept of cluster. The United Nations Industrial Development Organization (UNIDO, 2001) defined cluster as a sectoral and spatial concentration of complementary entrepreneurs. According to the Organization of Economic Co-operation and Development (OECD, 1999) a cluster is a production network in which strongly connected agents provide added value. Porter (1998) defined the spatial concentration of firms and institutions in a particular field as a cluster. Gordon and McCann (2000) also stated a similar definition with regard to the spatial concentration of related firms.

Even though small differences exist in these definitions, they have two important common points: related industries and spatial concentration. Studies on identifying clusters focus on these two points.

Feser and Bergman (2000) conducted an important study on identifying clusters. They suggested a methodology in which they first defined the relation of industries by analyzing an input-output (I/O) table showing industries' purchases and sales, then they used principal component factor analysis to group the related industries. They analyzed 478 industries in the USA in their study using data from 1987 and found 23 clusters. After defining these industrial clusters, they used a location quotient (LQ) analysis to reveal spatial distributions. Kelton et al. (2008) updated this study using the same method with data from 2002. They found 62 industrial clusters but did not analyze the spatial dimension. Lopes et al. (2010) also followed the same method to analyze the 55 manufacturing industries in Portugal and found nine industrial clusters. Delgado et

al. (2014) again identified industrial clusters in the USA. However, they used similarities in site selection and labor pool in addition to I/O tables. Argüelles et al. (2014) used an I/O table of 65 industries in Spain as well as a hierarchical clustering regarding the principal components. They identified three clusters but did not associate their findings spatially. To analyze the correlation between cluster growth and cluster specialization in Eastern Cape Province, Zeelie and Lloyd (2013) first identified the industrial clusters in South Africa using an I/O table of 90 industries in 2002 and identifying 12 clusters using Ward's hierarchical cluster algorithm. Duque et al. (2009) used the Colombian I/O table and identified 12 clusters, while also benefitting from the network-based approach to analyze the networks among the clusters.

Türkiye has had some studies on identifying clusters across the country. Akgüngör et al. (2003), Akgüngör (2006), and Çelik et al. (2019) used the model Feser and Bergman (2000) had developed. All these studies first identified the relations among industries using an I/O table, then used principal component factor analysis to identify the industrial clusters templates, and finished by calculating the LQ to analyze the clusters spatially. Akgüngör et al. (2003) identified seven industrial clusters at the geographic regional level using data on 64 industries in 1990. Akgüngör (2006) used the same method at the provincial level using data from 1996. Çelik et al. (2019) followed the same method at the NUTS-2 level using data from 2012. Meanwhile, Kaygalak and Reid (2016) used a different methodology to identify industrial clusters at the provincial level, in which they first used the global Moran's I method to analyze global clustering at the national level, then they used the Getis-Ord Gi* statistic to identify local spatial autocorrelations. Kirankabeş and Arik (2014) used the 3-star analysis that is frequently used in the EU. Their study analyzed and compared clusters at the NUTS-2 scale for the years 2008 and 2011.

Of these studies in Türkiye, the lowest geographical scale was at the provincial level. The current study identifies manufacturing industrial clusters at the district level and includes the importance of industries' spatial proximity in the analysis by focusing on a lower geographical scale. This approach is the study's contribution to the empirical area of the literature.

METHODOLOGY AND DATA

The methods for identifying clusters can be categorized as top-down and bottom-up, as in the studies mentioned above. Bottom-up methods are qualitative and cluster-specific, such as surveys and expert opinions. On the other hand, top-down methods analyze a region, a country, or a sector quantitatively based on secondary data to identify clusters, and these methods involve I/O analyses, network analyses, and LQ analyses (Cortright, 2006; Gwosdz & Micek, 2010; Brenner, 2017; Cho, 2014; Duca & Gribincea, 2019; Bergman & Feser, 2020). This study analyzes the manufacturing clusters in Turkish districts and thus applies the top-down method.

The study follows the methodology developed by Feser and Bergman (2000) and used by Akgüngör et al. (2003), Akgüngör (2006), and Çelik et al. (2019). This methodology allows both related industries and spatial concentrations, which are the main characteristics of industrial clustering, to be analyzed.

The methodology consists of three steps. The study first identifies the relations among industries using the I/O table, then groups related industries using principal component factor analysis, and finally defines the LQs of related industries spatially at the district level.

To identify the related industries, the I/O table of the purchases and sales between industries is used. Feser and Bergman (2000) suggested the two metrices of purchases (X) and sales (Y). These are derived as follows:

$$X_{ij} = \frac{a_{ij}}{p_j} \; ; \quad X_{ji} = \frac{a_{ji}}{p_i} \; ; \quad Y_{ij} = \frac{a_{ij}}{s_i} \; ; \quad Y_{ji} = \frac{a_{ji}}{s_j} \qquad (1)$$

where X_{ij} and X_{ij} are the respective purchases by *j* from *i* and by *i* from *j* as a percentage of *j*'s and *i*'s total purchases, and Y_{ij} and Y_{ij} are the respective sales from *i* to *j* and from *j* to *i* as a percentage of *i*'s and *j*'s total sales.

After defining the tables, four correlations are calculated among industries. $r(X_i.X_j)$ is the correlation coefficient between the purchase patterns of *i* and *j*, $r(X_i.Y_j)$ is the correlation between the purchases of *i* and sales of *j*, $r(Y_i.X_j)$ is the correlation between the sales of i and the purchases of *j*, and $r(Y_i.Y_j)$ is the correlation between the sales of *i* and of *j*. Finally, the largest is taken as the relation coefficient between industries *i* and *j*.

Principal component factor analysis is used to group the related industries according to the largest correlation coefficient between industries. Principal factor analysis is a method for grouping those industries in an industrial cluster according to their selling and purchasing similarities (Chu et al., 2010; Cho, 2014). This study performs the principal component factor analysis using the program Statistical Package for the Social Sciences (SPSS). Using varimax rotation as in Feser and Bergman's (2000) study, groups with an eigenvalue greater than 1.0 are evaluated as an industrial cluster template. Taking the eigenvalue greater than 1.0 allows for the optimal number of factors/clusters (Kanyongo, 2005). Feser and Bergman (2000), Akgüngör et al. (2003), Akgüngör (2006), Argüelles et al. (2014), and Çelik et al. (2019) evaluated industries with a loading factor greater than 0.60 as the primary industry in their cluster templates. Similarly, this study evaluates industries with a loading factor greater than 0.60 as the primary industry and others as secondary industries.

After defining the industrial cluster templates, the LQ is used to analyze the spatial agglomeration. LQ analysis is a method for analyzing the regional specialization of an industry. It is the ratio of the regional industry employment's share of the total regional employment to the national industry employment share in the total national employment (Isaksen, 1997; Brachert et al., 2011; Crawley et al., 2012). Besides LQ's common usage, it has two important points with regard to interpreting the results. The first one is that the cut-off value indicates which value shows the clustering or specialization of an industry. The literature has no common cut-off value, it instead varies by case (O'Donoghue & Gleave, 2004; Gwosdz & Micek, 2010; Crawley et al., 2012; Brenner, 2017). For example, it is 3.0 in Malmberg and Maskell (2002) and Isaksen (1996), 1.0 in Held (1996) and Bishop et al. (2003), and 2.0 in Sölvell et al. (2003). This study employs a cut-off value of 1.25, similar to the studies of Feser and Bergman (2000), Akgüngör et al. (2003), Akgüngör (2006), Argüelles et al. (2014), and Çelik et al. (2019). The second important point of the LQ involves the risk in evaluating small regions as being specialized. Small regions with a low number of employees can have a higher LQ, so the cut-off value should have a condition regarding employment (Gwosdz & Micek, 2010; Brenner, 2017; Pominova et al., 2021). In this study, the LQ values are calculated by employment at the district level. Also, this study assumes the districts with less than 50 employees in each industrial cluster template to be non-clustered, and their LQ values are shown to be less than 1.25 in the map legends.

This study uses two datasets. The first is the I/O table for manufacturing industries in 2019. There are 24 industries with NACE Rev.2 2-coded values like C24 - Manufacture of basic metals and the I/O table consists of a 24X24 cell of these industries. The table is available from the Republic of Türkiye's Ministry of Industry and Technology - Entrepreneur Information System. The second dataset involves the employment and number of workplace data of each industry with NACE Rev.2 2-coded values at the district level in 2019. This set was obtained from the Social Security Institution (SSI).

Findings

In 2019, more than 83 million people were living in Türkiye. According to data obtained from SSI, Türkiye had 16.332.069 employees and 1,.20.019 workplaces in 2019. The manufacturing industry took up 25.6% (4.84.756) of the total employment and 14.6% of the total workplaces (281.266). The manufacturing industry also was responsible for 16% of the gross domestic product (GDP) (48.988 million $ / 307.659 million $) in 2019 (Central Bank of Türkiye [TCMB], 2022).

To define the cluster templates, the principal component factor analysis is used for 24 industries according to the purchase and sale relations between two coded industries. The results revealed six factors (i.e., clusters). The six clusters are identified in Table 1 according to the primary and secondary industries. The primary industries have a loading factor greater than 0.60, and secondary industries have a loading factor less than 0,60.

The metal industry and electrical equipment have the most employees and workplaces. The manufacture of electrical equipment is one of the primary industries in this cluster, in addition to metal products and machinery equipment. The textile industry is also another dominant industry cluster template in the Turkish manufacturing industry. The non-metallic industry template, which is mainly a stone-based industry, has the lowest number of employees and workplaces (Table 2).

The maps for the industrial cluster template regarding LQ at the district level were mapped using Arc-GIS Pro. Türkiye has 970 districts. In order to interpret the clusters, the provinces are coded on the maps. The provinces and codes are given in Appendix 1.

For the metal industry and electrical equipment, 108 of 970 districts (11%) are specialized. Three regions are prominent, and they are close to the most populated and industrialized provinces. The first one is a corridor from Bursa (Province #16) to Sakarya (#54) through Kocaeli (#41). These provinces alongside İstanbul (#34) are among the most populated provinces. Automotive and related industries are agglomerated in this region, which has different types of transportation modes, including ports. This corridor also has a connection to the corridor starting from Eskişehir (#26). The second region includes the districts in İzmir (Province #35) and Manisa (#45). İzmir (#35) is the third most populated province, and Manisa (#45) is mostly linked economically to İzmir (#35). They may be described as a pole of manufacturing industries along the western edge. The third region is Ankara (#6) the capital of Türkiye and the second most populated province. Alongside Ankara (#6), the districts around Çankırı (#17) and Kırıkkale (#71) are also specialized in metal industry and electrical equipment. Especially in Ankara (#6) high population, wide labor pool, main transportation connections, historical development process, and having universities, and techno parks are the main dynamics of the metal industry and electrical equipment firms (Ankara Development Agency, 2014) (see Figure 1).

Of the 970 districts, 246 (25%) are specialized in the packaged food industry. The number of specialized districts in the packaged food industry is much higher than in the metal industry and electrical equipment. The specialized districts are generally dispersed, but some are located near highly populated provinces due to the high rate of consumption.

Table 1. Summary of the Principal Component Analysis Results

Cluster Definition	Industries	Industry type	Eigenvalue	Variance (%)	Cumulative variance (%)
Metal industry and	C24 - Manufacture of basic metals	Primary	7.4528	22.4845	22.4845
electrical equipment (1)	C25 - Manufacture of fabricated metal products, except machinery and equipment	Primary			
	C27 - Manufacture of electrical equipment	Primary			
	C28 - Manufacture of machinery and equipment n.e.c.	Primary			
	C29 - Manufacture of motor vehicles, trailers and semi-trailers	Primary			
	C26 - Manufacture of computer, electronic and optical products	Secondary			
	C30 - Manufacture of other transport equipment	Secondary			
	C33 - Repair and installation of machinery and equipment	Secondary			
Packaged food industry (2)	C10 - Manufacture of food products	Primary	3.6563	15.9295	38.4140
	C12 - Manufacture of tobacco products	Primary			
	C17 - Manufacture of paper and paper products	Primary			
	C18 - Printing and reproduction of recorded media	Primary			
	C21 - Manufacture of basic pharmaceutical products and pharmaceutical preparations	Secondary			
Textile industry (3)	C13 - Manufacture of textiles	Primary	3.5933	14.1860	52.6001
	C14 - Manufacture of wearing apparel	Primary			
	C32 - Other manufacturing	Primary			
Chemical industry (4)	C19 - Manufacture of coke and refined petroleum products	Primary	2.0764	11.2148	63.8148
	C20 - Manufacture of chemicals and chemical products	Primary			
	C22 - Manufacture of rubber and plastic products	Primary			
	C15 - Manufacture of leather and related products	Secondary			
Furniture industry (5)	C16 - Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	Primary	1.8590	9.8163	73.6311
	C31 - Manufacture of furniture	Primary			
Non-Metallic industry (6)	C11 - Manufacture of beverages	Primary	1.1940	9.0016	82.6327
	C23 - Manufacture of other non-metallic mineral products	Primary			

The region that includes Edirne (#22), Kırklareli (#39), Tekirdağ (#59), Çanakkale (#17), and especially Balıkesir (310) shows the clustering of the packaged food industry. This also applies to the region that includes Bursa (#16) and Bolu (#14). This same pattern can be seen in İzmir (#35), Manisa (#45), and Aydın (#9). Besides being near

Table 2. Employment and Workplace Distributions Based on Clusters, 2019

Clusters	Employment		Workplace	
	Number	Rate (%)	Number	Rate (%)
Metal industry and electrical equipment (1)	1.488.716	35.57	91.390	32.49
Packaged food industry (2)	658.403	15.74	57.086	20.30
Textile industry (3)	1.165.161	27.84	61.070	21.71
Chemical industry (4)	398.804	9.53	25.413	9.04
Furniture industry (5)	241.376	5.77	31.559	11.22
Non-Metallic industry (6)	232.296	5.55	14.748	5.24
Total	4.184.756		281.266	

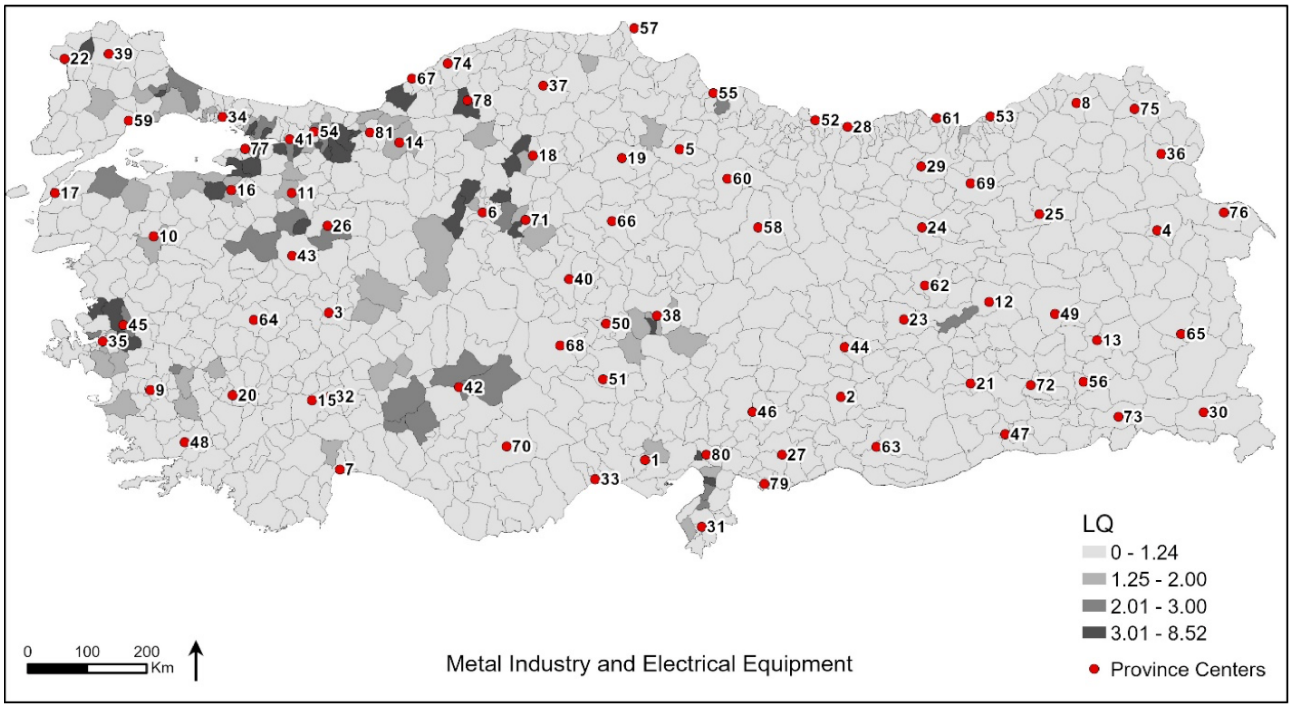

Figure 1. LQ map of metal industry and electrical equipment (Created by the author based on data from SSI- 2019).

highly populated provinces, plenty of fertile agricultural land, livestock, and demand for organic food are important for firms to locate in these provinces (İzmir Development Agency, 2014; South Marmara Development Agency, 2014; Trakya Development Agency, 2014). The map shows an additional two important regions. The first one started from the south in Karaman (#70) going north to Samsun (#55). This region has fertile soil, and agricultural production is converted to a final product through agricultural industries (agro-industries). The second region is in the north, going from Samsun (#55) to Artvin (#8). The industrial districts in this region occur primarily along the shoreline. The specific agricultural product like tea, hazelnut, and agriculture production from forestry called agroforestry attracts packaged food industry firms (Eastern Black Sea Development Agency, 2014) (see Figure 2).

Of the 970 districts, 166 (17%) are specialized in the textile industry. Unlike the packaged food industry, the textile industry clusters are not related spatially to the most populated provinces. Another difference is that the textile industry clusters are especially distinct in the southeast. Districts around Kahramanmaraş (#46), Gaziantep (#27), and Malatya (#44) are specialized in this region. The region including these provinces has high cotton production that attracts the firm to locate in this region (Eastern Mediterranean Development Agency, 2014; Silkroad Development Agency, 2014). Also, the region including Diyarbakır (#21), Batman (#72), and Mardin (#47) shows specialization. These provinces have relatively low industry employment, so having relatively high employment in the textile industry makes it specialized. The textile industry requires relatively low-skilled labor (Yülek et al. 2019), therefore this industry

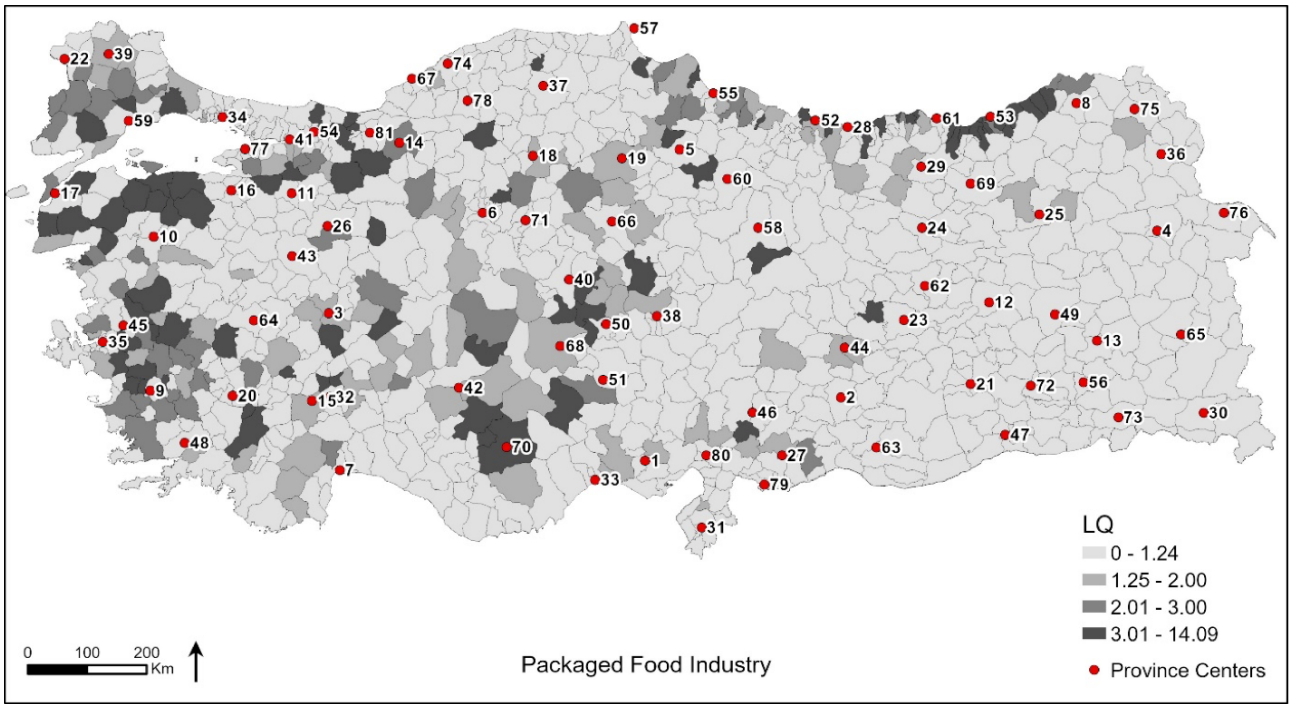

Figure 2. LQ map of packaged food industry (Created by the author based on data from SSI- 2019).

can be specialized in regions with comparatively low industrial development. Specialized districts are dispersed in northern Türkiye. Western Türkiye can be seen to have two regions. The first one includes Denizli (#20) and Uşak (#64). The textile industry has a historical background in these provinces, especially in Denizli (#20). The second region includes districts in Edirne (#22), Kırklareli (#39), and Tekirdağ (#59). The development of the textile industry is mainly related to the deindustrialization of İstanbul (#34) (see Figure 3).

The chemical industry is specialized in 112 (12%) of the 970 districts. The clusters of this industry show spatially similar patterns to the metal industry and electrical

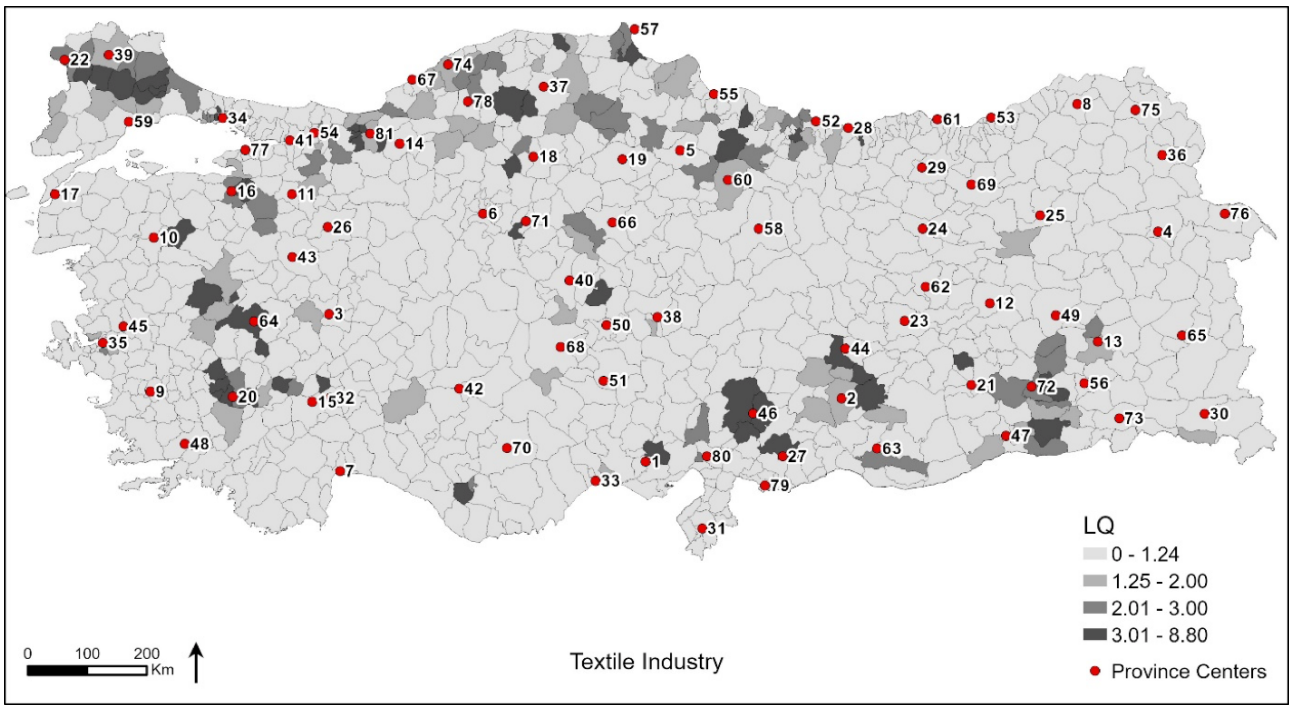

Figure 3. LQ map textile industry (Created by the author based on data from SSI- 2019).

equipment. The region from Kocaeli (#41) to Düzce (#81) as well as the region including İzmir (#35) and Manisa (#45) are specialized. Both these regions have refineries and related industries. Another region includes the districts between İstanbul (#34) and Tekirdağ (#59). This region is also specialized in the textile industry and, in relation to this, has textile dyeing industries. As with textile industry, southern Türkiye has chemical industry clusters in the districts around Kahramanmaraş (#46) and Gaziantep (#27). As in Tekirdağ (#59) these provinces has dyeing industry related to textile (Eastern Mediterranean Development Agency, 2014; Silkroad Development Agency, 2014). As well as other local clusters around Konya (#42) because of dyeing, rubber, and plastic for supplying the automotive industry (Mevlana Development Agency, 2014); and it is similar for Eskişehir (#26) in which the chemical industry supplies the automotive and military industries in the region (Bursa Eskişehir Bilecik Development Agency, 2014) (see Figure 4).

Of Türkiye's 970 districts, 161 (17%) are specialized in the furniture industry. The location criteria of firms in this industry are mostly related to being near raw material sources. Therefore, regions in northern Türkiye where forests cover a large percentage of land in particular are prominent. The districts around Kastamonu (#37), Zonguldak (#67), Karabük (#78), and Sakarya (#54) are where the clusters of the furniture industry are found. The corridor from Antalya (#7) to Balıkesir (#10) through Uşak (#64) also shows clustering characteristics for the furniture industry. On this corridor, the forest asset is distinctive, so the forest industries select this corridor to be near the raw material sources (West Mediterranean Development Agency, 2014; South Marmara Development Agency, 2014) (see Figure 5).

The non-metallic industry has the greatest number of specialized districts at 275 (28%) of the 970 districts. This cluster is spread out across the country. As in the furniture industry, the non-metallic industry that is generally stone based has a tendency to be located near raw material sources. The specialized districts are mostly located in western Türkiye. The corridor starting from Afyon (#3) and finishing at Bilecik (#11) and connected to İzmir (#35) and Muğla (#48) through Uşak (#64) has a strong non-metallic industry presence. Central Türkiye has specialized districts going south to north. The most important difference between the non-metallic industry cluster and the other five industries is eastern Türkiye has many districts specialized in non-metallic industry (see Figure 6).

CONCLUSION

This study has attempted to meet the need for identifying the manufacturing industry clusters across Türkiye and differs from other studies in Türkiye by analyzing these clusters at the district level.

The results show that manufacturing industries can be grouped into six cluster templates with respect to their buying and selling relations. These clusters differ spatially. In general, the manufacturing industry clusters are seen to

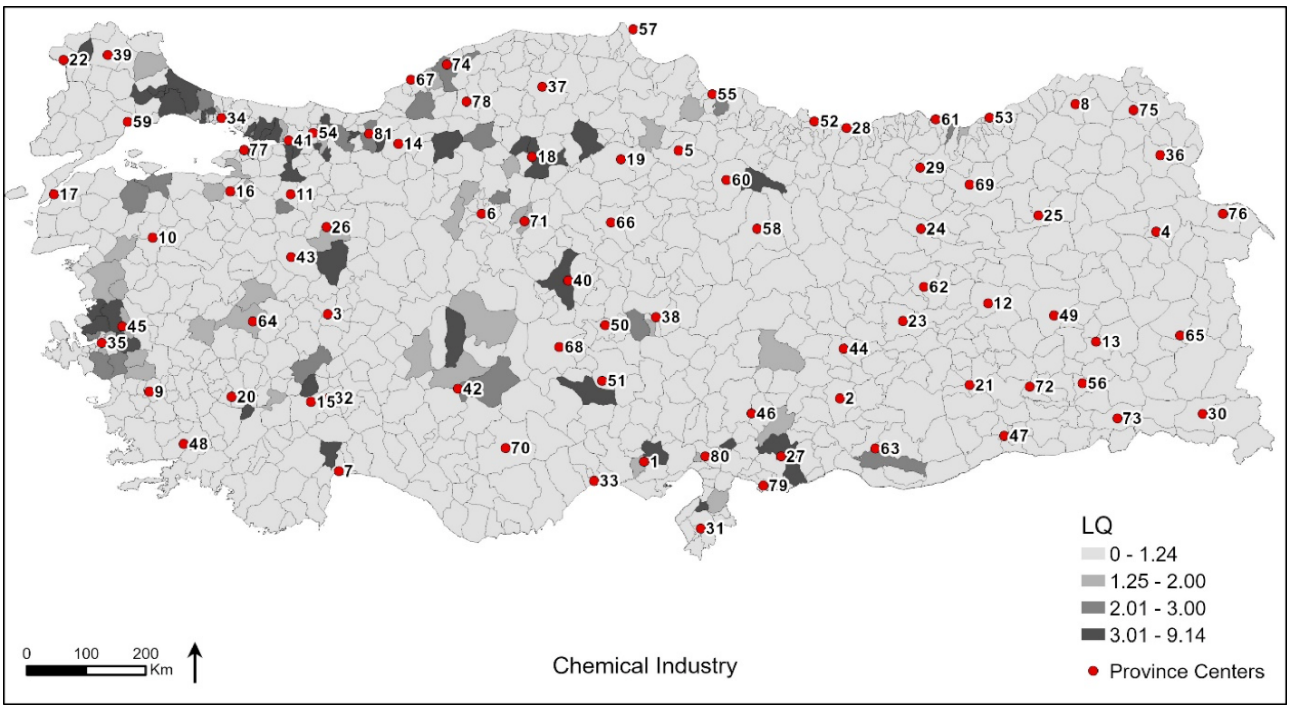

Figure 4. LQ map chemical industry (Created by the author based on data from SSI- 2019).

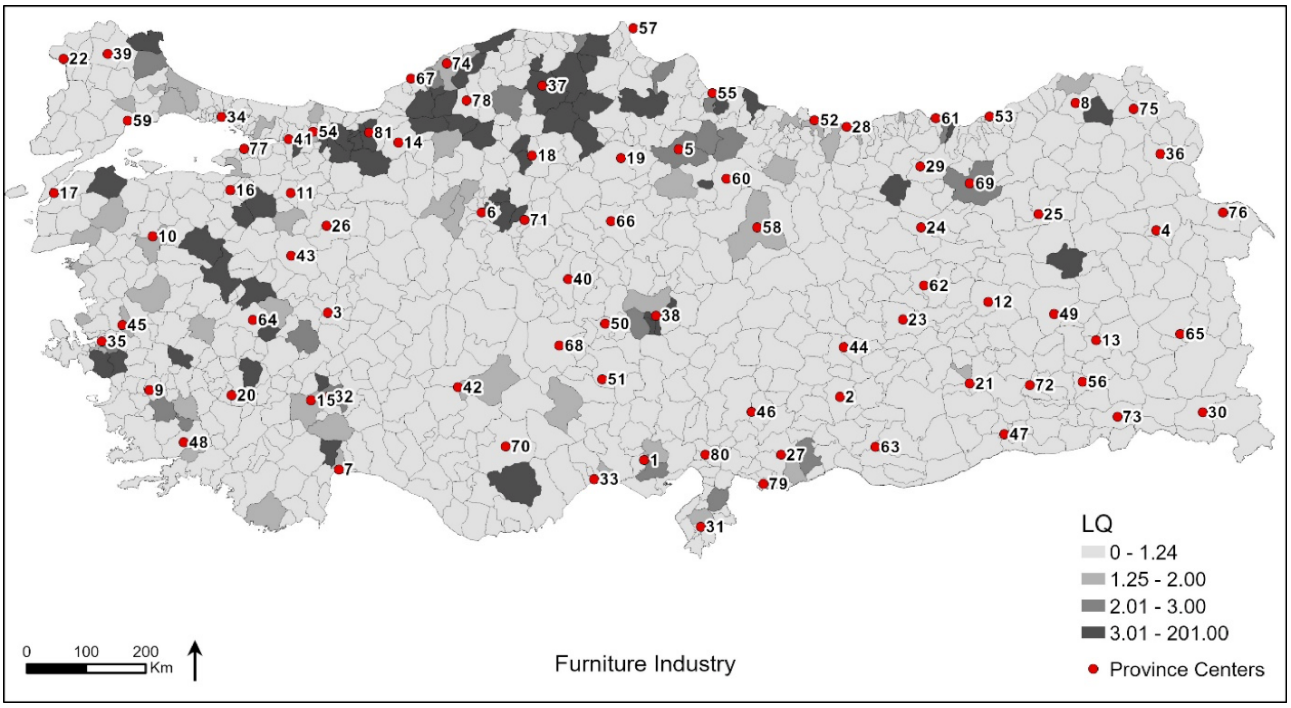

Figure 5. LQ map furniture industry (Created by the author based on data from SSI- 2019).

be mostly located in western Türkiye. Figure 7 shows the number of industries clustered in districts, with districts in western Türkiye, especially around Sakarya (#54), Kocaeli (#41), Bursa (#16), İstanbul (#34), İzmir (#35), and Manisa (#45) to be specialized in more than one industry. The same applies to the districts around Antalya (#7), Konya (#42), Adana (#1), Gaziantep (#27), Kahramanmaraş (#46), Ankara (#6), and Samsun (#55), with 107 districts (11%) that are specialized in more than two industries; these districts are located generally around these provinces, which are the more populated and industrialized provinces in Türkiye.

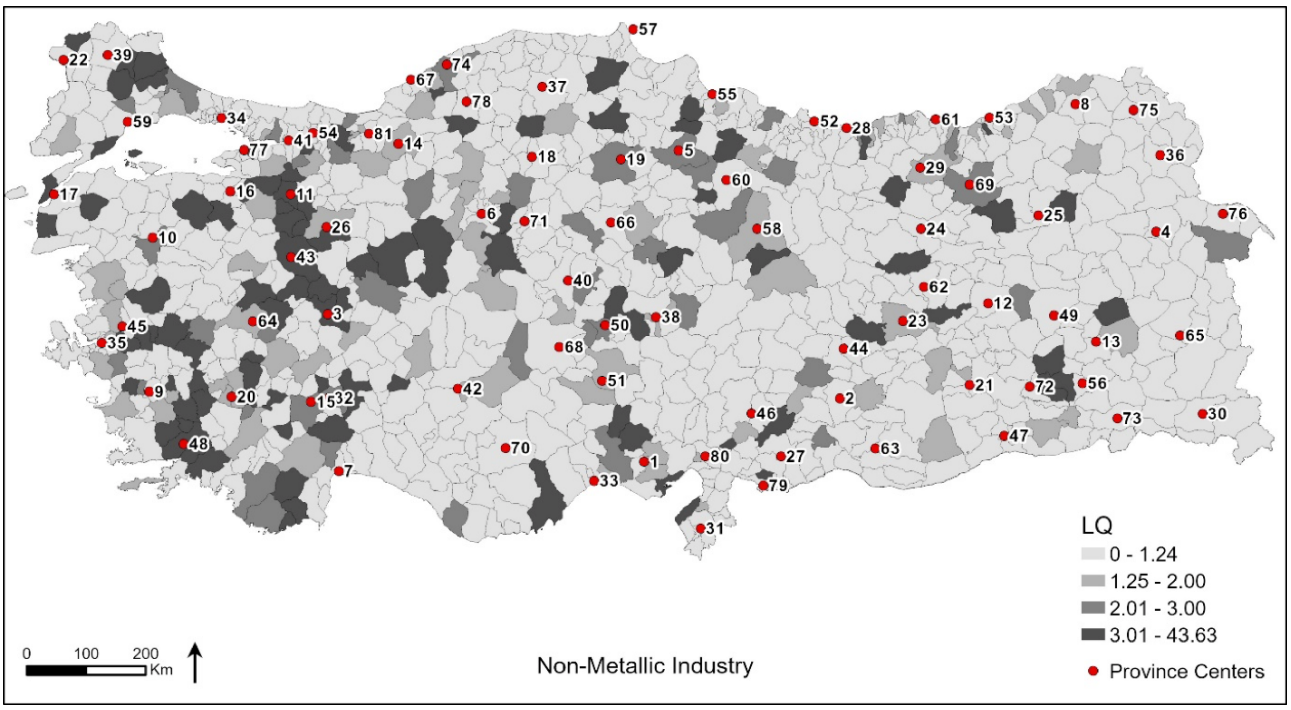

Figure 6. LQ map of non-metallic industry (Created by the author based on data from SSI- 2019).

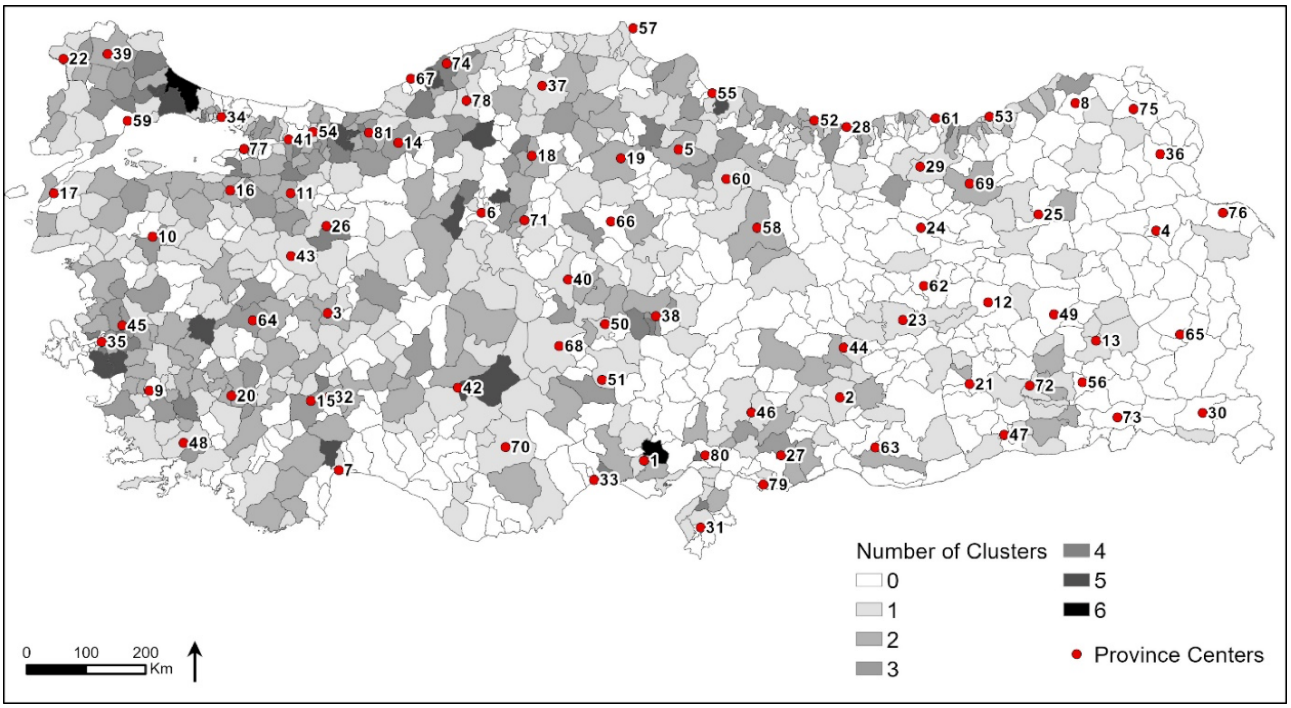

Figure 7. The number of industries clustered in the districts of Türkiye (Created by the author on data from SSI- 2019).

The spatial distribution of the metal industry and electrical equipment clusters show a similar pattern to that of the chemical industry clusters. The furniture industry clusters are generally near the raw materials. This is also the same for the non-metallic industry clusters, but more districts are specialized in this industry, and these districts are spread throughout the country. The packaged food industry clusters are near highly populated provinces to be near market area. The textile industry differs from other industries in that it has more clusters in southeastern Türkiye, because as mentioned before, the production of material used in textile industry is high in this region, and having relatively lower industrial employment makes the textile industry which does not require high-skilled labor, specialized in this region.

This study draws a picture of the manufacturing industrial clusters at the district level across Türkiye. This may help institutions, including development agencies, rethink their cluster policies and can provide a framework for organizing new cluster policies and projects. This picture may also provide a basis for where to direct incentives and investments with respect to the industries.

The results of the study differ from the studies made for Türkiye. This study gives a detailed spatial distribution because of focusing on the district level. For example, for the textile industry, Kaygalak and Reid (2016) found the spatial concentration around İstanbul (#34), Manisa (#45) and Kahramanmaraş (#46), Gaziantep (#27). This study shows that the textile industry does not concentrate on all districts in these provinces. For example, in İstanbul (#34) Kahramanmaraş (#46), and Gaziantep (#27) the districts that are the center of the provinces are dominant (Figure 7). Also, it was revealed that there are districts that have textile industry clusters in the northern part. For another example, Çelik et al. (2019) define the cluster at the regional level, and this study shows that the region TR 50 including Konya (#42) and Karaman (#70) has automotive clusters that have C28 (Manufacture of machinery and equipment n.e.c.) and C29 (Manufacture of motor vehicles, trailers, and semi-trailers) industries. These industries are in the metal industry and electrical equipment industries cluster in this study. Figure 7 shows that the center districts of the Konya (#42) have metal industry and electrical equipment industries clusters, and the other districts do not have the same pattern. Also, the districts in this region have packaged food industry clusters.

The findings from this research should be supported by cluster-specific studies using the bottom-up methodologies mentioned in the methodology section. This research has used inter-industry relations and spatial proximity for identifying the cluster, as has been done in studies that use a top-down methodology; however, clusters have more dimensions, such as social networks, traded and untraded interdependencies, cooperation, competition, factor conditions, demand conditions, and institutions. These can also be analyzed through cluster-specific studies by applying bottom-up methodologies in future research.

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Appendix 1. The provinces and codes.

Province	Code	Province	Code	Province	Code
Adana	1	Giresun	28	Samsun	55
Adıyaman	2	Gümüşhane	29	Siirt	56
Afyon	3	Hakkari	30	Sinop	57
Ağrı	4	Hatay	31	Sivas	58
Amasya	5	Isparta	32	Tekirdağ	59
Ankara	6	Mersin	33	Tokat	60
Antalya	7	İstanbul	34	Trabzon	61
Artvin	8	İzmir	35	Tunceli	62
Aydın	9	Kars	36	Şanlıurfa	63
Balıkesir	10	Kastamonu	37	Uşak	64
Bilecik	11	Kayseri	38	Van	65
Bingöl	12	Kırklareli	39	Yozgat	66
Bitlis	13	Kırşehir	40	Zonguldak	67
Bolu	14	Kocaeli	41	Aksaray	68
Burdur	15	Konya	42	Bayburt	69
Bursa	16	Kütahya	43	Karaman	70
Çanakkale	17	Malatya	44	Kırıkkale	71
Çankırı	18	Manisa	45	Batman	72
Çorum	19	Kahramanmaraş	46	Şırnak	73
Denizli	20	Mardin	47	Bartın	74
Diyarbakır	21	Muğla	48	Ardahan	75
Edirne	22	Muş	49	Iğdır	76
Elazığ	23	Nevşehir	50	Yalova	77
Erzincan	24	Niğde	51	Karabük	78
Erzurum	25	Ordu	52	Kilis	79
Eskişehir	26	Rize	53	Osmaniye	80
Gaziantep	27	Sakarya	54	Düzce	81

Megaron, Vol. 18, No. 1, pp. 43–58, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/MEGARON.2023.27048

Article

An investigation into the perception of space in children through visual representations: The Children's Library in Giresun (The Capuchin Catholic Church)

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ARTICLE INFO

Article history
Received: 21 October 2022
Revised: 08 February 2023
Accepted: 20 February 2023

Key words:
Children; perception; The Capuchin Catholic Church; The Children's Library in Giresun

ABSTRACT

Children's physical and mental activities cause them to show differences in their perception and evaluation of spaces. Correctly designed spaces specifically for the child support the physical and psychological development of the child positively. In addition, children who can establish strong relationships with historical places develop a sense of attachment and belonging to the place, which is also important in the transfer of such places to the coming generations. Capuchin Catholic Church (Giresun Central Children's Library) has an important place in the memory of the city and is the sole example in the region. It is used by children. The present study discusses how children perceive the church. The study aims, on the one hand, to reveal how the church is perceived by children, and, on the other, to examine how the child's perception of space and expression styles change depending on age. To this end, children were made to draw visual representations and these images were converted into numerical data. These data are discussed in terms of the preoperational period and the concrete operational period which takes into account the developmental stages of the child. The study employed observation and mapping methods. It was concluded that the child's perception of space changes depending on age, experience and frequency of use of the space, and historical buildings are important stimuli for the child's perception of space.

Cite this article as: Yılmaz Yıldırım D, Bayram Ş, Çakır Güngör N. An Investigation into the perception of space in children through visual representations: The Children's Library in Giresun (The Capuchin Catholic Church). Megaron 2023;18(1):45–60.

INTRODUCTION

Understanding how people perceive spaces is important to design spaces and creating liveable spaces for users. Creating a living space, especially for children who have free thinking and are creative, is a special situation because children's physical and mental activities differ from those of adults in their recognition, perception, evaluation, and interpretation of space. For this reason, one should examine how children perceive what, how they evaluate them, and how they make sense of them.

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The production of functional, mental, and ergonomic spaces that understand children, comply with their wishes, perceptions, and expectations, and make them flexible and free, is extremely important for their self-confidence and self-identity as members of society. In addition, the child interacting positively with the place feels a sense of attachment and belonging to the place, which is important in the transfer of such places to future generations.

Today, historical structures that have lost their original function are reused with different functions in order to keep them alive. The selection of the new function to be given to these structures, which have an important place in the city's memory, is another important issue. As one of these examples, the Capuchin Catholic Church has been transformed into the Giresun Children's Library by being re-functionalized as a first-degree monumental building, which has symbolic value for the city of Giresun. It is a remarkable and different example, especially with its re-functioning as a children's library, in addition to its unique architecture, which is not often seen in the Eastern Black Sea Region.

The study aims to discuss how children's perception of space changes depending on age (6- to 10-year-old). What are the prominent features of space depending on age, and how do children's expressions of these differ? For this purpose;

- In the representations of the building, which part of the space (indoor space, form/facade, or outdoor space) is depicted by children at the preoperational stage?
- Both at the preoperational stage and the concrete operational stage, what attracted the children's attention?
- What were the most perceived elements in the outdoor-close environment both at the preoperational stage and the concrete operational stage?
- What is the biggest difference between these two groups in the outdoor-close environment?
- What was the most perceived elements on the facades of form both at the preoperational stage and the concrete operational stage?
- What is the biggest difference between these two groups on the facades of form?
- What was the most perceived elements in the interior of the building both at the preoperational stage and the concrete operational stage?
- What is the biggest difference between these two groups in the interior of the building?
- Was the original aspect of the Giresun Children's Library that was converted from a church, perceived strongly by the children or not?

These are answered and the study was detailed using interview, observation, and cognition mapping methods.

Child and Space Perception

Perception is defined as the organisation of sensing the stimulant effects from the environment and transforming them into semantic experiences by simply memorising them (Morgan, 1986; Çolpan Erkan, 1996). According to another definition, perception is the formation and visualisation of all kinds of information obtained through the five senses in our brains (Aydınlı, 1992). The phenomenon of perception differs depending on who perceives, what he perceives, what he wants to perceive and how he perceives, that is, external factors and personal factors. Personal factors consist of features such as the individual's personality traits, gender, age, cultural and social values, social environment, feelings, and thoughts, needs and expectations, cognitive orientation, experiences, attitudes and behaviours, and instant attention (Aydınlı, 1992; Gregory, 1997; İnceoğlu & Aytuğ, 2009; Asar, 2013). External factors, on the other hand, consist of features such as the intensity and magnitude of the stimulus, the repetition or continuity of the stimulus, the contrast of the stimulus with the environment, the sudden change or extraordinariness of the stimulus, its differentiation from the environment, and the state of movement of the stimulus (Atkinson, et al., 2002; Hokelekli, 2008; Morgan, 2011).

Children's perceptions and evaluations differ from those of adults. The child develops from the day she is born, and accordingly her perception of space changes. These differences are clearly read by age. It is obvious that the work of the child is very unlike the work of the adult. Children use the environment to improve themselves; adults use themselves to improve the environment. Children work for the sake of process; adults work to achieve an end result (Lillard, 1982). Perception of the world is always a multi-sensory event that includes the use of every sense and the whole body. This causes difficulty in processing the simultaneous sensory stimuli (Day & Midbjer, 2007), and gives priority to senses in cognitive processes and makes them one of the main determinants of childhood. The information received from the environment is transformed into behaviour by the senses and instant emotions rather than logic. Whereas adults already understand things, children are still exploring the relationships between sensory messages (Day & Midbjer, 2007). The child's perception of space improves continuously and regularly in the form of an intertwined process depending on physical (physiological), mental (perceptual-cognitive), social-emotional age (Gür & Zorlu, 2002; Yılmaz, 2010; Piaget & Inhelder, 2016; Aydın, 2018).

The cognitive development of children is divided into four stages: the sensory-motor stage (birth to 2-year-old), the preoperational stage (2- to 7-year-old), the concrete operational stage (7- to 11-year-old), and the formal operational stage (11- to 18-year-old) (Piaget, 1970). The sensory-motor stage (birth to 2-year-old) is the coordination stage of the senses. The child makes inaccurate movements

while trying to catch the object whose colour and shape he perceives only. The movements of the hand trying to catch the object with the eye are uncoordinated, and the mind cannot clearly determine the distance and direction between the hand and the object. In this period, it is extremely difficult for the child to perceive space, and the perception of space begins to form only after the sixth month (Gür & Zorlu, 2002). In this period, there is no continuity in the perception of space (Piaget and Inhelder, 1967; Altman and Chemers, 1980; Akarsu, 1984; Kök, 2016). After the age of two, relations such as proximity, disconnection, enclosure, and continuity between the objects in the space form in his mind. The preoperational stage (2- to 7-year-old) is the stage in which the logical thinking process develops. Children are influenced by the appearance of objects, and they talk about objects that are not in the field of perception in space. However, he establishes random relations between all these objects (Gür & Zorlu, 2002). During this period, children perceive the space in general, but cannot elaborate (Piaget & Inhelder, 1967; Altman & Chemers, 1980; Akarsu, 1984; Kök, 2016). The concrete operational stage (7- to 11-year-old) is the period in which the ability of classification begins to develop. The child arrives at the distinction between fantasy and reality (Piaget, 1970). Children now begin to schematise the space while perceiving it (Piaget & Inhelder, 1967; Altman and Chemers, 1980; Akarsu, 1984; Kök, 2016). In the period up to the age of 8/9, the child cannot fully realise the concepts of quantity and quality, and the relationship between the part and the whole. The age of 8/9 is the critical age when the mental reality period is completed and concrete operations begin to take place. The formal operational stage (11-18-year-old) is the stage in which concrete operations reach maturity. The reality of formal operations shows continuous improvement with age (Piaget, 1970). In summary, while the perceptual and cognitive mechanisms of children's mental development are simpler, they become more complex later. However, the data that he has accumulated by experiencing the space over time complicates the mental process. (Zaporozhets, 1965; Baksi, 2018).

Coding the features of the space is important in the perception of space in children. Coding the space is divided into two such as primary coding system and secondary coding system. The primary coding system includes the creation of an egocentric body representation of the object, that is, an "egocentric representation" so that the child can express spatial characteristics. This system is defined as the child's coding by primarily evaluating the spatial features according to his/her own location and environment. On the other hand, the secondary coding system involves creating the representation of the object's relation to the object, that is, the "allocentric representation". This system is also defined as the child's coding by evaluating the spatial features according to the location of another object. Although both representations are present in children from an early age, the egocentric representation is more dominant in the sensory-motor and preoperational stages, and the allocentric representation begins to dominate towards the later stages (Acredolo, 1990; Campos et al., 2000; Galati et al., 2000; Bocchi et al., 2020). That is, children first realise their position in the place where they are. Then they learn to evaluate their relationships with objects in their close environment, distances, dimensions through visual perception. The perception of space relations includes figure-ground distinction (Reinartz and Reinartz, 1975). On the other hand, Piaget (1955) claims three types of relationships in children's perception and coding of space: metric space, topological space, and projective space (Hart & Moore, 1973). Metric space is a relationship that is based on the distance parameter in children's perception of spaces and explains the equivalence of shapes in a mathematical equation. Topological space is the relation regarding the qualitative properties that exist entirely within a form. The perception of relationships such as proximity, disconnection, organisation, enclosed and continuity in the topological space, objects structure and revitalise the intuitive space. In projective space, in addition to the topological space properties, it is necessary to identify the locations of the elements of the objects within the framework of their relations with others and within a certain perspective. Existing topological operations are enriched with the addition of perspective operations and gain new meanings. Briefly, children perceive space by being based on size, shape, and distance parameters, and make sense of the space by passing their perceptions through their personal filters (Hart, 1979; Altman & Chemers, 1980; Koç, 1999; Babaoğlu, 2007; Buluklu, 2015; Piaget, 2016).

While children have difficulty in expressing the perceived space clearly with language, they express their thoughts with a picture independently and freely. The picture, which is a symbolic game for the child, is the image that is related to his emotional and intellectual life. Therefore, these first spontaneous symbolic expressions of children are the simple expressions of the feelings and thoughts that they experience in their inner worlds (Piaget, 1955; Poyraz, 1999).

Artistic developments in children are divided into five stages that develop in direct proportion to age, from simple to complex and to more naturalistic expressions. These are the scribbling stage (2- to 4-year-old), the pre-schematic stage (4- to 7-year-old), the schematic stage (7- to 9-year-old), the dawning realism stage (9- to 12-year-old), and the pseudo-naturalistic stage (13- to 21-year-old). In the pre-schematic stage (4- to 7-year-old), children's drawings begin to become recognisable. Object drawing, which starts at the age of 4, leaves its place to the subject toward the age of 7. Feelings and thoughts begin to become clear. In the drawings, the relationship with the space is less and there

is a hierarchy. They can draw the important ones larger. In the schematic stage (7- to 9-year-old), their drawings are quite plain and concise containing sketches and repetitions. One may also see that real objects and events that are away from the imaginary world are reflected, and real colours are used. During the downing realism stage (9- to 13-year-old), space and perspective now show themselves. They tend to draw realistically in their drawings; they go into details (Malchiodi, 1998a,b; Paktuna Keskin, 2009; Uysal & Selvi, 2012). The pictures drawn by children are used as the best data collection tools to reflect their relationship with the space and to measure various perceptions in their subconscious.

MATERIALS AND METHODS

The study focuses on the subject (perceiver) and objects (perceived), which the two basic elements of perception are. Children in the age group of 6- to 10-year-old were chosen as subjects and their developmental stages were taken into account. As the object, a historical and architecturally original building that was converted from a church to a library was chosen. The study aimed to examine the child's perception of space, which changes depending on age, and the common and different aspects that are prominent in the form of expression, and to reveal how the church with a strong stimulating effect is perceived by children.

The study was carried out in two stages such as literature review and field study. In the literature review, the concepts of perception, space perception, space perception in children, and visual representation in children were examined and information was given about how the child perceives the space and how it expresses it. Different architectural aspects of the Giresun Children's Library were presented. To this end, the façades, floor plans, details, and functions of the building were examined. Secondly, by conducting a field study, both the library records were examined and the librarian was interviewed in order to determine by whom and with what intensity the library was used. Observations were made to determine which areas of the library were used by the children and for what purpose. Observations were made by an observer with architectural training for two months from a position that could see every point of the library, six days a week, between 2:00 pm and 5:00 pm, when the library was used the most. The data obtained through observations were plotted on the building plan and in this way, the study determined which area was used for what purpose and by which age group. Thus, the study tried to determine other variables that affect perception, such as whether it is used or not, and the frequency of use. Finally, the children in the 6-10 age group who actively use the library were asked the question "How would you describe the library" and they were asked to paint a picture expressing this. The type and technique of the paint that children will use were left entirely to children's interest, skill, and imagination. The children were asked to draw a picture at home describing the library and to write a composition expressing it in order to portray the images that were created in their minds by their spatial experiences, that is, not what they saw but what they knew. However, most of the children drew pictures of the library and did not want to write. As a result, a total of 100 pictures were obtained where 20 from each age group and these pictures were grouped according to Piaget's Child's Cognitive Development theory as preoperational period (6–7-year-old) and concrete operational period (8–10-year-old). The aim of the study is to investigate how spatial perceptions change according to children's age, so other data were not taken into account.

Common and different elements that stand out in the exterior/close environment, form, facade, and interior in the obtained pictures were determined, and these prominent elements in every age group were converted into numerical data. Thus, a priority order was made among the prominent items. Secondly, the originality that children used while expressing the space was determined. The different aspects that arose due to age were also discussed in terms of the preoperational stage and the concrete operational stage. In this way, the study aimed to unveil the effects of a child's developmental stages on space perception. The study employed observation and mapping methods.

Each of the cognitive maps is seen as a set of propositions that are determined by the individual as true value and stored about the individual's environment. One of the basic elements that make up the formation of these maps is the concept of environmental cognition. It is accepted that this concept is related to constitute, recall, storage and organisation of location, distance, and spatial information in the mind (Robinson & Petchenik, 2011). The actions of collecting, presenting, and processing all kinds of information belonging to the physical environment are also included in this concept (Kitchin, 1994). Down and Stea defined cognitive mapping as a process consisting of a series of psychological transformations by which an individual acquires, encodes, stores retrieve, and decodes information about the relative locations and properties of phenomena in his or her everyday spatial environment (Downs & Stea, 1973; Downs & Stea, 2011).

The concept of cognitive mapping was first proposed by Tolman (1948) in his research on the spatial relationships of animals in their environment. Later, this concept started to be used in the field of environmental psychology in a sense that expresses the inner image, mental/cognitive fiction, or representation of the environment in which people live (Göregenli, 2010). Kevin Lynch, a pioneer in this field, aimed to determine people's images of their cities through the cognitive mapping technique.

It can be said that there are detailed studies on cognitive maps, and some studies look deeply at children's cognitive maps (Golledge & Stimson, 1997; Golledge, 1999; Kitchin & Freundschuh, 2000). Among the first studies on children's cognitive maps, Trowbridge (1913) "On Fundamental Methods of Orientation and Imaginary Maps" was the first to examine the development of cognitive mapping in childhood. Hermer and Spelke (1994) used cognitive maps in their "a geometric process for spatial reorientation in young children" study. They clarified how children (between the ages of 18-24 months) use landmarks in a room. Piaget (1956) explained the development of children's spatial perception in terms of three categories of spatial relations: topological space, projective space, and metric space. Siegel and White used cognitive maps in their study which is "The development of Spatial Representations of Large-Scale Environments". They determined how children represent the large-scale environment (Siegel & White, 1975). In addition, Cousins, Siegel and Maxwell in their study, which is "Wayfinding and cognitive mapping in large-scale environments: A test of a developmental model", used cognitive mapping in primary school children (aged 7, 10, and 13) for determining prominent elements and routes of campus (Cousins, Siegel & Maxwell, 1983).

The children's drawing skills are different from each other. In the representations, the subject is more important than quality. In the study, cognitive mapping method is used. As the majority of the children, especially the little ages, did not want to make interviews about their pictures. Within the scope of the study, perceptual differences according to age were highlighted. In this respect, the study was limited to age. Other factors which affected children's perception such as gender, social/cultural differences were not discussed.

Subject (Perceiver) (2- to 10-Year-Old)

In terms of the subject affecting the perception, the study revealed information such as "who uses the library, how old the user is, how often the space is used, and how much time the user spends in the space". The result of the examination of the written records of the library and the interview with the librarian, it was found that the library is used approximately by 60–120 children per day. In general, it is used by the students of the nearby school to borrow books, return books, and do homework after school hours. In addition, during school hours, some primary school students make reading hours in the library with their teachers at certain hours on certain days. Especially 7- to 10-year-old group children study with their teachers in the library once a week. Again, children from 2- to 7-year-old group visit the library together with their teachers once a month on some special days, take a short tour, and do a one-hour fairy tale reading. It was observed that on days when there is no school, children (2- to 7-year-old group) usually come to the library with their parents, and spend a short time in the library before noon. In the afternoon, it was observed that children (6- to 10-year old group) spend more time individually in the library to borrow books, meet with their friends to study, and play board games. As a result, children (6- to 10-year-old group) who are the intensive users of the building, were grouped and discussed based on Piaget's developmental stages of the child as the preoperational period (2- to 7-year-old) and concrete operational period (7- to 11-year-old).

Object (Perceived) – The Capuchin Catholic Church (Giresun Children's Library)

The object that affects the perception is important to reveal the architectural features of the church, the form, the facade, the interior, and the actions that take place in the space. It is important to reveal which age group uses the library, when, and how often.

The Capuchin Catholic Church was built as a bell tower and a church between 1850 and 1900 by Franciscan Capuchin Priests. The Ministry of National Education functioned the Capuchin Catholic Church as Giresun Central Children's Library in 1964.

Giresun Central Children's Library is 23 m long, 10 m wide and 13 m high. It was built as a ground floor and a gallery in a rectangular plan in the north-south direction, with a roof inclined in two directions and a frame-system carrier. The building has a stone garden border with an iron railing on it, and it has an entrance to which a steel ramp has been added and is accessed by stairs from three sides. The entrance façade of the building facing the street is quite magnificent. It has four stained-glass guillotine windows with pointed arches and is covered with a vault from the inside and a cradle porch from the outside. This porch is supported by two square-section stone columns. The two-winged wooden entrance door of the building is one of the 19th-century door examples in Giresun. On the façade are rows of shallow niches with pointed arches arranged parallel to the eaves. There are metal rosettes inside the niches. The northern façade of the building, whose corners are arranged in the form of grooved plaster, ends with profiled stone eaves at the top. The east and west façades of the building are divided into two horizontally with a vertical five-stone moulding with grooved plasters. A window is placed inside each of the vertical partitions. Three of these windows in the middle have pointed arches and the two windows on the sides are in round form. The pointed arches of the windows in the middle are kept quite high. The joinery of the side windows is arranged in the form of a six-pointed star. On the eastern façade of the building, there is a second door with a flat weft stone that gives access to the square-section bell tower built adjacent to this façade. The bell tower has a simple façade arrangement which is illuminated by narrow crenelated windows. It has a large side garden with iron railings on cut stone (Bostan, 1997; İltar, 2014) (Figure 1).

Figure 1. Outdoor structural elements of Giresun central children's library.

With the conversion of Giresun Central Children's Library from Capuchin Catholic Church, some changes were made to its interior. The building is entered through a wooden double-wing carved door. In addition to the administrative units, there is a cloakroom in the landing section. The interior is accessed from the landing also with a double-winged wooden door. The interior is divided into two with elevations. The space consists of the ground floor and the gallery that was used as a gathering place at that time. On the first elevation on the first floor are colourful wooden bookcases along the right and left walls of the space. In addition, there are wooden bookcases in double rows also in the middle of the space. There are models of nature and science on the wooden bookshelves. Two circular tables and colourful chairs surrounding them are placed between the bookshelves in the middle. Again, there are colourful tables and chairs at many points in the space. On the second elevation on the ground floor, there are table chess games, a ground chess game, a television, and a DVD-CD library. For table chess games, there are tables and beanbag seating elements on the right and left parts of this elevation. The ground floor is covered with tile mosaic flooring with

Figure 2. Giresun Central Children's Library interior structural elements and equipment.

floral ornaments. The gallery is reached by the spiral staircase located to the left of the entrance to the interior. There are also tables and chairs on this floor. Finally, the interior space is covered with a Baghdadi ceiling, which is a gable roof on the outside, arranged in a vault with straight sides in the middle. The space is illuminated by three magnificent pendant chandeliers with arms on the middle axis (Figure 2).

In terms of the actions that take place in the space, children leave their belongings in the cloakroom in the entrance area of the building and work in the office to the right of this area. Borrowing books, reading, and group work are done in the second space, which is accessed by elevations after the front entrance area. Bookshelves are spread throughout the space, and science and nature models are also used as a part of the library. In the third area, visitors can play chess and watch DVD-CDs. In the gallery, visitors read books, do research, and play chess. In the garden of the building, visitors can read books and play games while working in groups (Figure 3).

Since Giresun Central Children's Library was converted from a religious structure, it draws attention as a structure that dominates and contrasts its surroundings and that differs from other library structures with its features such as pointed arches, guillotine or star windows, chandeliers, form, façade, and interior space.

THEORY/CALCULATION AND RESULTS

First, the number of elements determined in outdoor, indoor and mass/facade of space were counted in each visual representation. The preoperational stage consists of 40 children, the concrete operational stage consists of 60 children. Because of this, each element was calculated as a percentage within each group for making comparisons. This data is arranged in Table 1.

For determining prominent elements and showing differences clearly prominent elements were put in order in each age. The most prominent elements were signed in the 1st level of the diagram, and the least prominent elements were signed in the 8th level. The green circular structures were used for the preoperational age, the red circular was used for the operational stage and the blue line shows differences in degrees. This data is represented in Figure 4.

In the representations of the building, children at the preoperational stage depicted the indoor space more than the form/facade or outdoor space; contrary to this, the children at the concrete operational stage depicted the form/facade or outdoor space more than the indoor space.

Both at the preoperational stage and the concrete operational stage, the outdoor road, the garden railing, the tree at the church entrance, the bench in the backyard, the front of the entrance door, the library sign outside the building, the children's library sign and the Turkish flag attracted

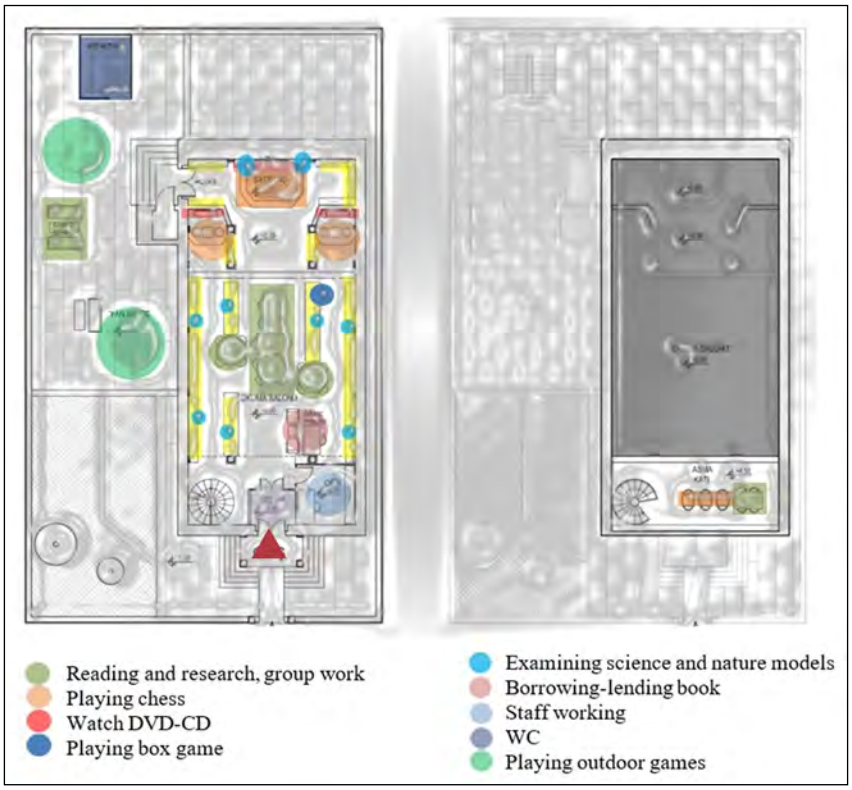

Figure 3. Activities taking place in the space.

Table 1. Percentage value of elements according to the ages

Outdoor									
	Road (%)	Garden Railing (%)	Tree at the Entrance (%)	Bench in the Backyard (%)	Front of the Entrance Door (%)	Library Sign Outside the Building (%)	Children's Library Sign (%)	Turkish Flag (%)	
The Preoperational Stage (40 person)	12.5	17.5	5	5	2.5	2.5	47.5	15	
The Concrete Operational Stage (60 person)	6.6	23.2	6.6	1.6	24.8	11.6	11.6	16.6	
Total (100 person)	9	21	6	3	13	16	26	16	
Mass / Facade									
	Triangular Pediment (%)	Triangular Porch (%)	Pointed Windows with Lambs (%)	Entrance Door (%)	Six-Armed Star Windows (%)	Entrance Column (%)	Pointed Arc (%)	Star Ornament (%)	Cross Decoration (%)
The Preoperational Stage (40 persons)	25	–	10	45	7.5	–	2.5	10	–
The Concrete Operational Stage (60 persons)	41.6	13.3	31.6	50	5	16.6	3.3	16.6	1.6
Total (100 persons)	35	8	23	48	6	10	3	14	1
Indoor									
	Wooden Door (%)	Spiral Staircase (%)	Column (%)	Mezzanine Floor (%)	Tile Coating on the Floor (%)	High Walls (%)	Vault Combination (%)	Nishes in the Wall (%)	Bookshelves (%)	Table (%)	Chair (%)	Television (%)	Game of Chess (%)	Socket (%)	Chandelier (%)	Earth Globe (%)
The Preoperational Stage (40 persons)	12.5	7.5	27.5	-	10	-	-	-	57.5	30	27.5	5	17.5	2.5	2.5	2.5
The Concrete Operational Stage (60 persons)	10	5	11.6	5	1.6	-	-	-	48.3	35	30	3.3	18.3	-	21.6	13.3
Total (100 persons)	11	6	18	3	5	-	-	-	52	33	29	4	18	1	14	9

the children's attention. The garden railing, library sign, and the Turkish flag were the most perceived elements in the outdoor-close environment, both at the preoperational stage and the concrete operational stage. The biggest difference between these two groups is that the front of the entrance door is perceived most at the concrete operational stage, while it is perceived less at the preoperational stage.

The triangular pediment, triangular porch, pointed windows with jambs, entrance door, six-armed star windows, the entrance column, the pointed arch, the star ornament, and the cross decoration on the facades of the form and the building attracted the attention of the children both at the preoperational stage and at the concrete operational stage. For both groups, the entrance door, triangular pediment, pointed window with jamb, and star ornaments were the most perceived elements on the facades of the mass and the building. No big differences were found between these two groups in terms of perceived items and their effects.

The wooden door, spiral staircase, columns, and tile coating on the floor in the interior of the building attracted the

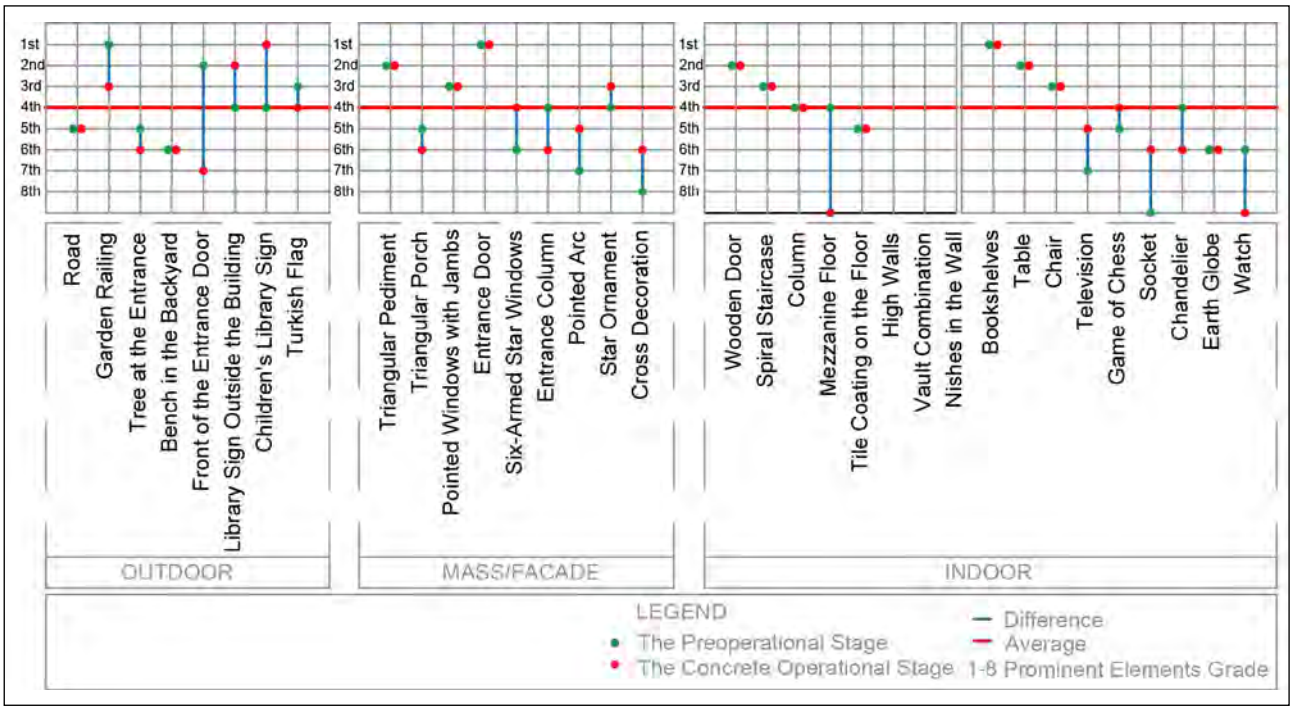

Figure 4. Prominent elements in children's visual representations (prepared by the authors).

attention of the children both at the preoperational stage and the concrete operational stage. The biggest difference between these two groups was that the gallery attracted the attention of the children at the concrete operational stage most, while it did not attract the attention of the children at the preoperational stage. It is thought that this stems from the fact that this area is not used by children at the preoperational stage. In addition, the high walls surrounding the interior, the places where the columns meet with the vaults and the niches in the wall did not attract the attention of the children.

Bookshelves, tables, chairs, television, games of chess, chandeliers and earth globe attracted the attention of children in terms of equipment, furniture, and accessories both at the preoperational stage and concrete operational stage. The bookcase, tables, chairs were the most perceived items in both groups. The biggest difference between these two groups is that the socket attracted the attention of the

Figure 5. Visual representations of children at the preoperational stage (6-year-old).

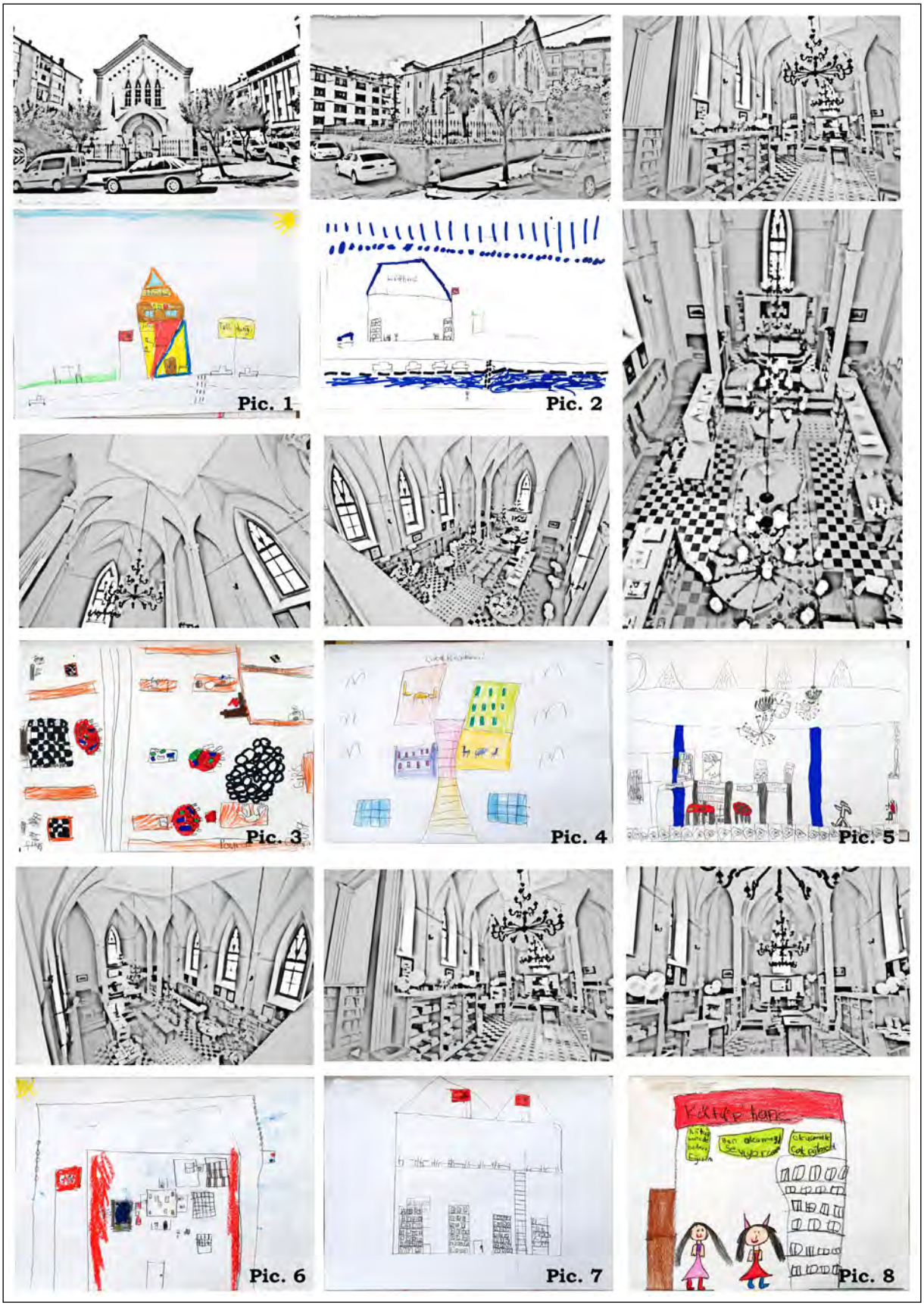

Figure 6. Visual representations of the children in the pre-operational stage (7-year-old).

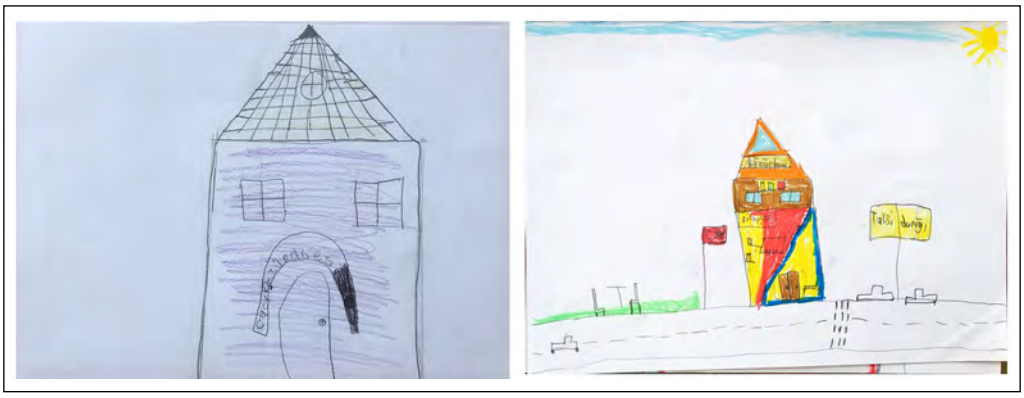

Figure 7. Visual representations of children (6- to 7-year-old).

children at the preoperational stage, but did not attract the attention of the children at the concrete operational stage, and the clock attracted the attention of the children at the concrete operational stage but did not attract the attention of the children in the operational period.

Elements in the triangular pediment structure pointed the six-armed star windows, the high and wide entrance door surrounded by wooden carved mouldings, which constitute the original aspect of the Giresun Children's Library that was converted from a church, were perceived strongly by the children both at the preoperational stage and concrete operational stage. Columns, spiral staircase, floor tiles, and arm chandeliers, which are the originalities of the interior, were perceived strongly. Apart from this, it was observed that children also perceive different/ordinary items arising from use, but apart from all spatial items, it was observed that children also portrayed themselves and their friends in their paintings (Figure 4).

When evaluated as a whole, it is possible to see the changes in children's perception of space over time, although there is no significant difference between the two groups in terms of the effective elements of this library structure, which was converted from a church. For example, in the preoperational age group (6- to 7-year-old), the building form was especially formally expressed together with its roof and door (Pictures 1, 2). Books, bookshelves, desk and chair items and the function of reading books were highlighted (Picture 3). In detail, the name of the children's library is written in most pictures (Pictures 2, 3). In addition, the children included themselves and their friends in their pictures (Picture 3) (Figure 5).

In the 7-year-old group, it is remarkable that the descriptions of the building and the immediate environment increased. Road and garden descriptions increased (Pictures 1, 2). Children described the exterior and interior of the building together (Pictures 3–5). Books, especially bookshelves, tables, and chairs stand out as basic elements in the interior. It is noteworthy that they also included their friends in the pictures (Pictures 6–8). It was observed that different functional parts such as the entrance, reading section, chess section, and exit, where the spatial organisation is expressed, are reflected in continuity in the interior. In addition, it is remarkable that the details go down to the equipment in the representations. In addition, it was found that the windows, chandeliers, and columns unique to the structure were also represented in the interior (Pictures 4–7) (Figure 6).

In the representations, the children in the 6-year-old group associated the library with a single item instead of bringing together multiple items in a single picture, and generally drew this item with a single colour or pencil. Contrary to this, children in the 7-year-old age group represented the outer borders of the library and placed the prominent equipment inside the representations, and expressed the exterior and interior descriptions together (Figure 7). The actions and the fields of action highlighted by the children at this stage also differ. While the entrance area of the building gains priority, especially in the 6-year-old group, the reading hall takes priority in the 7-year-old group.

At the concrete operational stage (8- to 10-year-old), it was observed that children aged 8 represented the outer contour of the building and the window and ornamental details next to the entrance door in the building form. The facade was represented in more detail, especially with its ornamentation (Pictures 1–3). In the paintings the form representation and the façade were dominant, while the bookcase and chandelier came to the fore in the interior (Pictures 4–6) (Figure 8).

In the 9-year-old group, the entrance area, outer door, staircase, and front door area were represented in the building form (Pictures 1, 2). Unlike other age groups, the interior and façade were expressed separately (Pictures 3, 4). Perspective representations highlighting the building style, door and window were found (Pictures 5, 6). The furnishing details increased even more in the interior space and besides the bookshelves, tables, chairs, chandeliers, and columns, the world globe, chessboard, and TV screen were represented. In some paintings, the functional parts of the building – the entrance, the lending area, the WC,

Figure 8. Visual representations of children (8-year-old) at the concrete operational stage.

the floor stairs, and the exit – were drawn in detail. In fact, these functional parts were highlighted and represented in different colours (Figure 9).

In the 10-year-old group, the interior space of the building was represented more. The details on the façade were represented less. As in the 9-year-old group, bookshelves,

Figure 9. Visual representations of 9-year-old children at the concrete operational stage.

tables, chairs, chandeliers, and columns stood out again, while the world globe and chess area were indicated (Pictures 1, 2). The use of colour increased, and different types of books were represented in different colours. Representation of toys increased (Pictures 3, 4) (Figure 10).

CONCLUSION

The study discussed whether the children's perceptions of the historical Capuchin Church, which is one of the buildings with high stimulus intensity and with its distinguishing features from other buildings, change according to age. It has been concluded that the original characteristics of the Capuchin Church – with its current name, the Children's Library – are strongly perceived by all children in terms of form, façade, interior space, and equipment. In addition, the fact that the height of the church is greater than its width in the children's paintings, i.e., the proportion, shows that the children also perceived the space metrically. This multidimensional perception of space by children is remarkable. Again, it was found that the difference between the ages was not between the objects that the children perceived strongly, but in the way of perception and expressions. There is a difference between simple to complex, which develops in direct proportion to age. Even a one-year difference between children's ages (6- to 7-year-old) in the pre-operational stage is clearly seen in the representations. This difference decreases with increasing age. Again, due to the development of logical thinking in children in the preoperational period, objects in the space, i.e., objects in the field of perception, were remembered. However, the relations between these objects were established randomly. In addition, the children expressed multiple objects together in a single composition. The space was portrayed in general terms with less use of colour, and the details were not specified. Children at the concrete operational stage, on the other hand, have more developed classification skills, and space was shaped, sized, and coloured in a way that is close to reality. Children in this age group used quite a lot of colours in their visual representations usually with simple and plain expressions. In children at the preoperational stage, the objects in the library representations were a single structure, a single desk, a single bookcase, etc., while in the children at the concrete

Figure 10. Visual representations of 10-year-old children at the concrete operational stage.

operational stage, the objects that children portrayed in the space increased in number. In other words, the details that are remembered and conveyed in the place increase with age in children.

Children's perception of space also changes depending on their experience and frequency of experience. The spatial experiences of children in the pre-operational stage that takes place in the form of short-term library visits with their parents or library visits with their teachers once a month are generally reflected in the library representations as the transfer of the structural features of the exterior. Since they actively use books, tables, and chairs during their time in the library, they become the most dominant elements that they use in library representations. On the other hand, the children in the concrete operational stage spend more time in the library individually and this is reflected in their library representations as the transfer of both the interior and exterior spaces. In addition to the representation of book-bookcase and table-chair equipment in spaces, the addition of more detailed equipment such as sockets and

television in the representations also indicates that the way children use the space is different (Table 1).

In summary, the child's perception of space changes physically, mentally, and socially depending on age. The mental development of the rapidly developing child should be supported by the spaces to be designed. The fact that children's perceptions of space change depending on their age, experience, and frequency of experiencing space should be taken into account when creating spaces for children. Especially in children, the increase in the details that are remembered, in, and transferred from, the space requires that the space be handled in detail from the whole to its equipment. In addition, historical buildings are important for children because they develop their perception of space. Making children experience historical buildings improves their aesthetic understanding. Children who establish strong bonds with historical buildings become important actors in the permanence of these structures.

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 59–71, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2023.12269

Article

The effect of hard coal activities on space production – Zonguldak Üzülmez Valley

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ARTICLE INFO

Article history
Received: 07 September 2022
Revised: 12 September 2022
Accepted: 07 March 2023

Key words:
Production of space; production of hard coal; spatial contradictions; Üzülmez Valley; Zonguldak

ABSTRACT

According to his studies on the production of space, Lefebvre mentions that each production method produces a new type of space, and this production rises on three constituent feet. Different indicators in the perceived, conceived and living dimensions of the space are essential to understand the truth of the space and determining its potential and handicaps. Also, spaces with different histories have different production histories in line with their living dynamics. Considering that each space has its own production history, the necessity of evaluating the production in the mining city with underground and ground distinguishes these settlements from the others. Production targets shape the required workforce, the workforce shapes the infrastructure and superstructure demands, and the infrastructure and superstructure demands shape the morphological structure. This study aims to reveal the relationship between space and meta production in the coal production city Zonguldak. Based on space production and related theories, the space production periods and space triad of Zonguldak have been determined. As Lefebvre mentioned, the deepening contradictions of abstract space have revealed the contradictory space period. The contradictions that exist in Zonguldak are based on the tense relationship between underground hard coal production techniques and space production shaped by changing policies on the ground. Therefore, from the past to the present the contradictions and tense relationship between meta and space production in Zonguldak have been explained through specific examples of the city. In conclusion, the change of meta and space production, which continues at different scales on the ground and underground, is explained through specific variables and conceptual and physical tensions that occur on the surface of the city are defined.

Cite this article as: Arslan N, Kerestecioğlu SF. The effect of hard coal activities on space production – Zonguldak Üzülmez Valley. Megaron 2023;18(1):59–71.

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INTRODUCTION

Lefebvre states that space is a social product and is constantly being reproduced in the historical process, and this production has special values for each community (Lefebvre, 1991: 377). If it is thought that each community has its distinctive sensing and evaluation processes, the space can also be said to differentiate as a social product. Lefebvre points out that the space has risen on three constituent feet. He is stating that by means of these constituent feet, the space can be descended into the truth, and it is a social reality (Lefebvre, 1991: 115). Proceeding from all these postulates, if each space bears its own distinctive values, the space production of the mining city is the integrated story of underground and ground. Today's Zonguldak basin, which is surrounded by an absolute nature until the discovery of hard coal, has a developing space layout that depends on hard coal production. Production, that is ongoing under the ground, has exhausted the ore belonging to the absolute and has given rise to a generation of new spaces above the ground. In this sense, Üzülmez Valley, which is one of the city's first production zone, is an example of which underground and ground productions can be observed holistically that is specific to a mining city. From the past to the present, the identification of the relationship between meta and space production as a social reality is in a key role to explore the reality of the mining city. It is important to explain the spatial-constitutive indicators, the spatial periods and the contradictions that emerged between the periods to discover the differential feature of the urban surface.

PRODUCTION OF THE SPACE – PERIODS AND SPATIAL TRIAD

For capitalism, the value of change is important rather than the use value of the space. Hence, space's historical production, usage and the values that are represented by it are not important for capitalism. Two places, whose histories are very different from each other, are abstract parcels or buildings that can be bought and sold in the market in terms of capitalism (Şengül, 2001: 15). Lefebvre presents a broad perspective on the subject by stating that space is not only an abstract and material object, but also has an ideological, living, and subjective structure. He focuses on the social context and the process of production rather than evaluating the space within itself (Turut & Özgür, 2018). Also, he states that space is a social product and has historicity due to the production process (Lefebvre, 1991: 26). Lefebvre's space theory structurally consists of two main frames that are associated with each other. These are the periodisation of space and the spatial triad. The spatial triad can be completely comprehended when it is considered together with space periodisation (Ghulyan, 2019: 2). He defines space characteristics for each production style by dividing the space into periods (Shields, 2005: 170). According to that space refers to production relations such as "absolute space" hunting and gathering and neolithic agriculture, "sacred space" Asian-type production and feudalism," historical space" ancient or classical production, "abstract space" early capitalism and "*contradictory space*" late capitalism. The *differential space* is Lefevbre's utopia as the collective and communal unity of communism, which acquires meaning through differences and experiences (Boer, 2005: 123).

Periods of Space Production

According to Lefebvre, the origin of the social space is based on the *absolute space* of nature (Lefebvre, 2014: 245–246). The most important feature of *absolute space* is the shaping and harmonisation of human life with the rhythms of nature. Since the production activities of people during this period continued based on the rhythm of nature the process of transforming the space from its natural context into a conceived space could not be realised (Ghulyan, 2017: 5–6). The abstract space of capitalism arises in the artistic phrases of Picasso (Lefebvre, 1991: 301–304) as well as modern architects (Gropius, Mies van der Rohe, Le Corbusier, etc.). Its characteristic is being homogeneous and fragmented. In this sense, Lefebvre states that Hausmann produced homogeneity for the new order and divided the space into fragments, but despite this partition, there is integrity (Shields, 2005: 176). Lefebvre defines abstract space as something that enables capitalist manufacturing, distribution and consumption processes (Stanek, 2008: 75) and abstract space is the field of exchange value (Gregory, 1994: 402). As a result of further capitalist developments, the contradictions of the abstract space further deepened and initiated the process of *contradictory space*. The abstract space has been named as a *contradictory space* in terms of its attribute and quantitative characteristics, and deeper contradictions have become more visible compared to the past (Ghulyan, 2017: 17–21).

Contradictions of the abstract space can be explained as the contradiction between quality and quantity, global and subdivided and centre and periphery. At the core of the contradiction between quality and quantity, there is the contradiction between usage and exchange values. The geometric representations of the space serve the quantisation process and allow the fragmentation of the space as parcels (Lefebvre, 2014: 353–357). Another contradiction is the contradiction between global and subdivided. Aside from the global perspective, a space divided by different processes can also be mentioned. It refers to structuring from state and administrative boundaries on a macro level and to urban parcels on a micro level (Ghulyan, 2021: 20). This fragmentation is always for exchange and sale (Lefevbre, 2014, 358). As a result of the contradiction between

the global and subdivided, the contradiction between the centre and periphery arises. Every generality brings centralisation with it. Centralisation brings the parts within a specific space together and allows gathering. Centrality attracts certain objects to itself and brings them together and formats (Lefebvre, 1991: 397). *Differential space*, as a utopia, indicates; use instead of change, differences instead of homogeneity, quality instead of quantity, and lived space beyond the conceived (Wilson, 2013: 373). According to Lefebvrian's consideration, the end of the 20th century is a period dominated by lived space and points to the *differential space* as a new type of space (Wiedmann et al., 2012: 36–37).

The Spatial Triad of Lefebvre

In today's capitalist society, the production of space is similar to any other meta-production, and the value of the exchange is more important than the value of the usage. However, the use value of the space is important in Lefebvre's opinion. In this sense, the space is produced dialectically through three constituent or formative moments. The physical, mental, and social which means perceived, conceived, and lived space forms are the components of this triad. Lefebvre denies that space is only perceived and conceived and defends that space is produced by contradictions of physical and abstract dualism (Avar, 2009: 7–10). The space triad has a special rhythm with the perceived (we live without questioning and that shapes our space-oriented practices and habits), conceived (shapes the design of the space, its theoretical and abstract concepts, planning and arrangement of the space) and lived (contrary, radical, revolutionary and art that interrupts the routine, the living space that carries the uncertainty and the irrational) space (Kurtar, 2015: 354).

Lefebvre conceptualises the space triad as a spatial practice, representation of space and representational space which are a three-dimensional production (Avar, 2009: 7). *The spatial practice* is first related to space, which is a material reality. It covers roads and networks that connect buildings, structures, workspaces, and private and leisure areas and is observed empirically. *The representation of space* points to the abstract space and depends on information, signs, codes, and facade relationships (Lefebvre, 2014: 63). It reflects this ideology through effective knowledge of their spatial textures. This space includes abstraction, which is formed by considered, designed and objectified plans (Ghulyan, 2017: 23). The site was thought notional and has become objectionable through a specific spatial practice. Thus, it is the space of urban planners, technocrats, and artists (Aslan & Yavan, 2018: 305). *The representational space* which has historicity rather than design is inhabited, speaks, and has a sensory core (Lefebvre, 2014: 71). In this space people's actions, feelings, and experiences are real (Figure 1).

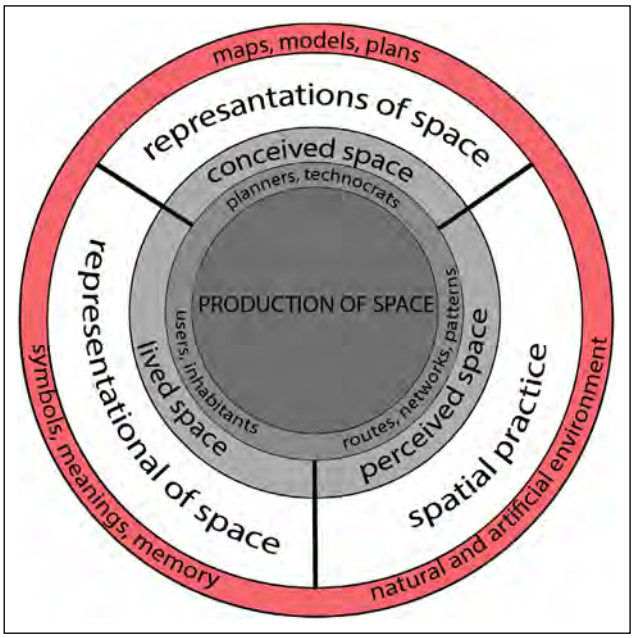

Figure 1. Conceptual model of Lefebvre's space triad (source: author adapted from Aslan & Yavan, 2018).

THE STORY OF THE ZONGULDAK – PERIODS OF THE MINING CITY FROM THE ABSOLUTE TO CONTRADICTORY SPACE

There are different periodisation studies to understand the history of Zonguldak hard coal basin. These studies divide the history of the basin mostly through the hard coal producer actors. Although this fragmentation facilitates periodisation, it creates artificial ruptures in certain issues due to its state-centeredness (Aytekin, 2006: 28). Despite the producer actors-oriented periodisation studies in the literature, dividing the mining city into periods based on Lefebvre's literature on the production of space will be useful to understand the relationship between meta and space production. As one of the first production zone of the city, Üzülmez Valley, is the most important example describing the change of space with different dimensions (Figure 2). The valley and the city can be divided into three periods and sub-periods depending on the production relations (Table 1).

Small Town on Undiscovered Ores – Absolute Space of the City

The city centre of Zonguldak, where there is a wooden pier and timber is loaded and transported on boats, was a village in the Ereğli district until 1896 (Zaman, 2004: 16–17). Especially when the origin of the name is analysed, the natural conditions and geographical features of the period can be determined. The region is named "Zongra" or "zongralık" because of the reeds covering the entire bay, as Zone Ghuel Dagh coming from Göldağı with 770 m (Karaoğuz, 2014: 29–30) or "Zonklatan" because of

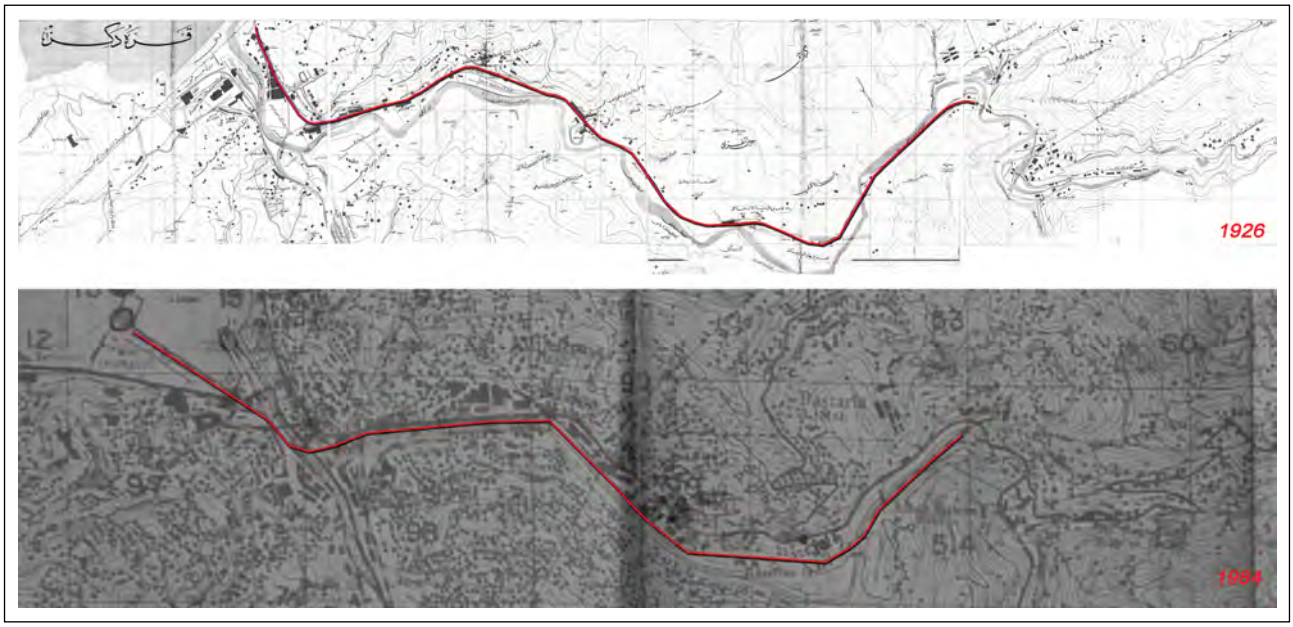

Figure 2. The map of Üzülmez Valley 1926 (above) and 1984 (below) (adapted from; Museum of Maden Şehitleri, 1926; Zaman's archive, 1984).

Table 1. Spatial periodisation of Zonguldak

Space period	Phase	Period	Characteristics	The model of production	Actors of production
Absolute space of the valley	I. Phase (absolute)	1848	A small town on undiscovered ores; absolute place of the city	No production	-
	II. Phase (from absolute to abstract)	1848–1882 (free market economy)	The discovery of hard coal and the first years of production; unplanned settlement in absolute space	Semi-planned, labour-intensive	Foreign capital+ State (Ottoman Empire)
Abstract space of the valley	I. Phase (pre-abstract)	1882–1923 (Republic of Turkey)	Hybrid multinational structure of new investments and planned production; abstract space of early capitalism	Planned, labour-intensive	Foreign capital+ State (Ottoman Empire)
	II. Phase	1923–1940 (EKI and Turkish joint-stock comp.)	Abstract space of national capital	Planned, labour-intensive	State (Republic of Turkey)
	III. Phase (abstract)	1940–1988 (privatisation)	Local values resisting global capital; abstract space of post-capitalism	Planned, semi-mechanised	State (Republic of Turkey)
Contradictory space of the valley	I. Phase	1988	New approaches toward a new future; contradictory space of globalisation	Planned, mechanised	State+ private companies

malaria disease (Sarıkoyuncu, 1992: 7–8). It is understood that tough natural conditions prevail in the region before settlement. Since there was no settlement and production plan in this period, the perceived space is more dominant than the conceived space.

The Discovery of Hard Coal and Pre-Production – First Formations From Absolute to Abstract Space

After the discovery of hard coal in 1829, operational problems arose with the start of production activities in 1848 (TTK, 2022). Although domestic and foreign capital was not at the corporate level, some civil producers started their activities in the region with the permission of the Ottoman Empire. Due to the lack of infrastructure, mostly unplanned and temporary structural elements were formed. Especially in this period, miners gain professional experience by following the hard coal seam without having any underground production plan (Quarted, 2006: 82). In this period, the perceived space is still dominant over other spaces. Since there is no foresight and plan regarding construction and hard coal production, it is understood that the perceived space is dominant rather than the conceived

space. On the other hand, the indicators of daily life regarding the lived space are observed around the mines.

Hybrid Multinational Structure of New Investments and Planned Production – Abstract Space of Capitalism

The abstract space of the city can be analysed under three sub-periods. The first period is the duration that foreign companies dominate the basin. With the end of the state monopoly on hard coal sales in 1882, small and medium-sized companies began operating (Quarted, 2006: 89–90) and planning initiatives were developed. Also, the first planned settlements and broad railway plans can be observed (the first parcel traces, railway plans, etc.). In this sense small miner colonies built by companies for both mine owners, workers and engineers are clustered near the mine entrance (Bakioğlu, 2014: 105–107). On the other hand, many of the shift workers still continue their irregular settlements. The workers who came to the mines from the close villages in shifts with the regulation of forced labour[1] (Quarted, 2006: 54–58, 96–98) have pointed to the peasant-working class (Yıldırım, 2017: 38). Peasant-workers who came to the mines for short periods built their own huts made from mud and bushes to stay temporarily around the hard coal mines (Naim, 2014: 18–20).

The second period of abstract space is the first years of the young Turkish Republic. With the proclamation of the Republic, the infrastructure investments, which increased the production acceleration to meet the energy needs of the Turkish industry, increased rapidly. State-funded Turkish joint-stock companies[2] were planning production in the city, where investments have increased with statist policies (Zaman, 2021: 275–289). In this period, it is possible to say that there are many colonies designed with many different functions such as state-supported education, accommodation, culture, and art. The campuses designed by Seyfi Arkan in 1935 (Figure 3), are modern colonies with different functional services such as workers' dormitories, engineer lodgings, primary schools, and canteens in Kozlu and Üzülmez (İmamoğlu, 2009: 131–132).

The period between the establishment of the 1940 EKİ (Ereğli Coal Enterprises) and the privatisation attempts of the late 80s is the 3rd period of abstract space. During this period, the efficiency of production was increased, especially for thermal power and iron steel plants (TTK, 2018). With the increase in production needs, internal migration and planning activities accelerated. Especially after the first development plans that started in 1953, (Zonguldak Municipality, 2015) Union of Metropolitan Municipalities was established in 1971 and the first regional metropolitan planning on a national scale was developed (Üzmez, 2014: 334). The abstract space of the valley with three sub-periods is a duration in which the dominance of the conceived space has increased and includes the contradictions of the perceived, lived, and conceived space.

Local Values Resisting Global Capital – Contradictory Space of Capitalism

In order to keep the rapidly increasing population and hard coal production of the valley under control, some kinds of plans have been produced at different scales. However, the zoning plans were prepared by the Union of Metropolitan Municipalities (Zonguldak-Kozlu-Kilimli-Çatalağzı), but they could not be implemented. After 1980, the holistic planning approach left its place to piecemeal planning in which each municipality made its own plan (Üzmez, 2014: 335–337). However, while the conceived space was expected to become dominant due to planning activities,

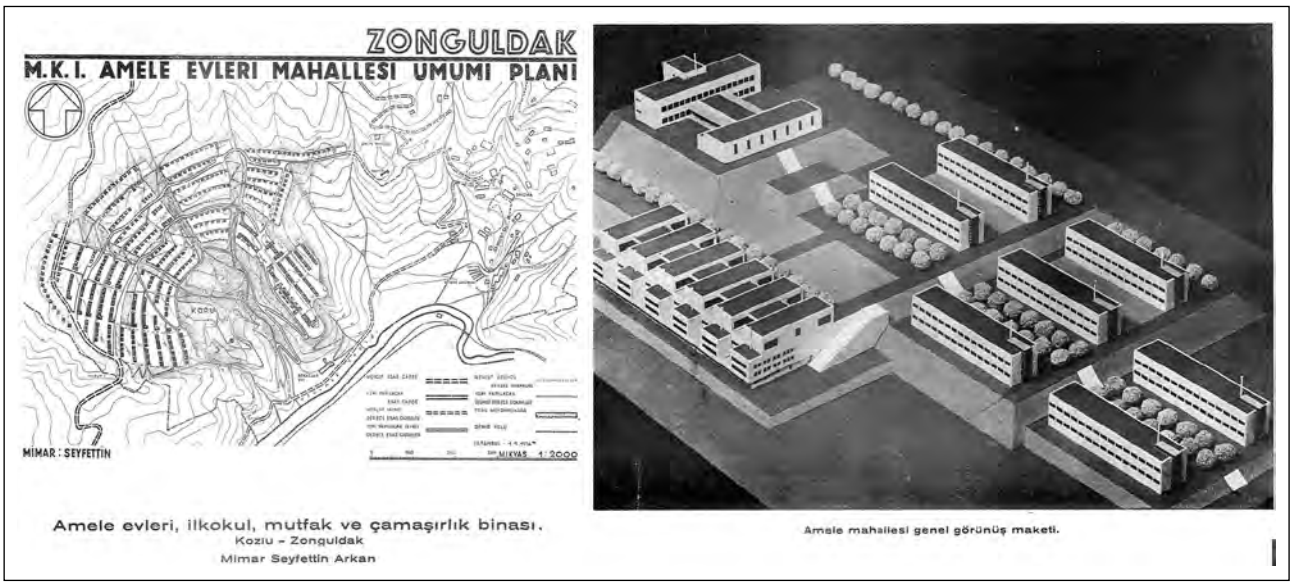

Figure 3. The site plan and model of the Üzülmez Worker Houses district (1935) (Kömür Havzasında İş Bankası, 1937).

the plans could not be implemented. Tezkere-i Samiye[3], which controls construction activities within certain limits, was also not effectively enforced, and the measures that can be taken regarding the artificial environment of the city have been insufficient (Zaman, 2021: 183–184; Zaman, 2004: 234–238). Urban texture spread towards the hard coal production zones with the effect of the topography and increasing population. Due to this spread, city pillars[4] had to be created underground. In addition, subsidence[5] effects are observed because of the suppression of underground hard coal production by space production on the ground (Figure 4). Therefore, this period, in which the conceived space is dominant, expresses full of conceptual and physical contradictions with both lived and perceived space characteristics.

FROM ABSTRACT TO CONTRADICTORY SPACE – THE SUB-INDICATORS OF THE SPACE TRIAD

In order to analyse the space production history of the mining city, the conceptual and physical indicators should be examined holistically with underground and ground. The three moments of the Üzülmez Valley, which have all the characteristics of underground and ground hard coal production as a first production zone, can be explained by specific indicators and sub-indicators. Whereas the production story of the space can be analysed with current maps, population, coal production data, underground production plans, and the cases in the memory of locals regarding worker and production policy. If it is considered that hard coal is an independent factor, the perceived space is shaped by the circumstance and transportation of the ore, the conceived space is shaped by production technology and administrators, and the lived space is shaped by collectivity and traumas (Figure 5).

As seen in Figure 6, the uncontrolled growth of the urban texture over the years and the resulting shift of production to the east of the Üzülmez Valley revealed a tense relationship between coal and space production. As a result of the transformation of the space into a meta that can be bought and sold, the content of the space has been emptied and fragmented. In addition to contradictions such as quality/quantity, global/subdivided, and centre/periphery (Lefebvre, 1991: 352–357), new specific contradictions have emerged. These contradictions can be explained through the space triad of the valley.

Change of Perceived Space from Primitive Abstract to *Contradictory Space* – Spatial Practice

Due to the working conditions, the miners had to live close to their workplaces and urbanisation styles and relations emerged that centred on the hard coal mine

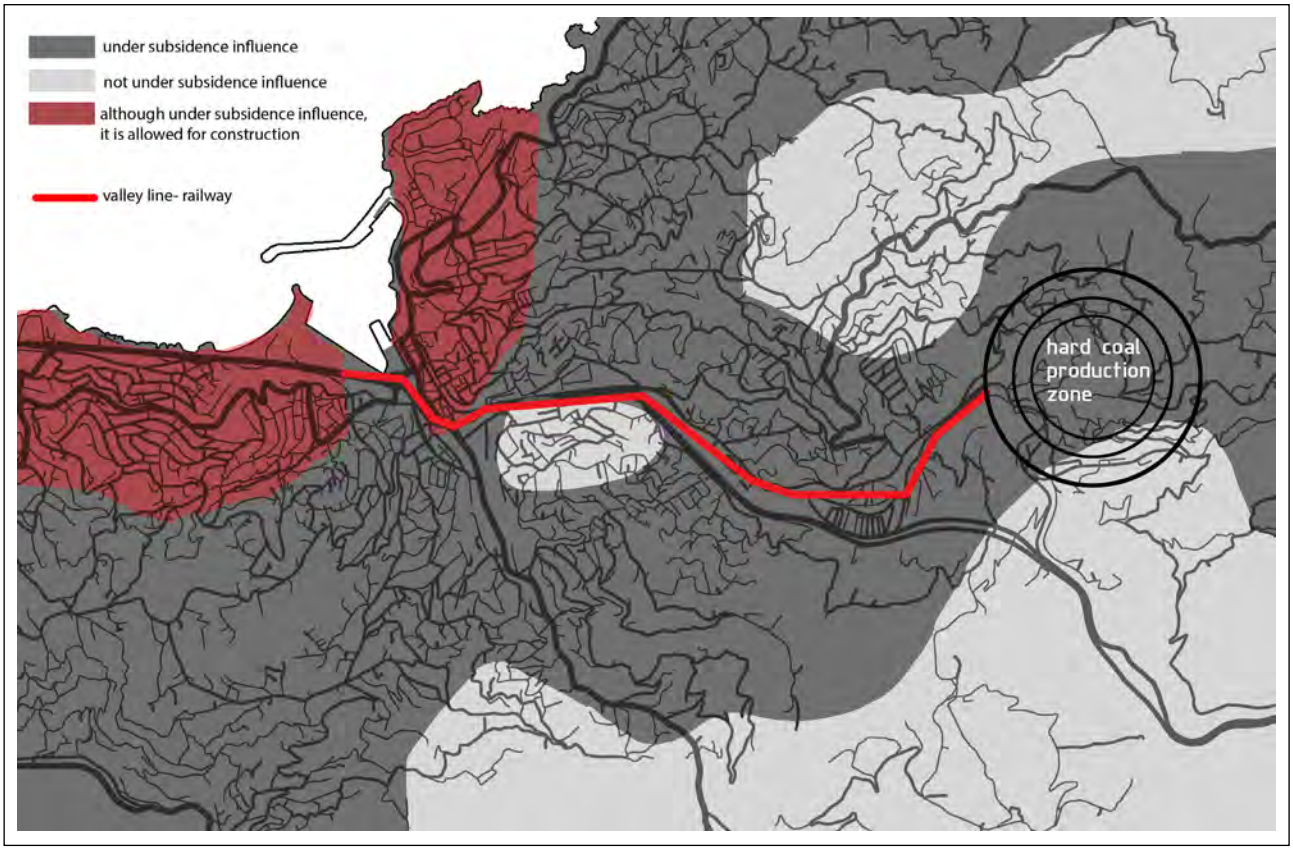

Figure 4. Subsidence map of Zonguldak (adapted from Aksoy & Doğru, 2015, p. 7).

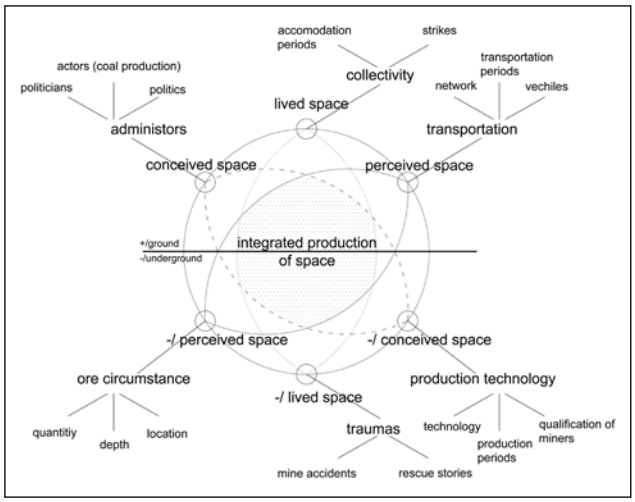

Figure 5. Sub-indicators of space triad in the mining city.

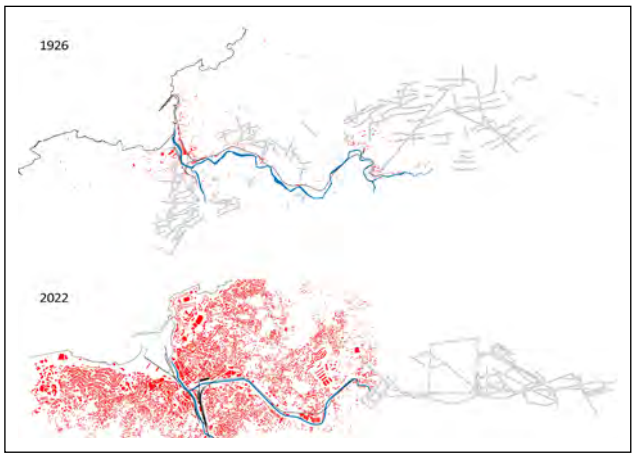

Figure 6. Urban texture and underground hard coal production plans at the beginning of the 20th and 21st century (adapted from BEÜ, 1903; BOA, 1908; Museum of Maden Şehitleri, 1926; TTK, 2021).

(Bakioğlu, 2014: 105). Colonies clustered around mines are settlements where different workers such as mine owners, engineers and workers lived together as Mine of Rombaki at the beginning of the 20th century (Figure 7) (Museum of Maden Şehitleri, 2022). However, the space shows the existence of settlements that prioritise quantity rather than quality in this century. The space, which is produced as a prototype with similar construction technology, design, and materials, has lost its local specificity (Kiper, 2004: 17). In the early 1900s, the hard coal was transported to the harbour by railway networks, while the spread of settlements along the valley led to the development of road networks today.

Change of Conceived Space From Primitive Abstract to *Contradictory Space* – Representation of Space

It can be said that the conceived space of the valley continues to exist not only on the surface but also underground.

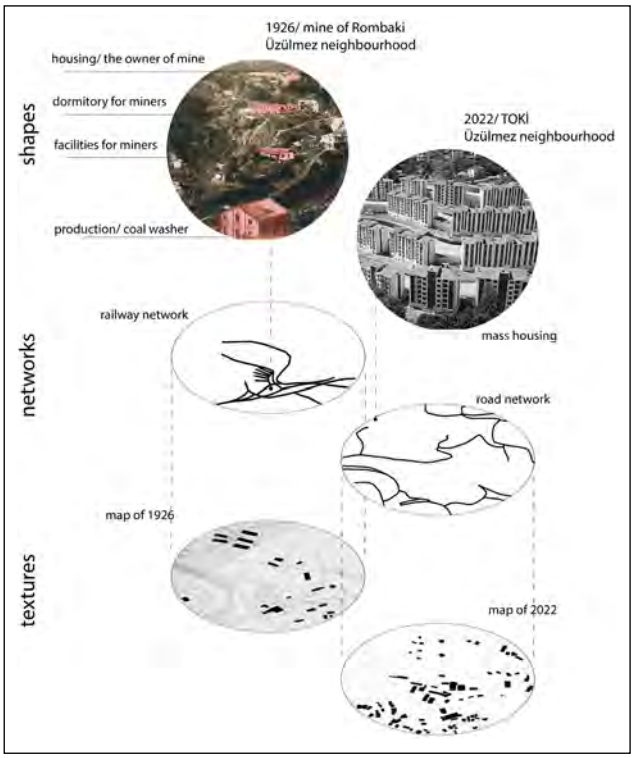

Figure 7. The change in perceived space over the years; a sample part of Üzülmez Valley (adapted from Museum of Maden şehitleri, 1926).

In this sense, projects developed based on production in pre-abstract space are small-scale. Considering the transportation constraints, it provides sufficient conditions at the minimum criteria. Since these projects aim for efficiency in production, working and living spaces are close to each other. As seen in Figure 8, while small colonies in the pre-abstract space formed their own original plans around the mines, today there is a hybrid and fragmented settlement. In addition, the hard coal production method underground has changed the production plans and the underground texture.[6]

Change of Lived Space From Primitive Abstract to *Contradictory Space* – Representational Space

The indicators of the living space as a third dimension covering the perceived and conceived space in the mining city are shaped by cases. Traumas in the underground and stories, memories and transformed using created by collectively refer to living space. It can be seen in Figure 9, collective resistance (strikes) and traumas have occurred in the city at different times. Because the change in the lived space has mostly occurred with the inclusion of working hours, workers' rights and technology in the production line. The lack of workplace safety and regulations on workers' rights, etc. have caused strikes at different times (Güler, 2019: 510–522). This collectivity and traumas brought space and case pairings. In this sense, Gazipaşa Street, which connects the mines and

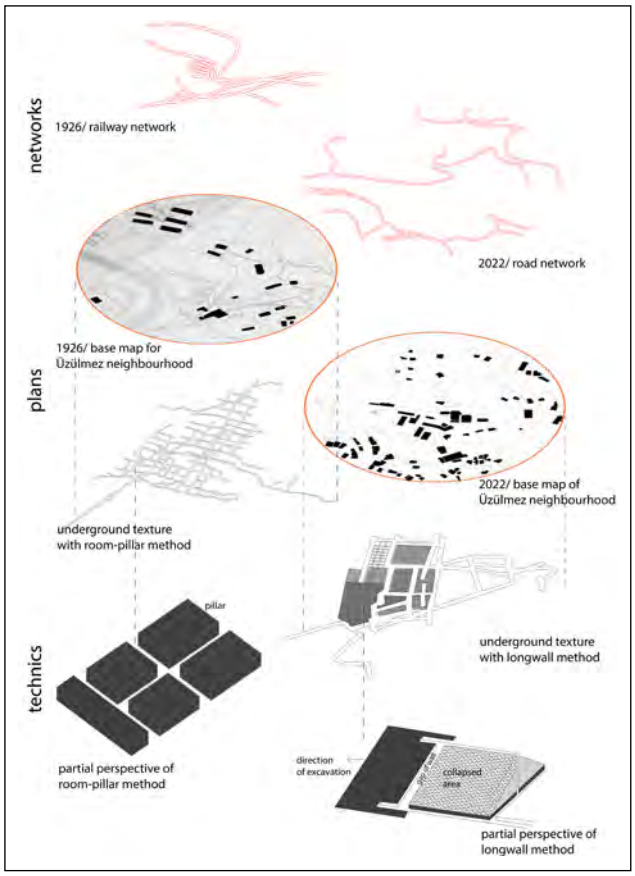

Figure 8. The change of the conceived space underground and above over the years; Üzülmez zone (adapted from BEÜ, 1903; TTK, 2021; Museum of Maden Şehitleri, 1926).

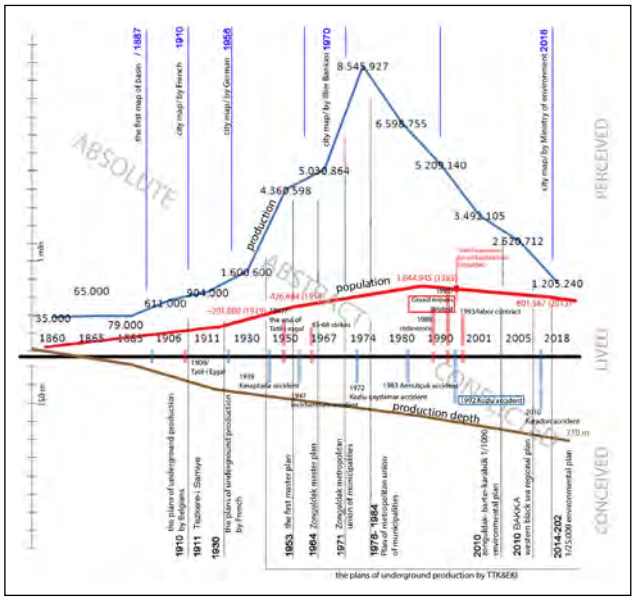

Figure 9. Indicators of the three dimensions of the valley from absolute to contradictory space (adapted from Quarted, 2006; TTK, 2018; Güler, 2009; Üzmez, 2014; TUİK 2022; Zaman, 2021).

the harbour, and subsequently the Ankara-Zonguldak Road, has become the symbol of the 91 protests (Kaya, 2008). On the other hand, mine entrances have evolved into a space where developed coordination due to rescue operations and the pain is shared with every new trauma (29 saniyede ölüm, 1992). However, hard coal production, which is fragmented into the private sector, prevents workers from developing a common discourse under different rights and economic conditions. Therefore, the lack of common discourse prevents the production of new space-case pairings.

THE RELATIONSHIP BETWEEN META AND SPACE PRODUCTION – THE DEEPENING CONTRADICTIONS OF THE MINING CITY

The periods of space production of the city and the space triad define the relationship between meta and space production that reveals today's contradictions. In the process from the *absolute space* to the present, the contradictions in the nature of the city have deepened day by day. As a mining city, Zonguldak added its own contradictions to the contradictions defined by Lefebvre. In addition to the contradictions of quality-quantity, global-subdivided, and centre-periphery existing in other cities, the city defines its own contradiction as plane-volume.

Contradictory Between Quality and Quantity

Especially since the 1940s, with the investments made in the city, spaces with different functions were produced beyond the facilities for production activities. The production policies shaped by the investments of the national capital required not only housing for the workers but also the construction of additional units supporting it. In this sense, different building typologies and contents have been developed such as canteens, schools, dispensaries, sports fields, etc. (Zaman, 2021: 424–447). While a total of 25,000 workers were employed underground and above in 1942, this number is approximately 8900 by 2021. Although salable hard coal has increased to 4.5 million tons over the years, it is around 870 thousand today (TTK, 2018, 2020). The amount of production and the number of employees have been affected by the decisions taken for the space as well as the mining policies. Accordingly, after the 1980s, the increase in corporatisation activities and the removal of some services from the responsibility of the TTK changed the content of the space, and there was a decrease in the number of workers, especially in the ground services. Special structures such as housing, workshops, canteens, and cinemas, which were designed to meet the daily needs of employees and reflect the daily life of hard coal production, were destroyed and transformed into units with high-profit rates. An example of the contradiction between quality and quantity is the mass housing projects built by the destruction of quality miner colonies and prioritising

quantity. As seen in Figure 10, the Üzülmez Worker's House neighbourhood was designed by Architect Seyfi Arkan as a campus serving different functions such as residences, schools, canteens, and dormitories in different typologies (İmamoğlu, 2009: 131–132). Today, some part of the area has been transformed into a mass housing project where repetition and quantity are prioritised.

Contradictory Between Global and Sub-Divided

As it can be understood from the quality-quantity contradiction, the production of the space itself has started from the things produced in the space. As observed in the valley, the city, which was divided into parts from the past to the present, has evolved into a feature where the space is bought and sold over parcels. In the early 1900s, although the productive actors kept their colonial structures under their protection and prevented the acquisition of property, today's space is divided into parcels and sold by different stakeholders. Especially the port area, where the valley ends, has high parcel values due to reasons such as ease of transportation, coastal factor, and commercial vitality. Although the different hard coal mines along the valley at the beginning of the 20th century focused on meta production for a common purpose, today, with the advantage of the production shifting to the east, the valley has been divided into neighbourhoods and parcels with different functions and profits.

Contradictory Between Central and Periphery

As a natural consequence of the contradiction between the global and subdivided, the contradiction between the central and the periphery arises. While the hard coal production zones are mostly clustered on the eastern side of the valley, the harbour, where trade is ongoing, has increased its density and centrality over the years. It can be determined that both the functional diversity and the unit values of the land increase from the production zone to the harbour, especially on the railway track in the valley (GİB, 2022). Therefore, the city centre, which is concentrated in terms of both content and quantity, excludes the production zone and consolidates its periphery feature.

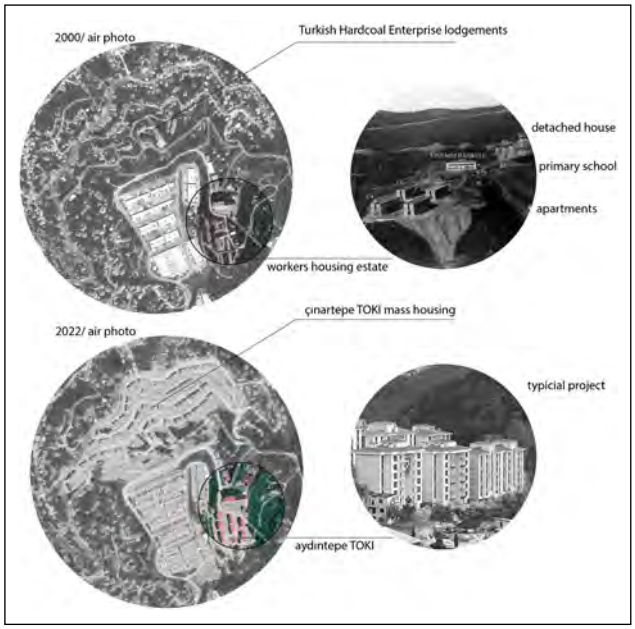

Figure 10. Change of mining colonies in Üzülmez neighbourhood between 2000 and 2021 (Google Earth, 2022; Kömür Havzasında İş Bankası, 1935).

Contradictory Between Plane and Volume

When the production story of the space is analysed, it can be said that the tense but dependent relationship between the underground and the ground is the main reason for other contradictions. The integrated geological structure above and below includes physical and conceptual contradictions that develop due to hard coal production. The contradiction between the production of meta and space has caused the specific contradiction for mining cities as a plane and volume.

The conceptual tension of the surface expresses the notional contrasts of both sides of the surface such as up-down, black-white, ceiling-floor, and individuality-collectivity. Although these contrasts seem to have started between the underground and the ground, they continued to generate the same dualities on both sides of the surface. It can be said that the contradictions get stronger and cause conceptual tension on the ground as getting closer to the surface. On the other hand, the physical tension of the surface arises depending on the direction, speed, and quantity of full-emptiness movement. The most tangible indicator of this contradiction is the subsidence effect, which indicates the danger for mining cities. This threat is important to understand the tension of the relationship between space and meta production.

The direction of movement – In the process from the absolute to the *contradictory space*, both the fullness and the emptiness move away from the surface. While the ongoing space production on the surface increases the floor heights with its structure in which the quantity is prominent, hard coal is produced by going deep because it is consumed by digging near the surface over the years. The fullness and the emptiness move in the opposite direction.

Quantity of movement – In the historical process, it can be mentioned that there is a continuous increase in the production of space on earth. Although the speed of space production changes on the surface, there is a constant increase in variables such as population, production policy, and ideology. On the other hand, the excavation technique of the mine affects the amount of emptiness created underground. In the room pillar method, the roof security is provided with the pillars, while the emptiness is produced continuously. In the longwall method, where the loss of

ore is minimised, the excavated area is collapsed, and the emptiness is kept under control (Figure 11). For this reason, there is no continuously produced space on the surface.

Speed of movement – Despite the continuous increase in the occupancy on the earth, the emptiness created under the ground is kept under control to prevent the danger of subsidence. This causes variability in the speeds of fullness and emptiness production. Moreover, the most important indicator of the speed difference is "city pillars" although the reserve continues underground, it includes physical and conceptual contrasts as the boundary point where the excavation is stopped so that the excavation activities do not cause deformation on the earth.

When the sub-indicators of the contradictions between plane and volume are evaluated, it can be said that the contradictions regarding the production of space have deepened due to mining activities. As can be seen in Figure 12, while a continuous emptiness is produced with the room and pillar system for hard coal production in the first years of mining, the surface is not filled at the same momentum. This situation expresses a balanced relationship between space and meta production. In addition, the settlement zones are not dense and close enough to suppress the mines. With the longwall system, although the underground emptiness is variable, the continuous increase of fullness percentage on the ground has revealed a tense relationship. As a reflection of this tense relationship, what kind of deformation the subsidence will cause on the surface is related to the panel[7] width, length, coal seam thickness and production depth determined by the production method (Arca & Kutoğlu, 2017: 33).

The specific contradictions of the mining city identified based on the Lefebvre literature reveal the tense relationship between meta and space production. The production of hard coal affects the production of the space that serves producers. The tense relationship between meta and space production which gives the urban surface a differential feature creates both physical and conceptual contradictions.

CONCLUSION

In the first periods of coal production, mines gathered around their spatial needs and space production developed depending on meta production. However, nowadays production is being withdrawn to the east of the Üzülmez Valley day-by-day to avoid the subsidence effect on the earth. While the production of hard coal shaped the production of space at the beginning of the 20th century, today it is under the pressure of the production of space. Moreover, specific urban contradictions create their own sub-contradictions at different scales.

The people-oriented contradiction of the city is about human health. Although hard coal provides economic benefits, it causes unhealthy conditions due to the production, transportation and burning activities. The sub-contradiction on the scale of production is that coal is a meta that is produced by consumption. Hard coal ore is removed from its location and transformed into energy input, and each new hard coal production ends its existence underground. At the spatial scale, its contradiction is the full-empty tension. Despite the changing gaps based on coal production underground, there is uncontrolled space

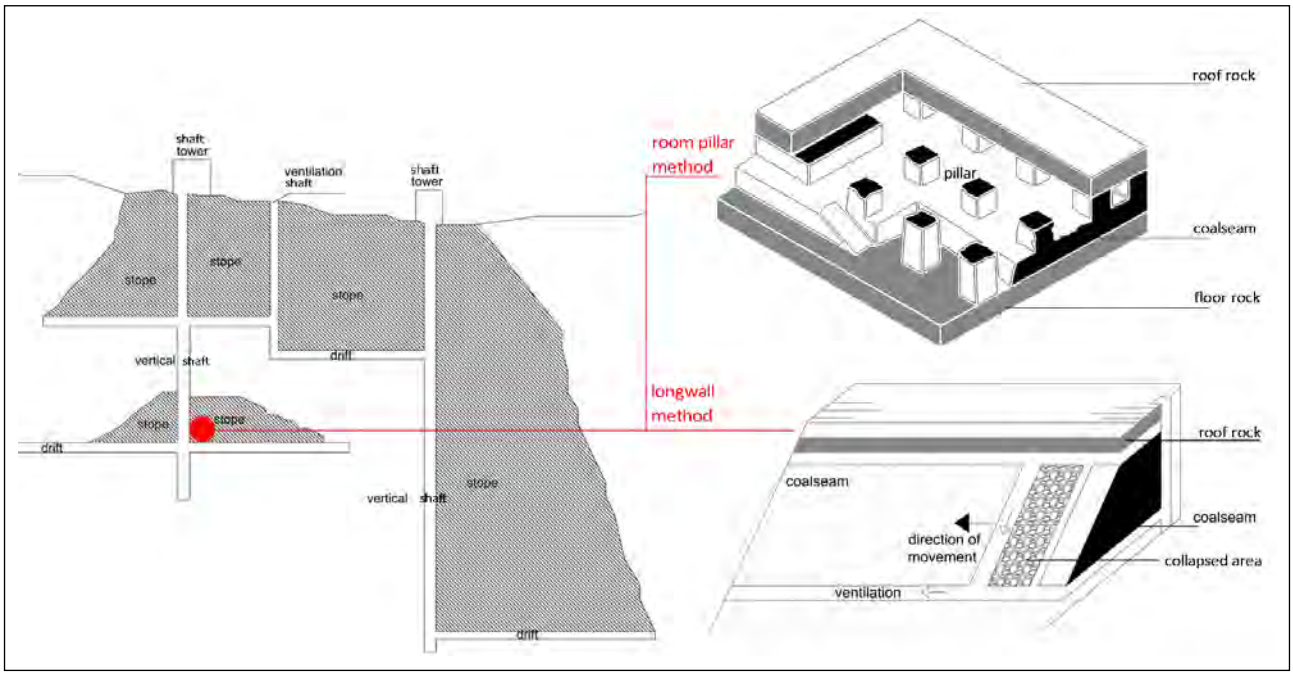

Figure 11. Schematic section of hard coal mines and modelling of longwall and room-pillar method.

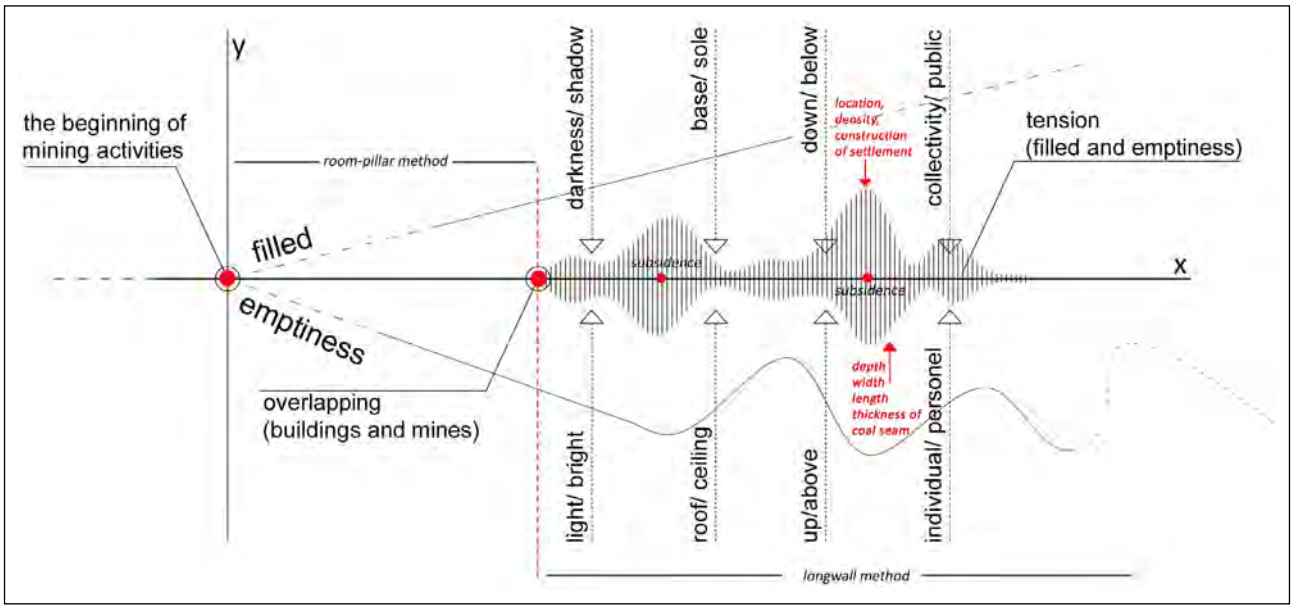

Figure 12. Schematic representation of the ongoing movement above and underground in line with the hard coal production method.

production because of its transformation into a meta that can be bought and sold. Therefore, this situation causes both physical and conceptual tension on the surface. On the other hand, the city is a set of contradictions regarding the tense relationship between the production of meta and space as an embracive scale.

The spatial production of hard coal, which has developed from its production nature, has created subjective contradictions as well as revealed similar contradictions as today's cities. The tense relationship that develops between meta and space production emerges with the transfer of what belongs to *absolute space* to the present. Considering that hard coal has a history of 300 million years, Zonguldak, which brings together millions of years ago and today, shows a differential feature with the similarities and contrasts of space and meta production.

[1]*"In 1882, when 40% of the sale of coal was allowed to be sold to the free market, many foreign companies have come to the region and more labour force was needed to increase the production volume. In this sense with the Dilaverpaşa Regulation, that is regulating the working conditions and rights of workers, the locals who are reluctant to work in mines have been forced to work in the mines for tax relief. According to the Dilaverpaşa Regulation, workers work in 12-day shifts and at the end of 12 days, they return to their villages to continue their agricultural activities (Quarted, 2006:54–58, 96–98).*

[2]*İş Bank- Türk Kömür Madenleri TAŞ, Kozlu Kömür İşleri TAŞ, Kireçlik Kömür Mad. TAŞ, Maden Kömürler İş. TAŞ, Kilimli Maden İş. TAŞ., Amasra Kömür İstimar Mın. TAŞ, etc.* [3]*It is the prime minister's letter numbered 1910 and 289, which prohibits the construction of buildings and assign the lands to the state due to the suppression of production by the construction activities around the mines. It is prohibited to build and open land without state permission within the concession areas determined by the state (Zaman, 2021: p. 183).*

[4]*Pillar: A mineral mass that is left in or between the places where production is ongoing in the underground operation. It has no definite shape and will be taken or not taken later. The task of the pillar is to hold the roof and maintain the integrity of the formation between the layers (ETİ, 2021).*

[5]*Subsidence, displacement, slope, curvature changes and unit strain effects caused by underground mining activities on the land (Arat & Kuşçu, 1992, p. 113).*

[6]*"In room and pillar mining, seams of coal are mined partially, leaving large pillars of coal intact to support the overlying layers of rock" (Gianfrancesco, 2017: 647). There is a 40% loss of ore in this method (ETİ, 2022). "Longwall is a mining method in which very long rectangular blocks of coal are defined during the development stage of the mine and then extracted in a single continuous operation by an automated cutting head moving parallel to the coal face" (Cleveland & Morris, 2015: 355).*

[7]*Extraction panel: The part between the floors in a coal seam which is taken into operation and excavation (ETİ, 2022).*

Acknowledgments

This article is based on the PhD Dissertation entitled as Spatial Values Developing on the Axis of Mining Activities and New Possibilities: Zonguldak Üzülmez Valley by Nazlı Arslan and completed under the supervision of Assoc. Prof. Dr. Server Funda Kerestecioğlu at YTU, Department of Architecture in 2023.

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 72–87, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/MEGARON.2023.55631

Article

A computational design strategy for integrated façades

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ARTICLE INFO

Article history
Received: 15 February 2021
Revised: 19 December 2022
Accepted: 03 February 2023

Key words:
Computational design; integrated façade system; media façade; parametric design strategy

ABSTRACT

Over the last decades, computational methods have provided significant potential for integrated façade systems with energy efficiency, the generation of numerous alternatives, the optimisation of complex requirements, and the inspiration of creativity in architecture. In this sense, the study addresses two primary issues. First, conventional methods are inadequate in a holistic perspective of the multiple objectives of façade systems. Second, poorly designed or transformed media façades are a common problem in many developing countries. This study developed a design strategy for an Integrated Façade System (IFS) that consists of (i) simulation, (ii) analysis, and (iii) optimisation stages in a feedback loop. This design strategy was implemented to integrate the façade in terms of multiple data based on functions. The methodology is organised into two main sections based on the urban scale fieldwork and test of the suggested strategy through the case study. The fieldwork has been done to determine the case study building in Istanbul. Two additional façade functions, media display, and solar shading are chosen here to investigate the constraints, correlations, and consistency of multifunctional integration in a façade system. The finding showed that the developed IFS can contribute to the use of factual data as a design input. Another result showed that this IFS decreased solar radiation by 51% during the summer period. This algorithmic system has flexibility and affordance that refers to enhancing building performance within different contexts.

Cite this article as: Gürcan CG, Heyik MA, Taştan H, Zoroğlu F. A computational design strategy for integrated façades. Megaron 2023;18(1):72–87.

INTRODUCTION

Computation has become a part of the design process with the ubiquitous use of digital tools and systems in architecture. With the inclusion of these tools and systems, design cognition has been important as the product. When the design process is well-defined, cause-effect relationships, criteria, objectives, and rules have more impact on the product. Although subjective design outcomes remain unpredictable, it ensures that precise results are achieved more than ever. The limitations are eliminated by using various types of data as input in the preliminary design phase and evaluating multiple factors together computationally. The data obtained from the simulation is the most accurate data, but it is less adopted in general practice due to its time-consuming (Roudsari & Pak, 2013). Because of the gap between the simulation results and the design process, the value of an integrated

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approach appears to remain incomplete. The visualisation of the simulation provides quantitative data as a design parameter at this point (Gadelhak, 2013).

There are many studies on computational approaches for daylight, energy and thermal performance of façades (Hudson, 2008; Brotas & Rusovan, 2013; Khorasani et al., 2014; Caetano & Leitão, 2016; Alagoz & Beyhan, 2020; Karakoc & Cagdas, 2021) due to the requirements for successful management of the impacts of environmental factors. Besides its performance requirements, the façades also provide communication with the environment as the shell of the building. In this context, there are many different objectives that need to be considered together, such as environmental factors, cost efficiency, sustainability, and interaction. Conventional design methods are inadequate in a holistic approach to these multiple and complex objectives. That is a common problem that affects the flexibility and resistance of the façade negatively.

This paper reconsiders the poorly designed façades from various aspects. It develops a design methodology with a holistic approach to integrated façade in terms of multiple data based on functions. In light of these explanations, the aim of the study is to investigate the integration of multiple parameters on the façades at the early design stage by enabling quickly generated alternatives. For a comprehensive evaluation, this study has implemented a new integrated facade design and investigated its effect on indoor solar irradiation. The study also contributes to the literature with a reasonable design strategy based on a computational approach by including simulation tools in the theoretical and practical framework.

THEORETICAL BACKGROUND

Envelopes, shells, layers, or skin—most notably façade—reflect a critical overlap between performance and aesthetics (Zemella & Faraguna, 2014). Façade, as an interface or mediator, fulfils a multitude of additional functions concerning the environmental performance of the building and the user requirements (Boeke et al., 2019). Since it has a significant role in building performance and interaction, the façade is a critical element in the design process. Several studies have documented many developments in the complexity of façade design over the last few decades (Ochoa & Capeluto, 2009). The current literature contains numerous modern systems, methods, and cases for design, restoration, transformation, and reconstruction.

Glass curtain walls are one of the modern, ubiquitous façade systems that have been mostly seen in metropolitan cities. Despite providing shade control through new technologies such as electro-chromic glass, most glass curtain walls need additional control (Jamrozik et al., 2019). Sunlight and solar radiation can be useful in providing natural light and heat for buildings, reducing the need for artificial lighting or heating. This can reduce energy use and emissions. However, excessive solar radiation can result in overheating, which may need to be countered with energy-intensive cooling, or can cause glare, a form of visual discomfort experienced when lighting is excessively bright. Correspondingly, shading devices are one of the main elements of glass façades (Tovarović et al., 2017) to provide optimal use of daylight and solar radiation by controlling solar gains and reducing the negative effects of sunlight through façades (Kuhn et al., 2001). Solar shading strategies differ in geometry and pattern (Brotas & Rusovan, 2013), movement with dynamic parameters (Grobman et al., 2017; Hosseini et al., 2019), and material (Pelaz et al., 2017; Gunawardena & Steemers, 2019). By networking solar performance, interaction, and industrial production within an integrated system, the affordance of the façade has increased in accordance with the new principles and computational design methods.

The integration of the additional functions mostly refers to the "Double Skin Façade" (DSF) as an overall system. Within the scope of the different façade functions and characteristics, DSF systems are examined for two main reasons: environmental and aesthetic (Ahmar & Fioravanti, 2017). The distinction between these two reasons is related to the environmental performance of the building façade and interaction on an urban scale. For each function, the technology and computational design tools have been intertwined.

The first part of this study refers to enhancing building performance based on the defined dynamic parameters in environmental conditions (Gerber et al., 2017). In the second part of this study, media displays offer great potential for interaction as a new form of communication in the digital age (Globa et al., 2019; Halskov & Ebsen, 2013). Digital out-of-home (OOH) advertising, including media displays, has the fastest-growing impact on marketing. According to research by Foursquare, total OOH spending will reach $7.74 billion (growing by 15%) in 2021 due to the impact of the COVID-19 pandemic (Johri, 2020). Therefore, the global importance of media façades is growing over time. The interactive possibility of the media façade is composed of different elements: such as digital display skins with light-emitting diodes (LED) and kinetic solid panels. As in the research case, many developing countries, and their metropolitan city centres have common problems with poorly designed or transformed media façades. It is possible to characterise the media facades on an international scale in terms of their functions (commercial, economic, political) and technical descriptions (physical-digital, temporary-permanent, partial-entire façade, etc.). For example, it is seen that media facade examples are mostly used for construction sites to make restoration and rehabilitation works invisible (Figure 1). However, many examples, especially economy-driven,

Figure 1. Exemplification of temporary/permanent media façades in Madrid City centre.

are not temporary. There is a lack of sustainable solutions by ignoring thermal comfort and visual interaction (Cikic-Tovarovic et al., 2011).

The development of new technologies, materials, and fabrication methods has led to new integrated systems in architecture. Integrated Façade Systems (IFS) as a component of shading devices (Ibraheem et al., 2017) are facades that incorporated different technological solutions lower environmental impacts and improve façade performance (Ibraheem et al., 2020). IFSs offer heat gain control which leads to administer air-conditioning loads, and glare control while the use of natural light is maximised (Ibraheem et al., 2017).

The main concern of this study is to develop a holistic view of IFS by concerning the potential of the computational design approach by discussing two functions together. This holistic view includes visibility distance and resolution for media function and shading function to control solar radiation. Consequently, the hypotheses are as follows:

Hypothesis 1. A computational design approach formulated by analysis, synthesis, and evaluation steps with a holistic approach has the potential to be a tool for the early design phase of integrated façade systems.

Hypothesis 2. Perforated panels such as IFS can serve as both media display and solar shading devices.

Hypothesis 3. Solar radiation simulations and analysis for designed IFS for media display function enable improvement of solar control performance of existing façade.

RESEARCH METHODOLOGY

The methodology of this study consists of two main sections based on the literature review and the case study. In the first section, the design framework is of IFS for the integrated media façade to examine the H1 and H3. As shown in Figure 2, the framework provides context, data analysis methods, and simulation tools. Fieldwork and the significance of media façade topics are examined in the second section. Façade functions, attributes, and project information are identified regarding the integrated media façade.

This study was carried out using some results of the computational design workshop five different student groups (consisting of three or four students who have doctoral degrees) participated. The workshop was organised in cooperation with the university and industry in 2019–2020. It was aimed that the participants proposing the facade design by thinking over and discussing problem definition, ideas, and production processes. The current production potentials (such as robotic and CNC) and requirements of the industrial environment were shared with the workshop participants during the preliminary information process. Robotic fabrication and material resources (panelization) have an impact on the process regarding the production and testing of the prototypes (H2). The project proposals from the groups were a PV-supported dynamic shading system, an interactive campus shell, and wave-based shading arches on the deck. Besides these, the researchers' project for this study was the environmental media façade system. Façade/shell/skin design proposals are created as IFS with the function of mobility, interactivity, and energy efficiency.

This study suggests interdependent façade functions and dialectic for IFS with the shading function and media display working together to enhance the functionality of the façade. The suggested integrated façade system in the parametric design framework consists of (i) data inputs, (ii) simulation & analysis, and (iii) panelization steps (Figure 2) for the early design phase. As sub-attributes, shading function and media display are identified to improve façade affordances and visual interaction. By networking these attributes, the framework has the capability to generate numerous possibilities for the design solution. This algorithmic process is reparametrized according to the percentage of display and resolution type (low-high). The visual custom scripts were developed based on parameters

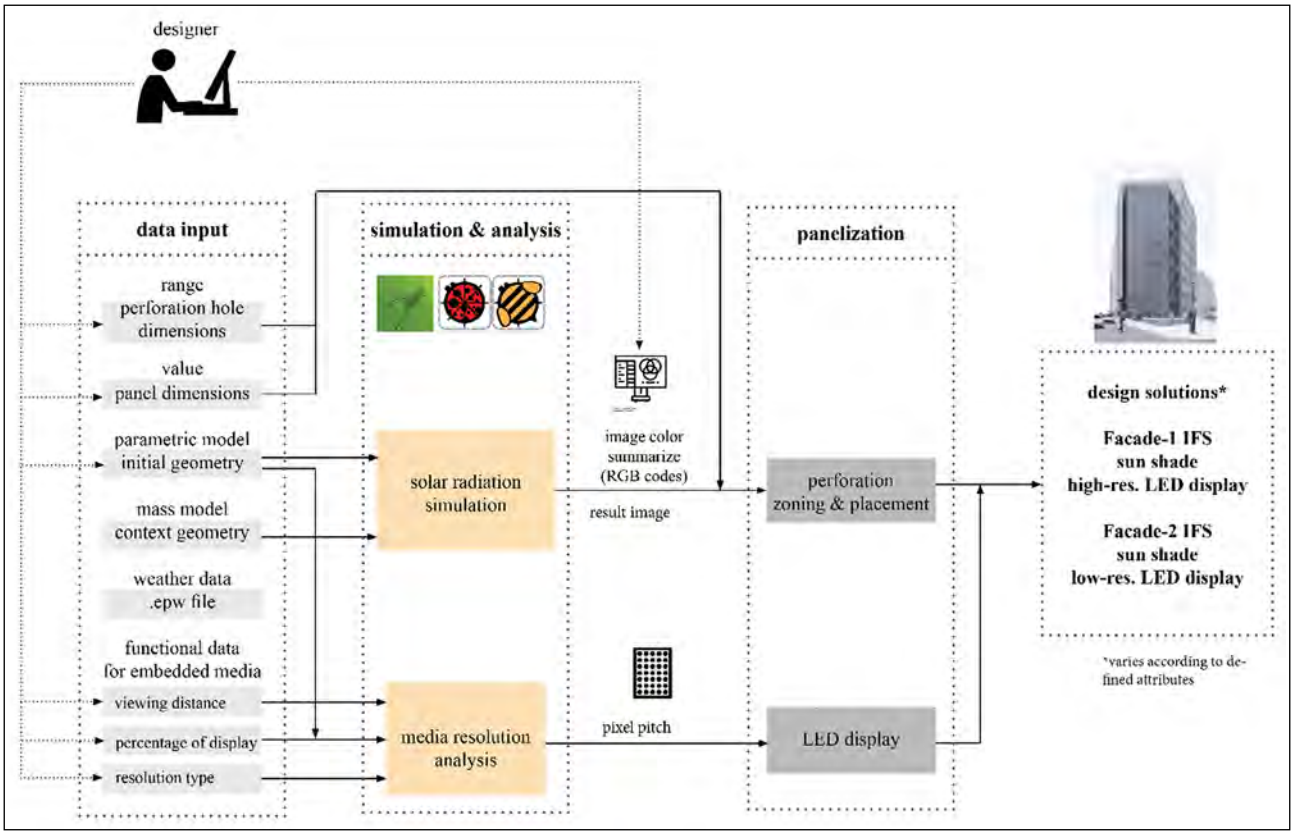

Figure 2. Design framework.

and attributes, sub-attributes, simulation, and analysis to allow for an automated generation of façade panels.

FIELDWORK

The terms metropolis and historical topography refer to the international economy, crowded population, urbanisation, and different conflicts within the topography. In particular, media façades and urban commercial economies are in a mutual relationship with each other regardless of public/private user requirements. There are different approaches to this common urban problem that refers to urban identity, screens in capitalism, etc. (Derviş et al., n.d.). However, the issue of meeting the commercial requirements, which leads to conflict with the performative functions of the façade, is one of the most significant architectural problems of media façades. The design approach has to reduce the negative effects of the media interaction on the primary functions of the façade and the sustainability of the building and provide flexible systems that add value to the building.

The research site is Istanbul which is among the world's metropolises with its cosmopolitan, diversified, and historical topography. Fieldwork clarified the significance of media façades on a metropolitan scale. Here, media examples with high levels of interaction applied directly to the surface, such as murals and graffiti, are excluded from the scope of the study because of the blind façades. In addition, the media façade layers of the first floor show a general situation in the trade zones. This situation is questioned in the existing literature through the perception of the cities and streets at eye level.

The fieldwork to determine sample buildings has examined media façades on medium and high-rise buildings in metropolitan areas of Istanbul. Although these applications are generally seen on one façade, examples with two and three façades are also included here. In this direction, general determinations of the situation were conducted for the public spaces. The mapping of the urban modern and historical parts of the city provided us with intensified points. As shown in Figure 3, the media façades of the buildings are classified into three types: square and public space (Type 1), intense commercial routes (Type 2), and arterial highways such as D100 (Type 3). This mapping was created to highlight the commercial concerns with public interaction in the media façade layer of the city. Therefore, the close environmental openness and orientation values of the media façade, which will provide public interaction, relate to the sunbathing values. Particular examples in the double-direction traffic flow (Figure 3, Types 2 and 3), corner parcels (Figure 3, Type 1), and intense public spaces (Figure 3, Type 1) are at a critical point with media façade potential.

All constellations have in common that they aim primarily

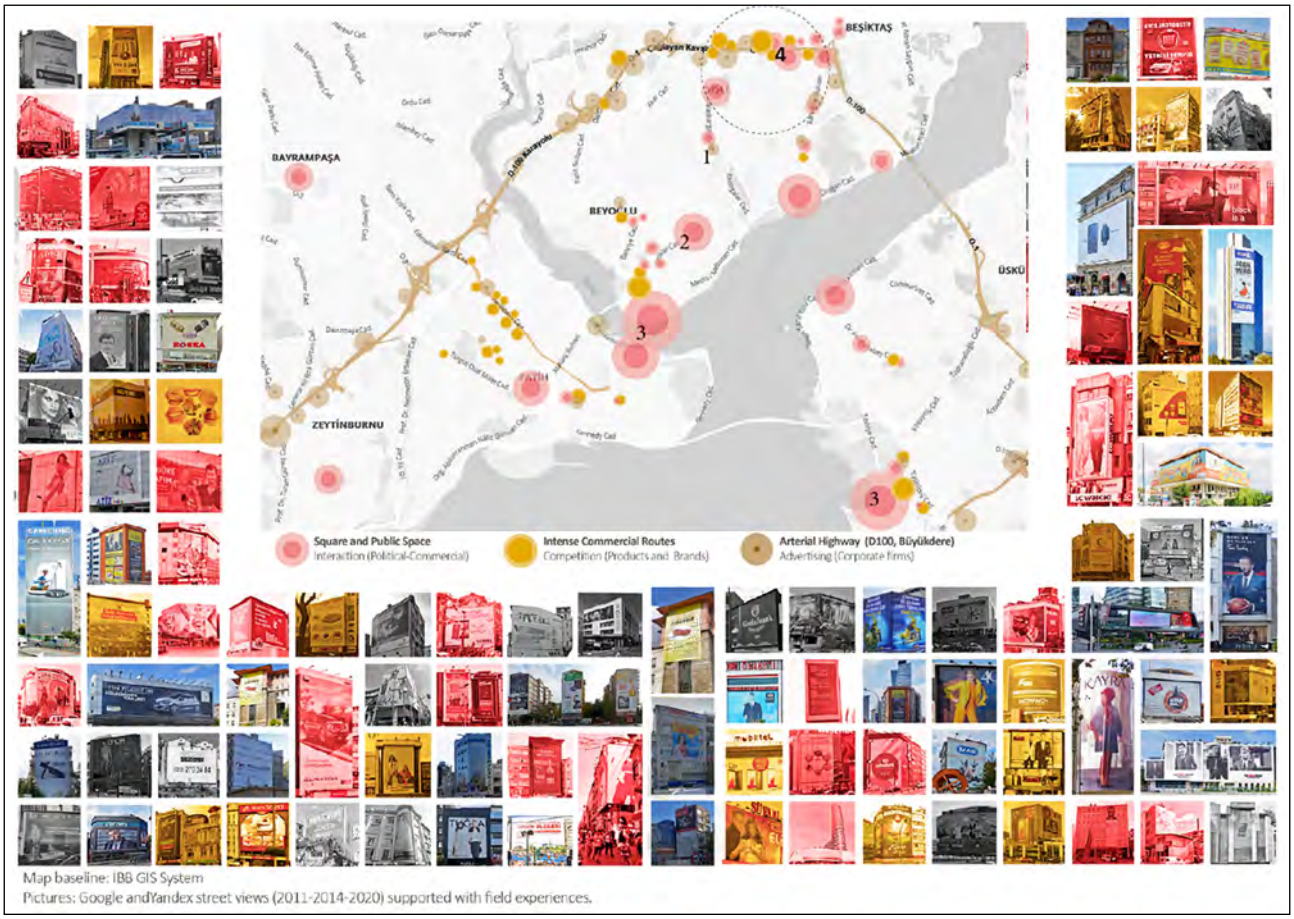

Figure 3. Fieldwork and mapping.

to interact with the objections of commercial, political, creative, social responsibility, informing, aesthetics, etc. Nişantaşı Shopping centres' media façade (1) commercial, Marmara Hotels' roof media box (2) mark, Karaköy, Eminönü and Kadıköy squares (3) political and commercial, Mecidiyeköy-Levent high-rise office buildings and shopping centres' media façades (4) political, commercial, creative, and aesthetics are just some of them.

The results of the analysis according to the three categories showed that intersection points between the Mecidiyeköy high-rise commercial zone and the D100 arterial highway have all three evaluation categories and they condense at these intersection points. The building located in the intersection of busy streets was determined for the case study to investigate the media and shading functions of the façade. This building is a corner building and has three facades facing the streets. The corner structure positioned towards the south is analysed in detail for this case study.

CASE STUDY

The case study involves a computational model that is linked to the parameters and simulation tools in Rhinoceros™ and Grasshopper (as fundamental computational design tools). The design flowchart details the parametric model and IFS components by including data input and design parameters.

A case building is a seven-story building and located in the central city square near the D100 viaduct. This building has a high window wall ratio on its east, north and south facade but has no window west facade. The solar radiation on the working plane changes according to the direction of the facade, window wall ratio and external shadings. The south facade is the most effective facades for solar radiation control. In the scope of this study, the IFS, PVC perforated film banners, covered the external surface of the eastern façade (Façade 1 (F1)) and the southern façade (Façade 2 (F2)) excluding the entrance face of the first floor. The dimensions of the eastern façade (Façade 1) are 9 m wide by 28 m high, and southern façade (Façade 2) is 18 m wide by 28 m high. The building's gross floor area is 1400 m2. The ground and first floor are occupied by a patisserie, while the second through seventh floors are occupied by an English course.

Data Input

Research has multimodal data related to shading and media interaction. Most of the data is directly from the

current condition, but there is manipulative flexibility for the designer. Therefore, panel surfaces are determined according to the simulation results. These simulations are composed of two parts one of them is the optimisation and the second is an analysis of the effect of the developed IFSs. For optimisations, one of the joint parameters is embedded media data, which refers to pitch value according to media resolution and human-façade distance. Another joint parameter is solar radiation. These two parameters, along with another interdependent input -façade size- provide high or low resolutions by pixel pitch value (Svilainis, 2018). IFS data inputs are linked with shading and embedded media sub-attributes.

Regional climate data as a weather parameter is used for the determination of the hole size of IFS. The file with the "epw" extension is obtained for Istanbul located in Region 6, from the webpage of WMO (World Meteorological Organization) (Climate.OneBuilding, 2019).

The solar radiation has been calculated for all years to determine the shading effects of IFS in both the summer and winter periods. The calculation period was settled from 8:00 to 17:00, depending on working hours in order to provide proper shading by considering user requirements, since the case is an office building.

The reflection coefficient of building surfaces is determined according to standard EN 17037 (Organization, 2018). The reflection coefficient of ceilings is p=0.9, walls are p=0.7, floors are p=0.2 and shading panels is p=0.5. The visual light transmission of window glass is 0.75, thermal transmittance (U value) is 1.8 and solar heat gain coefficient is 0.63 according to TS 825. A detailed explanation of the properties of shading panels is given in "Panelization" section. For simulations, the properties of the building and panels were input on the 3D model. The panels were located 0.55 m away from façade for calculations.

Design Parameters

The use of two façades in different directions with different attribute values reveals the applicability diversity of this method. The main differences between the façades are the resolution of the media display and the percentage of the display surface. F1 is perceived from the human point of view. Regarding media display on this façade, high-resolution is required to allow readability. However, F2 is perceived during the rapid movement of vehicles due to the viaduct in front of the building. Therefore, a low-resolution display is sufficient to make it possible to get more sunlight. The shading function and embedded media sub-attributes are defined for the design workflow through (1) solar radiation simulation, (2) media resolution analyses, and (3) panelization steps (Figure 4). Each step is linked algorithmically to the next step as a visual script on the computer with an Intel i7 processor, 32 GB RAM,

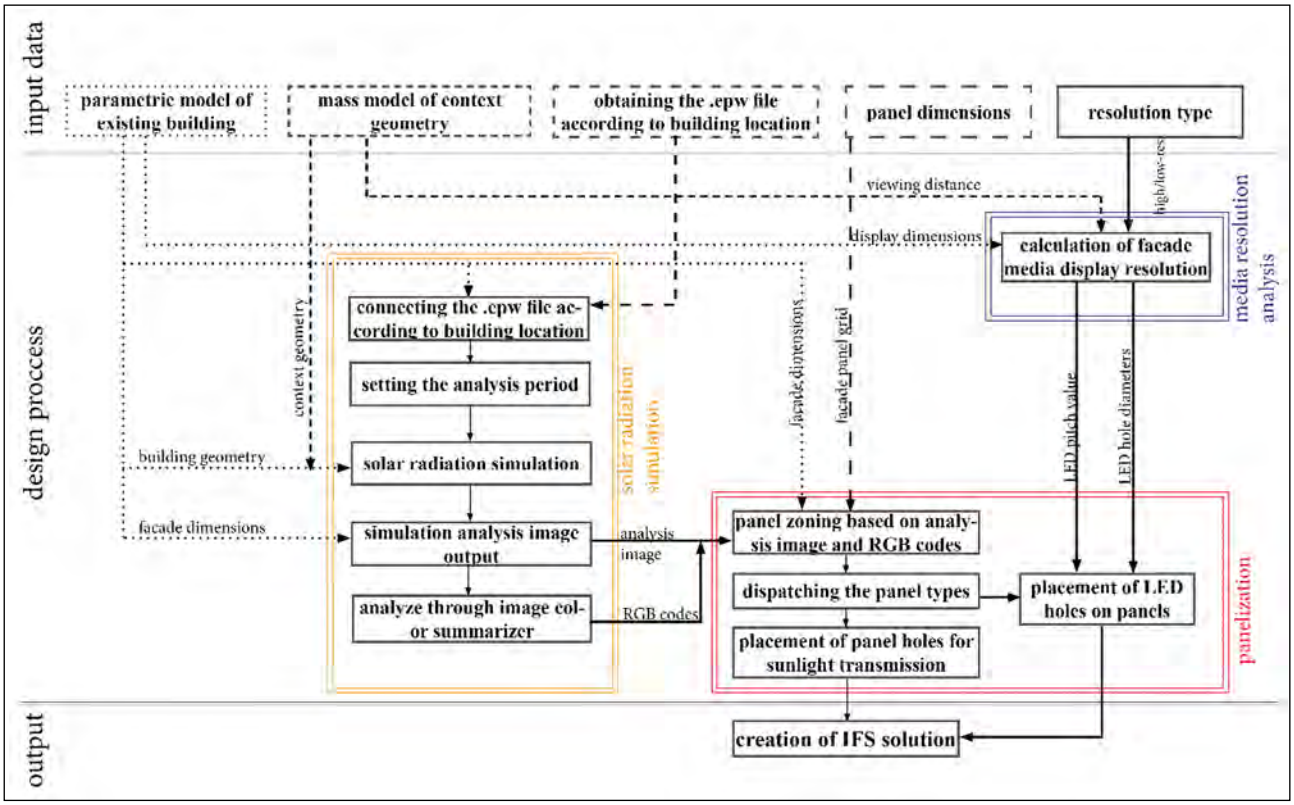

Figure 4. Design flowchart.

and NVIDIA GeForce RTX 2060 graphics card technical specifications.

Simulation

The first part of the simulations aims to determine the holes of IFS according to optimisation results. The optimisations have been done by calculating media performance and solar radiation performance (detailed information is given in Panelization). The solar radiation is reflected, absorbed, and transmitted after comes to the façade. A big part of it is reflected or transmitted depending on the features of the facade (window wall ratio, properties of shading devices). The transmitted and reflected solar radiation are related to each other. Therefore, in the first part, the calculations have been done to determine the incident solar radiation on the façade. The second part aims to compare the effect of developed IFSs after optimisations on the working plane. The second part focused on the analysis of transmitted parts of solar radiation by calculating the solar radiation on the working plane. The input data and settings for the simulations such as weather data, calculation period, building properties and IFSs properties are given in data input and panelization.

Firstly, for optimisations, the simulation tools were utilised to analyse the amount of solar radiation received by a façade surface through parametric strategies. The building was modelled by using Rhinoceros 3D with Grasshopper. Solar radiation was calculated with the Grasshopper3D (Rutten & McNeel, Rutten, 2007) add-on Ladybug (Roudsari & Pak, 2013)that uses GenCumulativeSky (Robinson & Stone, 2004) for the calculation of radiation amount. Building and site 3D massing models were connected to the LadyBug Radiation Analysis component. This add-on was used in many scientific studies (Anton & Tanase, 2016; Perini et al., 2017; Vartholomaios, 2017; Panya et al., 2020) and its reliability has thus been demonstrated.

Because of the extensive calculations, the consequences of physical conditions are frequently deferred until the next phases of architectural design. These add-ons allow for physical conditions to be effectively incorporated into the early design phase as well. This tool was used to simulate solar radiation for each geometrical input. The ray-tracing capabilities of Radiance (Reinhart & Walkenhorst, 2001) were used for simulation with the setting of a 2 m × 2m grid value in order to take advantage of the correlation between output and façade panels. The image output of results is interrelated with the façade width and height dimensions provided by the simulation. The colours of the image output were evaluated with their numerical equivalents on the legend (Figure 5) which gave us the opportunity to associate them with the panel holes.

In the second part of simulations the solar radiation was calculated by using Ladybug Radiation Analysis component to evaluate the effects of developed IFS. The calculation surfaces (working plane) were determined 0.85 m away from floors by reference working plane as given in standard EN 17037. The grid size of the calculation surface was 0.5 m × 0.5 m. As a result of the grid sizing, there are arisen 1085 test points on the working plane for each floor. The solar radiation results of the working plane have been visualised in terms of results with and without IFSs. The results were also graphed according to floors and total building. The results have also shown in a graph for floors and the total building.

Media Resolution Analysis

Optimum visibility and resolution on media façades become important factors as they affect the visibility of the medium (Lee & Sul, 2017). The resolution value depends on the centre-to-centre distance between two pixels, i.e., the pixel pitch value. The distance from the viewpoint to the screen creates closer pixel gaps. There are several assumptions to calculate the optimum range of pixels according to the distance (every 1m away from the screen the pixel pitch should increase by 1 mm). The optimum viewing distance is determined according to screen dimensions, and the pixel pitch value. In this direction, an algorithm is generated that provides an 80 mm pixel spacing value for the high-resolution display of F1.

Low resolution is tested to allow readable images, videos, and text to be displayed. For F2, a 250 mm pitch value is defined according to the two-story height along the façade. Each hole radius is 50 mm for LED pixels. The black and white image with text is placed on the façade surface via the image sampler component. It is suggested that the following properties can be applied in the production of the designed panels. They can be produced as separated panels are dimensions 0.8 m × 3 m, but panel size can also be customised. According to 8000 mm × 3000 mm dimensions and a pixel pitch of 250 mm, the actual pixels are 32 pixels × 12 pixels for each panel. The weight of the mesh screen will be between 2 and 5 kg/sq. m. The colour processing can be between 12 and 16 bits. IP rating should be IP 65. Their scan mode is static, and their estimated consumption is between 200 and 600 W/sq. m. supply from AC 100–240 V; 50/60 Hz with 7.5 V DC (*HM Series – LED Pixel Display Screen, n.d.; M6 – LED Mesh Screen, Soft LED Display, Transparent LED Mesh*, n.d.).

Panelization

Simulation outputs and pixel values are used for panelization parameters. Image output is analysed and evaluated via the "image colour summariser" and "image sampler". The colour summariser is a method that reports a summary of colours in an image using clustering, to group similar colours together and derives a set of colours that are representative of the image, histograms of colour

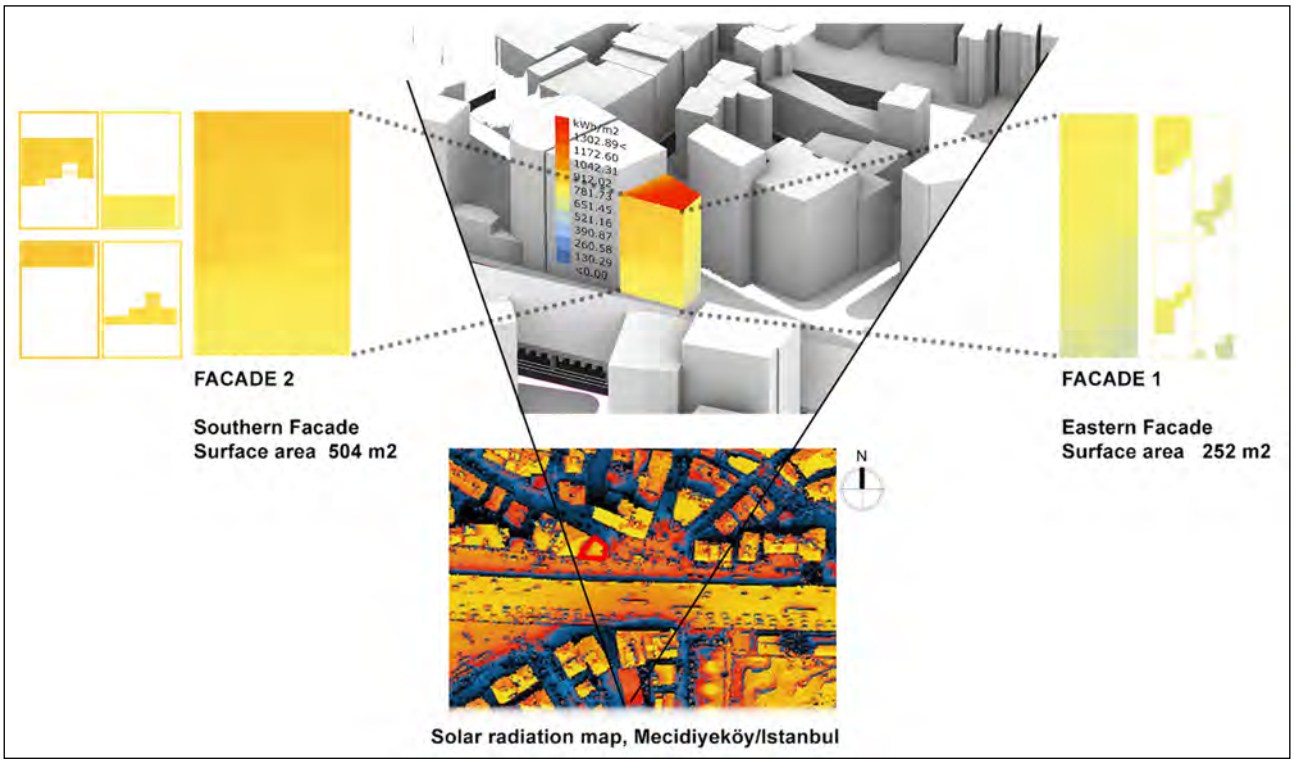

Figure 5. Simulation of solar radiation and colour clusters.

components (Krzywinski, 2018). Four colour clusters were determined as shown in Figure 5. There are two correlations: the panel gaps with colours in the algorithm, and the number of panel types with standardisation.

Simulation outputs (transformed RGB—red, green, blue—codes in coordinates) and measurements were used to calculate the solar transmissions on the panel. The coefficient value (0.2) corresponds to the colour with the highest solar irradiation value and indicates the minimum solar transmission. In this way, the rate of sunlight transmissions provided data to the algorithm. Each panel type was primarily divided into four zones that were adequate for the computer capabilities used in this research. Panel grids related to the colour clusters, measure 200 cm × 150 cm for both façades. In the final stage, 84 panels were formed with 8-panel types in F1 (Figure 6). On the other façade (F2), 144 panels were formed with five-panel types. While the whole data set was inputted to the parametric system, IFS panels were created by the rule of smaller maximum sunlight transmission hole diameter than the pitch value set by the algorithm. The LED placement was defined by pixel value as an input at this stage. After subtraction of the LED holes from the panel surfaces, the rest was perforated for light transmission.

Details of the system (cable connections, application, maintenance, and automation) are designed based on the material of the panels. Perforated metal is to provide ease of production (Figure 7). Perforated metal material was used for shading panels to provide not only the enhancement of performance as a reduction of solar radiation (Mironovs et al., 2017) and noise (Sakagami et al., 2010) but also the additional function of communication through images (Kim et al., 2017). In this direction, panel types were created and tested with the help of the CNC machine system. With this test, the producibility of the metal panels within the CNC machine system was checked for rapid prototyping. The glossy material of shading panels has 50% reflectance (p=0.5) (3% in specular and 47% in diffuse). The RGB (Red Green Blue) values are 0.47, 0.48 and 0.48, respectively. The perforated media façades were simulated with the 3D building model. Then, the compatibility of the moving image with the number of pixels on the media façade was simulated on the Grasshopper-image sampler component. With this simulation, the relationship between any moving image that will be displayed on the façade and the number of pixels was tested.

RESULTS AND DISCUSSION

Over the last decades, a wide range of studies and applications on the façade has contributed to a new knowledge of categories with new notions and attributes. Computational design approaches that provide potential for simulation tools and systems have to broaden the research area with these new opportunities. However, there is a disconnection between the simulation results and the design process with

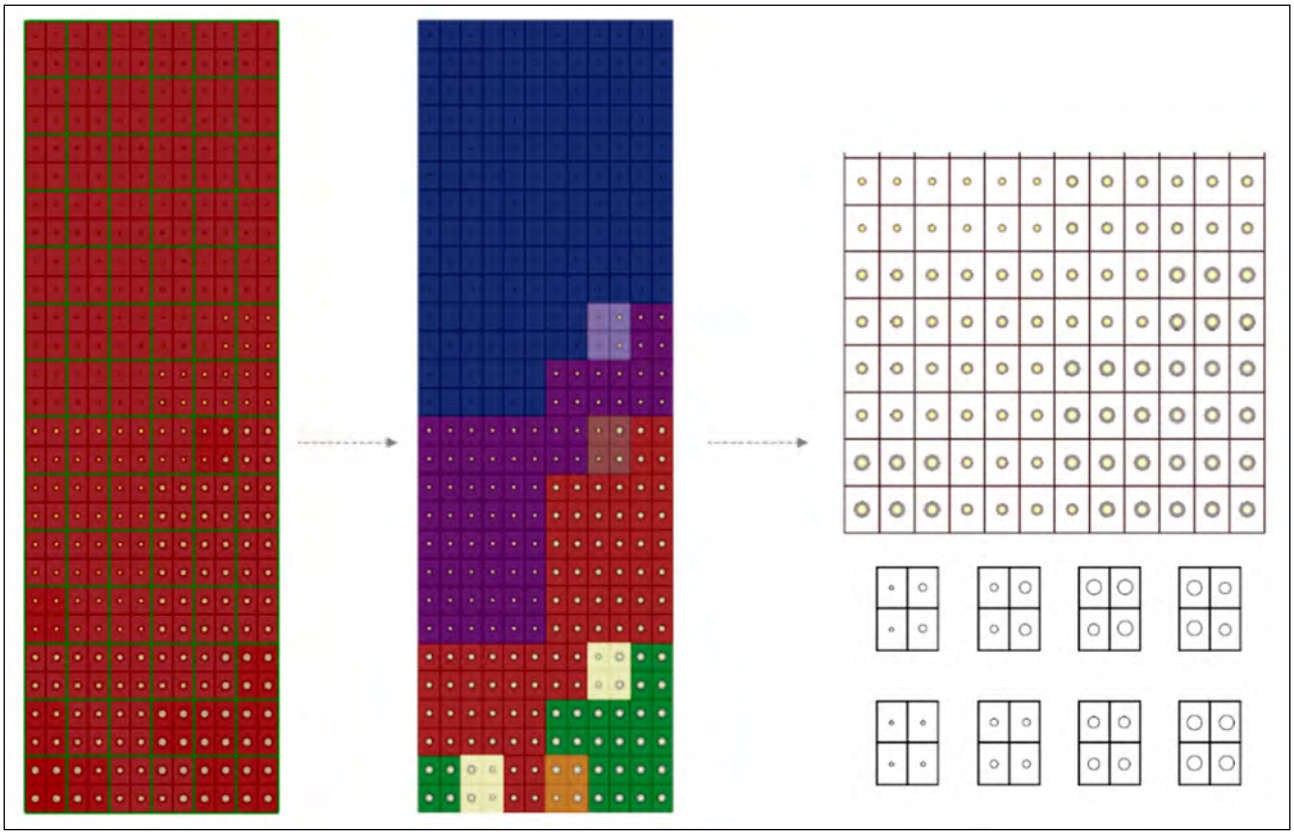

Figure 6. Façade 1 panelization based on simulation outputs and determining panel types.

the lack of a holistic approach (Roudsari & Pak, 2013) To achieve this holistic approach, this study developed an attribute-based IFS with the concern of shading and media functions. These attributes are represented as RGB codes and resolution values, which are fundamental design parameters and are integrated into the design process. Data conversion from RGB codes to the panel holes proves that the environmental conditions can be parametrically linked to the design framework (H1). H1 contributes to H3 by integrating the solar radiation simulation with display resolution analysis, which provides enhancement of current façade shading and media functions according to parameters (H3). The visualisation of the simulation on the model allows the use of it as a design parameter in the framework (Mallasi, 2019).

Although the fabrication stage of this study has not been completed, the affordance of metal panels is researched by observation of the production process of perforated metal panels (Figure 8) by partial mock-up attempts. The observed production process and other studies (Caneparo, 2014; Kalo & Newsum, 2014) have shown the ease of precise perforation on the panel. Besides the ease of production, moderating the solar gain (Blanco et al., 2019) also provides a potential for using the perforated metal panels on the façade (H2). Metal panel supports H1 with a wide range of sizes, both in length and width. It also provides flexibility to the design framework by allowing holes of different sizes on the panel for both sunlight and LEDs.

The existing façades of the case building are covered by PVC, which allows only one-way vision through the perforated banner. The design framework of IFS allows users to manipulate diameters and to see the user perception from the inside (Figure 9) and outside of the building. It also provides more daylight transmission than the existing façade through patterns with bigger holes compared to the existing PVC media system. This IFS model allows decorative perforation with a larger diameter with a lower resolution. This ornamental decision depends on the designer and users in the renewal process. F1 and F2 are compared according to their shading function performance by calculating the solar radiant exposure of each floor. With the IFS, the current disposable and poorly designed façade is replaced with a context-driven and sustainable solution.

Different applications based on the literature are analysed to clarify IFS impacts on the façade (H3). Essential parameters of IFS 1-2-3-4-5 (Tscherteu, 2008; Boeke et al., 2019; Bomfim & Tavares, 2019; Erkol & Sayın, 2021) investigated with the analysis matrix. Conceptual details of Environmental Media, PV Integrated, Green, Dynamic Shading, and Smart System Façades were associated with the façade functions (FF) to enhance their performance (Figure 10). The scope of this study was limited by the

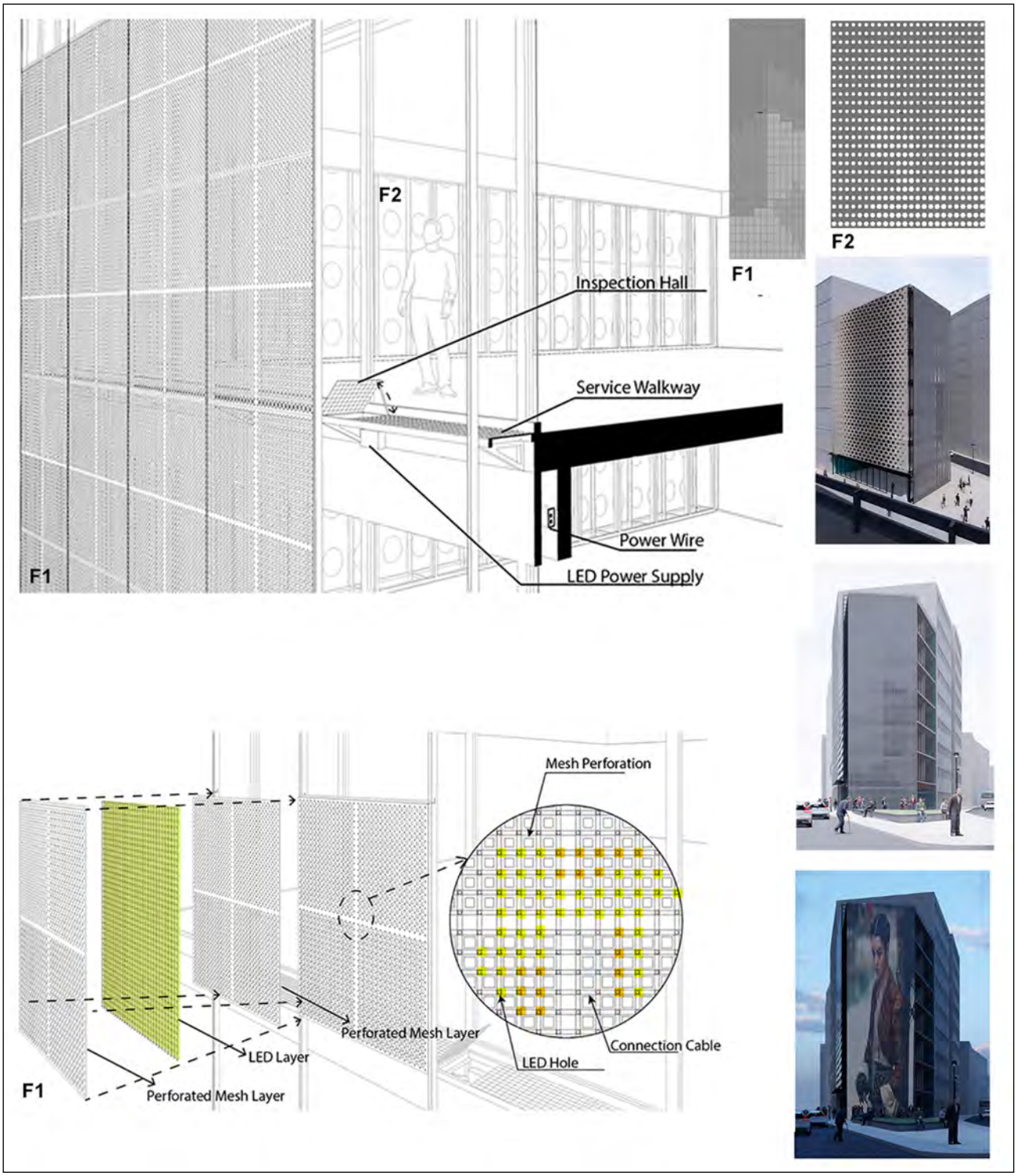

Figure 7. Perforated metal panel detail.

effect of IFSs on solar radiation. However, it should be remembered, solar radiation is, directly and indirectly, related to glare, air temperature, visual contact, energy consumption, and interaction. As shown in Figure 10, other studies in the literature have contributed to the IFS production model with different materials and methods, including various attributes. This conceptual table and other applications showed that media façades could be associated with IFS in an aesthetic, flexible, and sustainable way by using perforated metal panels.

One of the indirect findings of the research can also be discussed in relation to the identity of the city and the built

Figure 8. Perforated metal panels (Authors' archive).

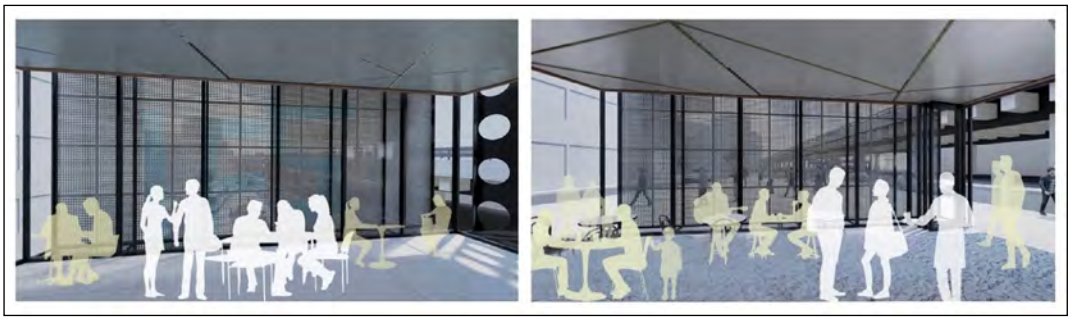

Figure 9. F1 and F2 interior demonstrations.

environment. In particular, fieldwork showed the importance of this subject in the scope of Istanbul. Besides, there are numerous and continuous discussions based on literature, urban transformation, gentrification, interventions on historical topography, academic perspectives, associations, and daily life. As a current situation, the green wall applications along the Istanbul highways have been removed by the municipal decision in 2020. Different criticisms were brought as justification, such as the financial and maintenance burden compared to its ecological benefit and its pure visual function. Even such non-building—public—façade applications, with significant annual expenses, can be associated with the research approach and findings. The need for individual advertising billboards and green walls along the highway should be addressed in a sustainable approach within IFS. The "Konuşan Duvarlar" project (IBB, 2020) instead of the high-cost green walls is also a matter of debate from a different perspective. This current debate shows that research findings mainly discussing interaction and shading have great potential for interrelated subjects like spatial identity and environmental psychology in the built environment.

Another research discussion mainly focused on the tests for the media interaction and the solar shading function of IFS compared to existing façades (H3). The facades should be designed to control solar radiation to provide thermal and visual comfort and so decrease energy consumption. Solar radiant exposure was evaluated in terms of the effect of the perforated metal media façades in terms of the shading function. Using the Ladybug plug-in in Grasshopper software, the effect of solar radiation is compared to the case with and without IFS (Figures 11 and 12). The baseline façade is referred to as the glass curtain wall, current PVC coating is not included for the baseline façade.

The solar radiation was calculated for all year, summer, and winter periods. So, the results can be compared according to the effect on two periods. The summer period was determined as June, July, August, and September which have mean air temperatures >25 C°. The winter period was determined in November, December, January, February, March, and April which have mean air temperatures <15 C°. Since the months are determined according to mean air temperature May and October are included in these two periods. In the other words, the summer period is from May 15th to October 15th and the winter period is from October 15th to May 15th.

The results showed that solar radiation value decreased from 272/ sq. m. to 116/ sq. m. When panels are used total solar radiation (total of all floors) has decreased by 57% for both all year and summer periods. The difference in solar

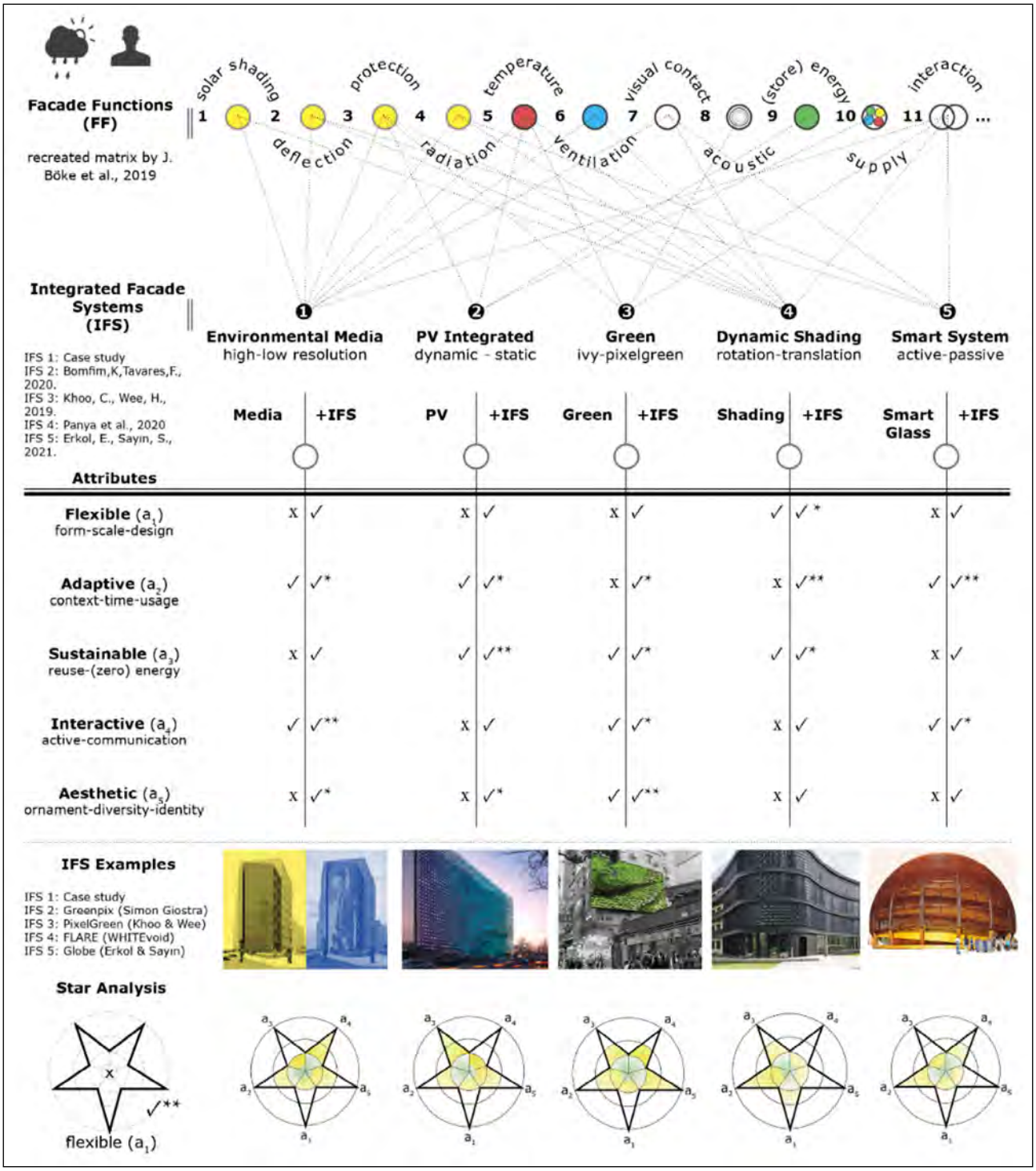

Figure 10. Schematic representation of the IFS attributes and correlations.

radiation between the summer and winter periods is 7% without panels and 6% with panels. As expected, the panels decreased the solar radiation for all year, even in winter period.

The results showed that the first floor has higher solar radiation than others under conditions "with IFS panels". The reason for that is the calculations have been done considering that the first floor hasn't panels on its south facade as different from other floors. With the using IFS panels, the solar radiation has shown a decrease towards the upper floor except on the last floor (seventh). The panels have smaller holes towards the last floor and this explains the decrease in solar radiation. The panels are away from the facade 0.55 m, and this leads to solar radiation getting

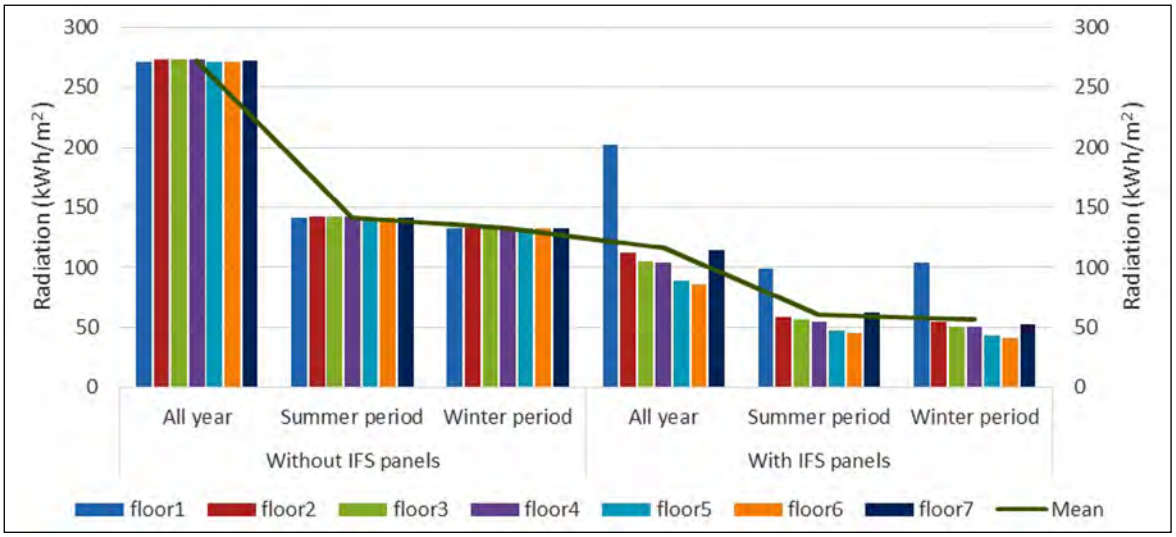

Figure 11. Solar radiation of floors without and with IFS panels for all year, summer period and winter period.

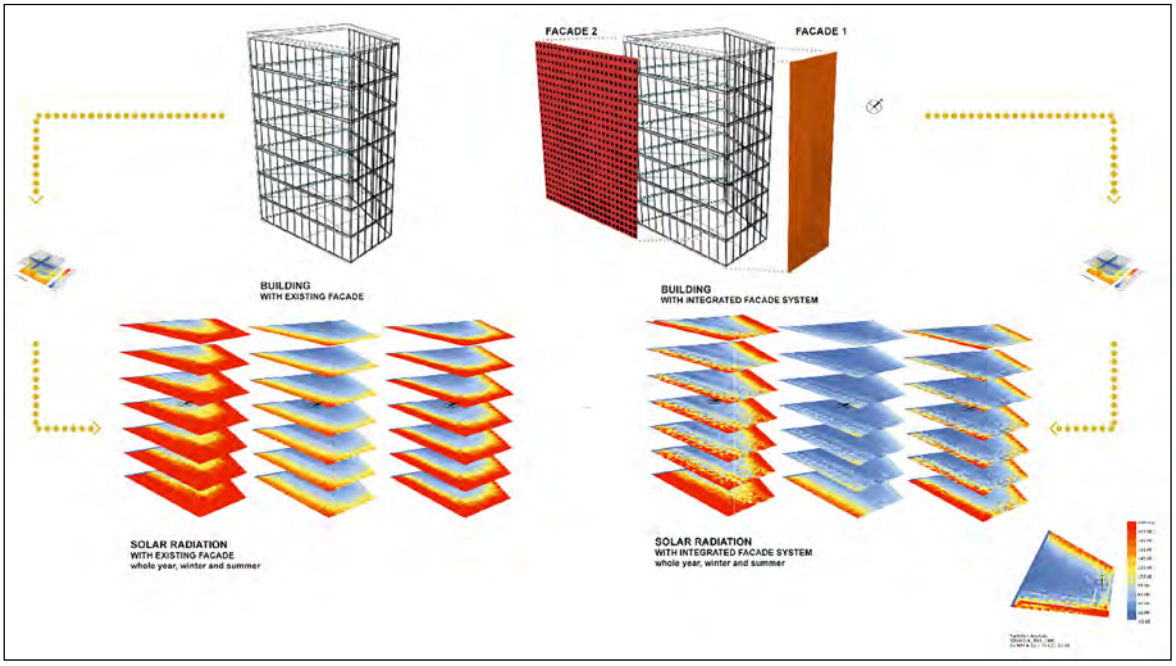

Figure 12. Comparison of solar radiation values for baseline façade and IFS: with the existing façades on the left and with the new developed façades on the right.

inside from the upper gap. As a result of this situation, the last floor has higher solar radiation.

The decrease in solar radiation after using panels can lead to a decrease in the cooling loads during the summer period. However, it also can lead to an increase in the heating load. This study aimed to develop IFS via computational design strategy and investigate it in terms of media display and its effects on solar radiation. So, the effect of IFS on energy consumption can be a subject for future studies. It may be recommended to use IFSs during the summer period and to limit their use in the winter period. In addition, when IFSs are used, they can also be analysed in terms of visual comfort in future studies, as they will also reduce the daylight brightness of the indoor environment.

CONCLUSION

Despite the growing literature on energy-efficiency, interaction, interior comfort, and other related subjects with facades, there are few examples of research that combine the different facades requirements computationally. This paper presents a computational design strategy for IFS, as a sustainable solution for media display and solar shading on building façades. The design framework is developed and

tested with the main concerns of two façade types. In detail, it is based on attributes and parameters between data, geometry, and simulation. In particular, the designer is able to use effectively visual output and numerical data from solar radiation analysis. The algorithmic system can adapt to different situations with considerable affordances that guide different project designs rather than a single project. Along with the solar simulation which is included with all-year solar radiation values in this case, daylight, shadow, wind, and precipitation simulations can also be integrated into the algorithm according to the design requirements.

According to hypotheses, results refer to achievement, especially in three sections:

(1) IFS provides an appropriate and practical model for the synthesis of simulation and analysis output data in a wide range of environments since it is a parametric and computational design model.

(2) Multi-functions on the façade can be moderated together with the ease of use of perforated metal panels. However, new material compositions, technical and structural details can offer better solutions. To deepen this research in this direction, an interdisciplinary perspective related to concerns of the façade system should be part of this model.

(3) The shading function of the façade is aided by the simulation of site-specific local climate data in winter and summer periods, and the contextual analysis of the media display allows interaction depending on the resolution.

Regarding the design and renovation process, especially wicked problems requiring adaptive and integrative strategies, the research provided significant correlations between different IFS, and compartments with the baseline structure. As a result, the IFS approach offers higher productivity by decreasing the time spent on developing and testing design alternatives. In particular, one of the most valuable aspects is resilience to the systems when dealing with challenges and adaptation to constantly changing conditions.

Finally, several limitations need to be reconsidered. The scope of the study was limited by computational design and partial mock-up experiments in the early design phase due to the high cost of the LED-integrated perforated panels. Digital fabrication techniques have great potential to improve the integration level of LED and perforated panels. The research has the opportunities of a workshop that was held in university and industry collaboration. Thanks to the collaboration, the interaction of different project groups and a participatory process have been created. However, it is necessary to increase the practical potential of the design idea with the opportunities of fabrication to find consistent solutions to the problem by realising requirements and constraints. The production of a 1:1 prototype can also be seen as an opportunity for the design process and the development of IFS approaches. With the production at 1:1 and experimental study, some details can be evaluated, like panels' distance from the façade, material, thickness, etc. This production can also be integrated with more detailed results of simulations. In future studies, different physical simulation inputs can be added, so that the produced façades can be made more efficient.

Secondly, "the panel" as Euclidian geometry needs to be enhanced to non-Euclidian geometry to overcome the form limitation. Therefore, future research could examine the potential and limitations of non-Euclidian-geometry. For the last limitation, numerous IFS samples are critical to understanding the potential. Research can extend to different dialectics beyond façade applications.

To further our research, the researchers of this study intend to design a new graphical user interface (GUI) to make the system utilised for other stakeholders. Therefore, the GUI is more user-friendly than the visual script-based structure, with high utility in manipulating the design system without specific knowledge. One of the desirable future investigations is to enable interactivity in a panelized media façade by increasing user interaction with any game engine.

Acknowledgements
The study presented in this paper is part of the Ph.D. course instructed by Assoc. Prof. Dr. Togan TONG (Yildiz Technical University).

We would like to thank our industry collaborator KASSO Engineering for providing the opportunity to use equipment and technical facilities.

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 88–97, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/MEGARON.2023.00868

Article

Comparison of hemp fibres with macro synthetic fibres in lime-metakaolin matrix incorporating pumice as coarse aggregates

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ARTICLE INFO

Article history
Received: 11 November 2022
Revised: 05 January 2023
Accepted: 06 January 2023

Key words:
Hemp; lime; macro synthetic fibre; metakaolin; pumice

ABSTRACT

Significant developments are observed in the design of composite building materials nowadays, especially on environmental and sustainability issues. For structural usage, nowadays researchers reveal lime, which is the traditional binding material known since ancient times. Lime known for its sustainable feature is often used with supplementary cementitious materials (SCM) such as metakaolin, fly ash, ground granulated blast furnace slag, and silica fume due to unfavourable properties regarding durability, strength, and slow hydration rate. On the other hand, cellulosic fibres with the advantages such as low density, high tensile strength, and moderate elastic modulus have cost competitiveness and eco-efficiency for fibre-reinforced composites. The structural use of cellulosic fibres may be possible if the degradation of hemp fibres in an alkali environment is mitigated. In this study, the experimental studies on hemp fibres were carried out by comparing with two types of macro synthetic fibres in a lime+metakaolin (L+MK)-based matrix. Durability as well as compressive and flexural characteristics were addressed in those fibrous matrices. First time in the current literature, macro synthetic fibres were included in the lime-based mixture. Besides, as a new contribution, coarse lightweight aggregates (LWA) were incorporated into this type of matrix with those fibres. The experimental findings indicate that the degradation of hemp fibres can be mitigated successfully, and three types of fibrous mixtures provide proper mechanical characteristics in their categories.

Cite this article as: Havva Merve Tuncer, Zehra Canan Girgin. Comparison of hemp fibres with macro synthetic fibres in lime-metakaolin matrix incorporating pumice as coarse aggregates. Megaron 2023;18(1):88–97.

INTRODUCTION

Lime is an important binding material from the past to the present and is a natural component for sustainable design. Cement came into prominence after the industrial revolution. However, due to the relatively high carbon footprint of cement, lime as a traditional material has become popular as a sustainable structural material again. On the other hand, eco-friendly and low-cost cellulosic fibres such as hemp, jute, and flax have become another important part of sustainable design with their proper mechanical characteristics (Yan et al., 2014) in recent years.

Air lime (L), which is different from natural hydraulic lime (NHL), should not be used as a binder alone due to

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poor durability and mechanical characteristics. Hence, supplementary cementitious materials (SCM) such as blast furnace slag (Seo et al., 2021), fly ash and silica fume (Koteng and Chen, 2015), and metakaolin (Silva et al., 2014) are combined with air lime for secondary hydration reactions.

Polymeric fibres such as polypropylene or nylon fibres have low elastic modulus and high elongation capacity (Zhang et al., 2020), and are used in implementations not requiring high toughness, often to prevent drying shrinkage cracks. Macro synthetic fibres are a rather new group of polymeric fibres and the studies in the literature focus on only cementitious matrices (Altoubat et al., 2009; Amin et al., 2017). On the other hand, cellulosic fibres with moderate elastic modulus are sustainable and cost-competitive materials. Using cellulosic fibres with structural aims is only possible by mitigating degradation under alkaline conditions. Lignin and hemicellulose content of cellulosic fibre can easily degrade (mineralisation, decay of cell wall) in an alkaline environment and the fibre loses its integrity (Wei & Meyer, 2014; Ardanuy et al., 2015). Removal of these unstable phases necessitates the fibre treatment through alkali solutions (e.g., NaOH), or more practically and economically SCM replacement to fix Ca(OH)2 (portlandite, CH). Alkali treatment may not be practical, economical, and effective (le Troëdec et al., 2009; Kabir et al., 2013). The other alternative via SCM for cellulosic fibre-reinforced concrete, especially silica fume and metakaolin mitigate the degradation in fibres, and prevents the drop in the mechanical characteristics (Mohr et al., 2007). For lime binders, some studies (Gameiro et al., 2012; Pavlík & Užáková, 2016) indicate the efficiency of metakaolin to remove CH. Metakaolin (MK) usage enables a more economical solution compared to silica fume as well.

Among different cellulosic fibres, hemp (*Cannabis Sativa L*) is cultivated for the manufacturing of ropes, textiles, and papers over the years. However, in the construction industry, mostly shiv (the woody core of the *hemp* plant) is used as coarse aggregate in low-strength lime concrete for insulation purposes (Delannoy et al., 2018). Hemp, as a fibre type, can be combined with cement-based (Sedan et al., 2008) or lime-based mortars (le Troëdec et al., 2011) as chopped fibres or textile mesh in last years. The purpose of this study is to enhance the structural performance of hemp fibre in a lime-based matrix and to compare it with macro synthetic fibre. The current literature on lime, metakaolin and cellulosic fibres especially is on mortars (Walker et al., 2014; Wang et al., 2022) and there are no studies on lime-based matrix reinforced with macro synthetic fibres, as the authors' knowledge so far. In addition, coarse lightweight aggregates are also a new contribution to current literature for this matrix type including cellulosic and macro synthetic fibres. The experimental findings indicate the hemp fibre and two types of macro synthetic fibres result in proper mechanical and durability characteristics in a lime+metakaolin-based matrix.

MATERIALS AND METHODS

Fibres

Two types of macro synthetic (Figure 1a, b) and cellulosic-based hemp fibre (Figure 1c) were used in the experiments. The main properties of those fibres are given in Table 1, the volumetric ratio in the mixture is V_f=1%. Hemp fibres were used without applying any chemical treatment and by

Table 1. Characteristic properties of fibres

	Copolymer Fibre* (PP/PE)	Polypropylene Fibre* (PP)	Hemp Fibre (H) (Thygesen, 2006; Dittenber & Gangarao, 2012)
Raw material	Pure Copolymer	Polypropylene	Hemp
Length (mm)	54	54	54
Tensile strength (MPa)	550–750	550	690
Modulus of elasticity (GPa)	5.75	8.5	30–`70
Density (g/cm^3)	0.91	0.91	1.5

*Manufacturer data.

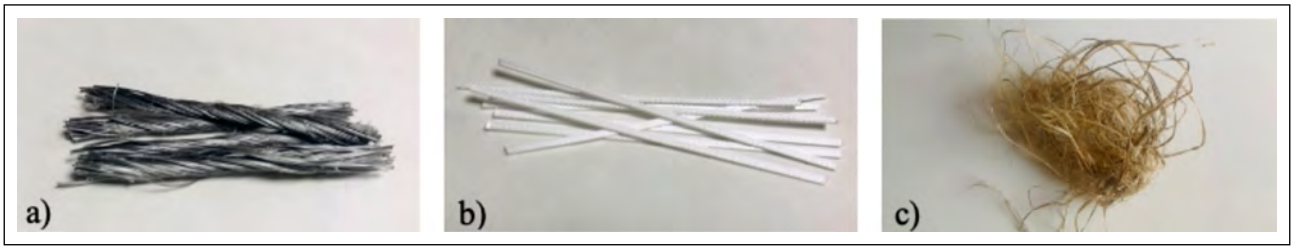


Figure 1. Fibres types. a) Copolymer fibre, b) Polypropylene fibre, c) Hemp fibre.

cutting them to a length of 54 mm. Due to the high water absorption capacity of hemp fibres, up to five times their own weight (Elfordy et al., 2008), they were soaked in water for two hours prior to mixing. Then, their surfaces were wiped with a towel (Poletanovic et al., 2021), and then they were added to the mixture. Co-polymer fibres are in a twisted bundle form composed of thin filaments (<1 μm), PP fibres are in 0.5 mm × 1.5 mm textured multi-filament strip form as well. Each hemp fibre essentially consists of numerous individual fibre cells down to <0.1 μm in diameter.

Aggregates

Fine aggregates are natural silica sand (0.125–2 mm) and crushed limestone (max. 4 mm). As coarse aggregates, volcanic pumice (VPA) aggregates (D_{max}= 9 mm) from the Nevsehir region in Turkiye were used. Physical tests were carried out according to ASTM C127-15 (ASTM C127-15, 2016). Water absorptions in 10 min and 24 h were determined at 13.1 and 19.9% by weight, respectively. Loose, and rodded bulk densities, and saturated surface dry density were found as 0.65, 0.68 g/cm^3, and 1.27 g/cm^3, respectively. Pumice aggregates were soaked in water for 24h prior to the experiments. The volumetric ratios of coarse VPA, silica sand and crushed limestone were chosen as 50%, 30%, 20%, respectively. Sieve analyses of the aggregates, combined gradation, and comparison with the Fuller curve are given in Figure 2.

Lime-Based Matrix

Lime and metakaolin were used as binding materials, the chemical composition and the particle size fractions are given in Table 2 and Figure 3. In order to decide the quantities of L and MK as well as water to binder ratio, the lime-based mixtures in the literature were examined. The targets for compressive strength were realised to be very low (with shiv) (Kinnane et al., 2016), and low (Stefanidou et al., 2017). MK replacement was used as 1:1 to remove CH from previous literature (Silva et al., 2014).

Mixture Characteristics

For the usage with structural aims as well, to achieve a compressive strength about 20 MPa was adopted. As all the coarse aggregates are pumice aggregates a few preliminary trials on the mixtures were carried out, and finally, it was decided to use a binder content of 350 kg/m^3, and water to binder ratio of 0.45. The quantities of ingredients and fresh densities of the mixes are given in Table 3. Herein, LLM denotes the reference mix, the first letter (L) implies lightweight, and LM indicates lime+metakaolin. H, PP/PE, PP signify hemp, copolymer fibre and polypropylene fibre, respectively.

In the preparation stage of the mixture, first, dry materials (binders, aggregates, and fibres) were mixed, then the water divided into three equal parts was added to the dry mixture.

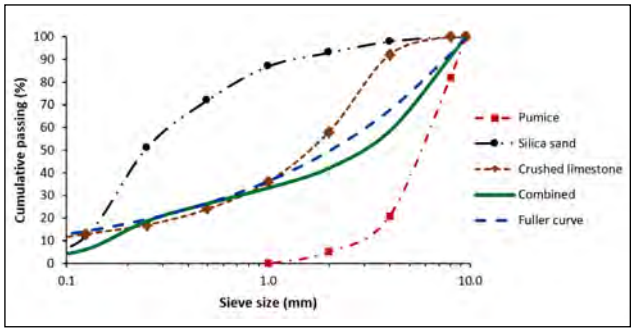


Figure 2. Sieve analyses of aggregates and combined grading.

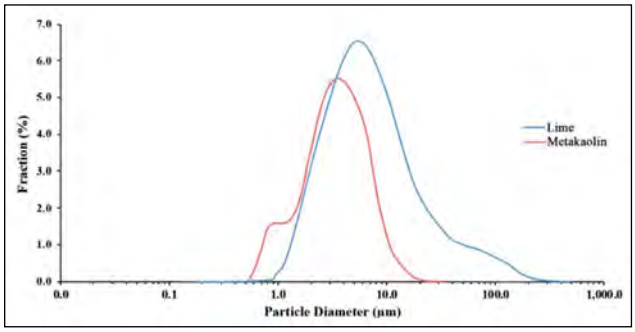


Figure 3. Particle size distribution of lime and metakaolin.

Table 2. Chemical composition (in wt.%) of lime and metakaolin

Binder materials and symbols	CaO %	SiO_2	$Al2O_3$	$Fe2O_3$	MgO	SO_3	Blaine fineness, m^2/kg
Lime	90	2.5	2.0	2.0	1.0	2.0	1072
Metakaolin	0.19	56.10	40.23	0.85	0.16	-	14600

Table 3. Mixture characteristics

Mixture	Lime (L)	Metakaolin (MK)	Pumice	Crushed limestone	Silica sand	Hemp fibre	Fresh densities
	kg/m$_3$					V_f (%)	kg/m^3
LLM	175	175	422	350	523	0	1790
LLM-H	175	175	415	345	514	1	1782
LLM-PP/PE	175	175	415	345	514	1	1799
LLM-PP	175	175	415	345	514	1	1792

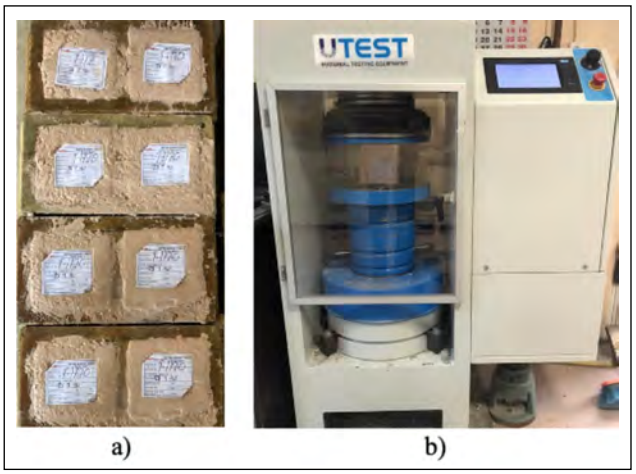


Figure 4. a) Cubic specimens, b) Compression test machine.

After then, about 1.5% HRWR was added in a controlled manner along with one-third of the water. The mixing process continued until the formation of a homogeneous mixture and a target slump of 10-15 cm was obtained. After demoulding one day later, the samples were cured at 20±2°C and 50%RH until 7- and 28- days for testing. In addition, the aging period following 28 days was conducted for the samples of LLM-PP/PE, LLM-PP, LLM-H series in a hot water tank at a constant temperature of (50±2)°C for 10 days according to ASTM C1560-03 (ASTM C1560-03, 2016).

Meanwhile, the fresh density for LLM samples was measured as an average 1790 kg/m^3 (±15 kg/m^3) (Table 3). Theoretical fresh density with normal aggregate (limestone, by assuming its particle density as 2700 kg/m^3) is calculated as 2285 kg/m^3, this means 22% lower density for LLM due to coarse pumice aggregates.

PREPARATION OF SPECIMENS AND TEST SET-UP

For compressive strength tests, three cubic specimens (100 mm) were prepared for 7 and 28 days in each series, i.e., total of 24 specimens. Those tests were performed in accordance with BS EN 196-1 (BS EN 196-1, 2016) (Figure 4a) using 3000-kN UTC Automatic Compression Testing Machine (Figure 4b).

For flexural tests, seven prismatic specimens (40 × 40 × 160 mm), were prepared (BS EN 12390-1, 2021) for 7, 28 days, and after aging in each series, i.e., 84 specimens (Figure 5a). Three-point bending tests were carried out in a deformation-controlled testing machine (MTS Criterion Model 43) at a load rate of 0.3 mm/min (BS EN 12390-5, 2019) (Figure 5b). Accelerated aging tests were conducted in accordance with ASTM C1560-03 (ASTM C1560-03, 2016).

A typical load-deflection diagram is given in Figure 4c. P_{cr} and Δ_{cr} in stage (I) signify critical load level and deflection that the matrix cracks. After a sudden decrease in Pcr level, the fibres bridge the matrix cracks and transfer loads. The other terms P_p and Δ_p in stage (II) define peak load and peak deflection. The following stage (III) is involved in toughness and Δ_u represents the ultimate deflection.

TEST RESULTS

Compressive Strength Tests

Compressive strengths of four series in 7 days and 28 days are shown in Figure 6 with standard deviations in parenthesis. For LLM-PP/PE and LLM-PP series with macro synthetic fibres, increments of 19% and 13% compared to 28-day reference specimens were observed, respectively. From 7 days to 28 days, the least change (46%) within all fibre-reinforced series was observed in LLM-PP/PE series.

In the hemp-fibre series (LLM-H), 7-day compressive strength decreased by 33% compared with reference ones, however, the reduction in 28 days was only 14%. The strength

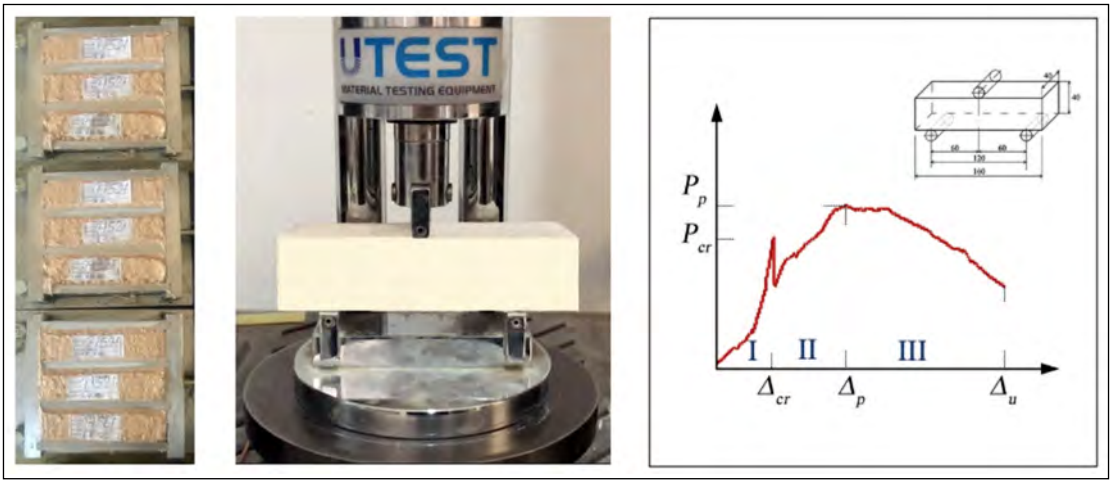


Figure 5. a) Prismatic specimens b) Bending test set-up c) Typical load-deflection diagram.

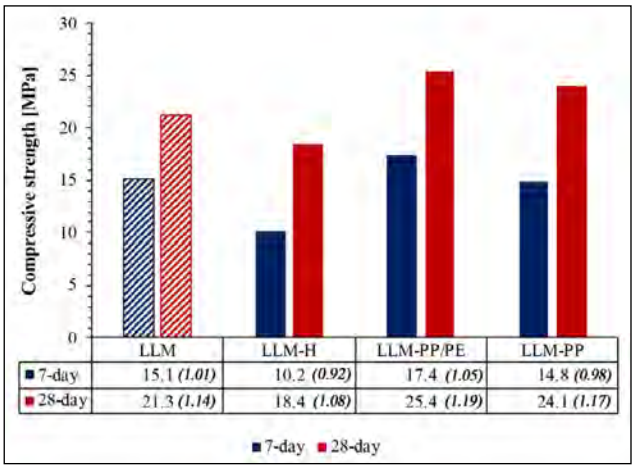


Figure 6. Compressive strengths of four series.

increment from 7 days to 28 days is 80%, the highest one within four mixtures. Herein, the higher reduction in 7 days can be partially attributed to the saturation of hemp fibres with water prior to the experiment. As another parameter affecting 7 and 28-day strengths, it is noted from a previous study (Awwad et al., 2012), the decrease in compressive strength is expected as the cellulosic fibres in the matrix are weak under compression.

Bending Tests and Evaluations

For all series, the flexural parameters (P_{cr}, P_p, Δ_p, Δ_u) in bending tests (Figure 5c), are given with averaged values for the tests of 7-, 28-day and after aging in Figures 7 and 8, the values in parenthesis are standard deviations.

The peak loads (Pp) in the series with macro synthetic fibre (LLM-PP, LLM-PP/PE) significantly increased (55–60%) in 28 days compared with reference samples (LLM). From 7 days to 28 days, the increment of P_p is the highest (64%) in the LLM-PP/PE series and the second highest (31%) in the LLM-PP series within four series. The ultimate deflections (Δ_u) enhanced about two times compared with the deflection in peak load (Δ_p). The highest increase (38%) in Δ_u values occurred in LLM-PP series after aging. Two polymeric macro synthetic series are essentially in hydrophobic characters (Bentur & Mindess, 2007). The flexural performances of those fibres in this study are attributed to better bonding performance owing to mechanical shear resistance due to their twisted bundle and textured multifilament forms in addition to interfacial frictional adherence. It is interesting that the frictional resistance governed the flexural behaviour, especially after aging, and this behaviour indicates the mechanical anchorage between hydrated products and fibre surface not to be so effective in this stage. In addition, there is an abrupt drop, or loss in bonding, immediately after the peak load in the LLM-PP series after aging.

In hemp fibre specimens (LLM-H), a 17% increment in P_p was observed from 7 days to 28 days. P_p values, 28 days and after aging, are 8%, 24% higher than P_{cr}, respectively. Ultimate deflection (Δ_u) increased 38% from 7 days to 28 days and decreased only 15% after aging. Deflection capacity over three times exists from Δ_p to Δ_u level, and there is no abrupt drop. The ductile behaviour even after aging is attributed to the mitigation of degradation due to binding

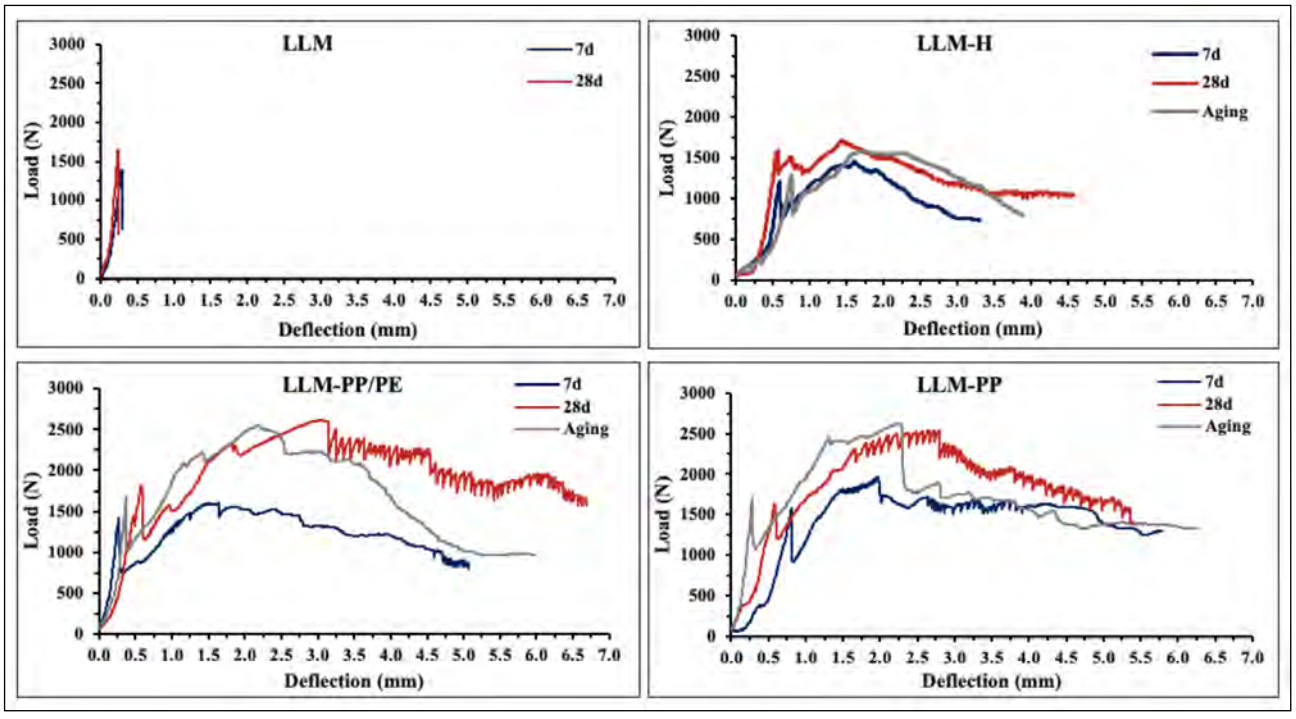
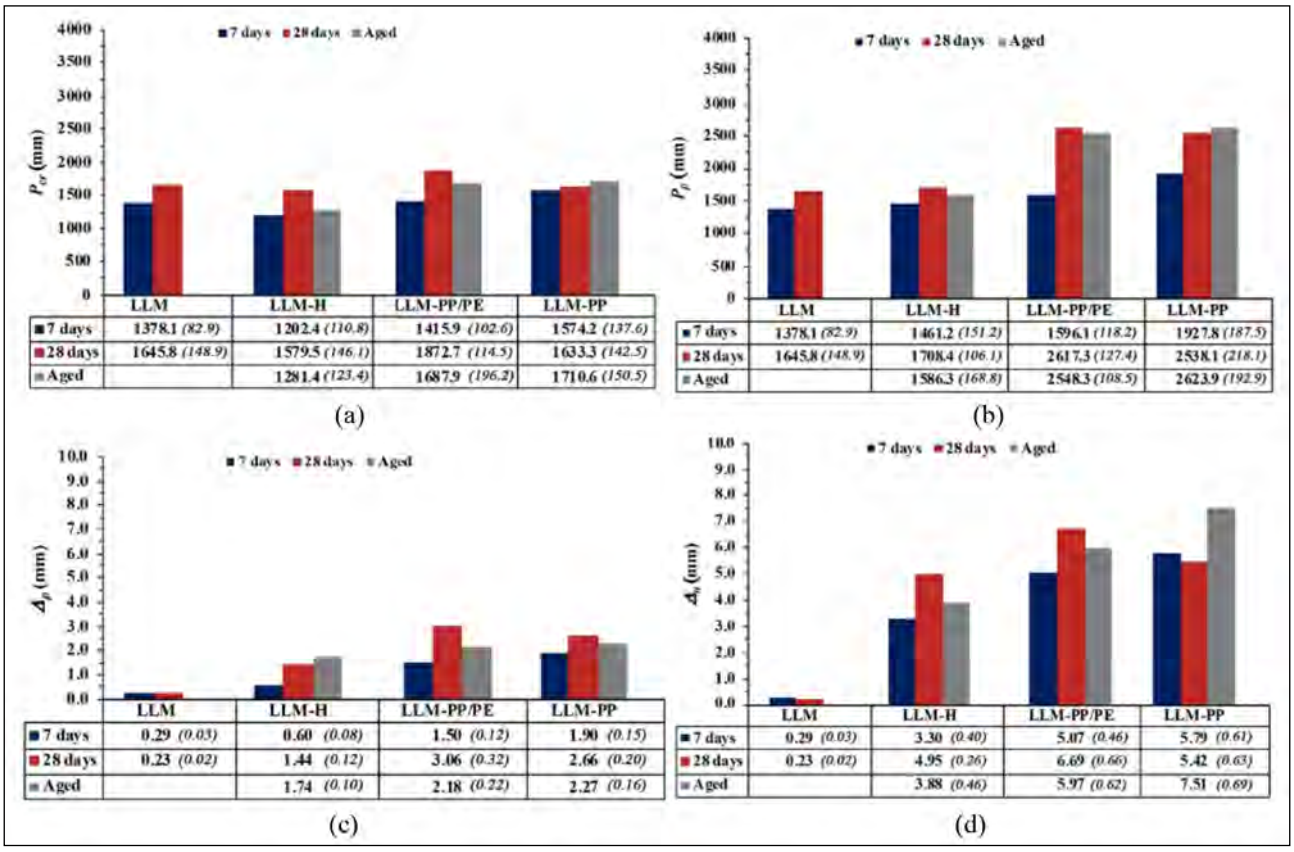


Figure 7. Load-deflection curves of mixes at 7, 28 days and after aging.



(a)	LLM	LLM-H	LLM-PP/PE	LLM-PP
7 days	1378.1 (82.9)	1202.4 (110.8)	1415.9 (102.6)	1574.2 (137.6)
28 days	1645.8 (148.9)	1579.5 (146.1)	1872.7 (114.5)	1633.3 (142.5)
Aged		1281.4 (123.4)	1687.9 (196.2)	1710.6 (150.5)

(b)	LLM	LLM-H	LLM-PP/PE	LLM-PP
7 days	1378.1 (82.9)	1461.2 (151.2)	1596.1 (118.2)	1927.8 (187.5)
28 days	1645.8 (148.9)	1708.4 (106.1)	2617.3 (127.4)	2538.1 (218.1)
Aged		1586.3 (168.8)	2548.3 (108.5)	2623.9 (192.9)

(c)	LLM	LLM-H	LLM-PP/PE	LLM-PP
7 days	0.29 (0.03)	0.60 (0.08)	1.50 (0.12)	1.90 (0.15)
28 days	0.23 (0.02)	1.44 (0.12)	3.06 (0.32)	2.66 (0.20)
Aged		1.74 (0.10)	2.18 (0.22)	2.27 (0.16)

(d)	LLM	LLM-H	LLM-PP/PE	LLM-PP
7 days	0.29 (0.03)	3.30 (0.40)	5.07 (0.46)	5.79 (0.61)
28 days	0.23 (0.02)	4.95 (0.26)	6.69 (0.66)	5.42 (0.63)
Aged		3.88 (0.46)	5.97 (0.62)	7.51 (0.69)

Figure 8. a) Critical load (P_{cr}) b) Peak load (P_p) c) Deflection in peak load (Δ_p) d) Ultimate deflection (Δ_u).

CH through MK substitute with air lime. Otherwise, the brittle behaviour via a sharp drop is expected after peak load, largely similar to the LLM series. P_p and Δ_u levels are not as much as macro synthetic fibres, which can be attributed to the fact that hemp fibres are cellulosic-based, hydrophilic, and in a different category.

DISCUSSION

Air lime which has non-hydraulic properties is known to be unsuitable especially in point of durability characteristics, e.g., low frost or moisture resistance, high shrinkage strains (Pavlík & Užáková, 2016). In order to gain hydraulic characteristics as well as higher strengths, the L+MK combination is known to be very effective. There are several compounds from that chemical reaction, one of those products is katoite ($Ca_3Al_2(SiO_4)(OH)_8$) having negative effects on the durability of the matrix. A 50% MK substitute was proven to the katoite formation to prevent during 1.5-year curing (Silva et al., 2014), and this ratio – not a lower ratio – fixes almost CH starting from the early period of curing as well.

The modulus of elasticity in polymeric fibres is low, and the deformation capacity is high (up to 30%) (Zhang et al., 2020) compared to well-known fibres such as glass or basalt fibres (2–3.5%). In this study, the deflections in the series with macro synthetic fibres (Figures 7 and 8, Figure 9) are attributed to those characteristics. On the other hand, some cellulosic fibres such as hemp, jute, and flax attract attention with their moderate modulus of elasticity, and deformation capability similar to glass or basalt fibres (Yan et al., 2014; Zhang et al., 2020). Finally, rather similar tensile strengths to polymeric fibres are also an important feature for the structural use of cellulosic fibres. Thus, the lower deformation ability of hemp fibres in bending tests is not a deficiency, similar deflections are observed in glass and basalt fibres for moderate toughness.

The hydrophobic structures of polymeric fibres (Bentur & Mindess, 2007) negatively affect interfacial bonding with cement. In the absence of chemical reactions, the adherence can be tolerated to some extent by enhancing mechanical bonding, e.g., the changes in the form such as textured multifilament or twisted bundle similar to macro synthetic fibres in this study. Thus, the pull-out of macro synthetic fibres was substantially observed through debonding in Stage III (Figures 5c and 7), especially in 28 days, and this performance is very satisfactory. However, it is observed that the mechanical anchorage in 7 days and after aging was not so effective. Herein, MK ratios lower than 50% may be proposed to explore the variation in flexural performance, e.g., 33% MK ratio in which CH is not fully consumed and katoite is not formed in the long term (Silva et al., 2014).

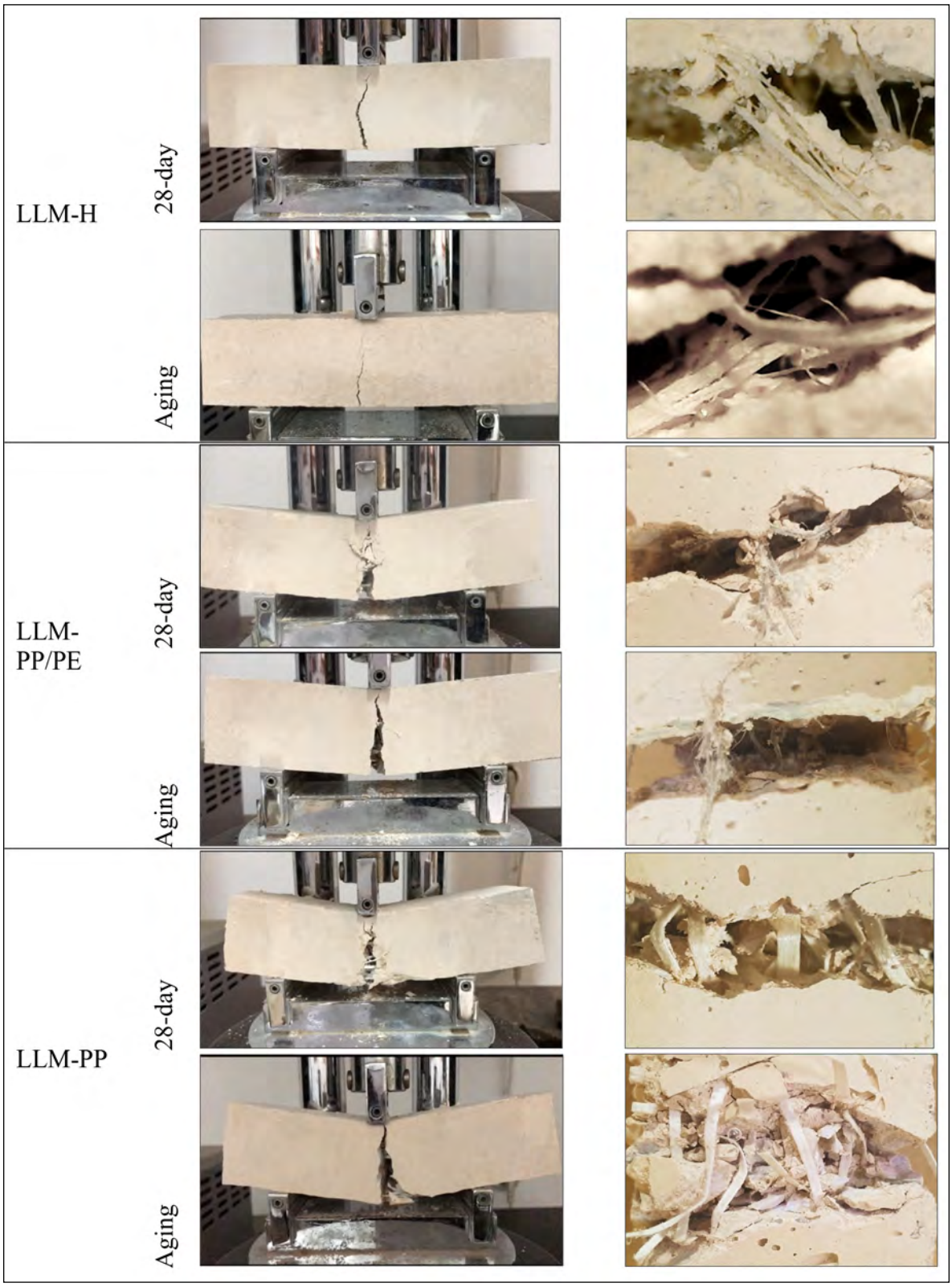


Figure 9. Crack patterns and microscopic images in 28-day and after aging.

Brittle behaviour in mixtures with cellulosic fibre is attributed mainly to the crystallisation of CH in the lumen, walls, and voids in the cellulosic fibre (Ardanuy et al., 2015). The adsorption of calcium and hydroxyl ions (Filho et al., 2013) by fibre surface leads to the disintegration of fibre structure (Ghosn et al., 2020), and the deformation loss

Figure 10. Views from hemp fibres after aging.

under bending happens through a sudden rupture almost without pull-out even at 28 days. In this study, especially the mitigation of the degradation and the maintenance of flexural deformations were the main targets. Enhanced flexural performance rising from the experiments is a result of consuming CH in the matrix, and brittle behaviour was prevented. Its evidence can be observed in the existence of strain softening (Stage III, Figure 5c) governing the toughness (Figure 7), crack mouth (Figure 9) and clean fibre surfaces (Figure 10).

As another comparison, the fresh density of LLM cubic samples was measured as an average of 1790 kg/m^3 (Table 3), which is 22% lower than the theoretical normal-aggregate mix of 2285 kg/m^3 (crushed limestone by assuming as 2700 kg/m^3). Prior to compressive strength tests, the density of LLM samples was measured at 6.3% lower (average 1678 kg/m^3) as a result of coarse pumice aggregates in the mix design which have lower density and gradually release water for internal curing.

The combination of L+MK, in comparison with the poor performance of L, is very efficient to decrease shrinkage deformations. Pavlík and Užáková (2016) investigated the effect of curing conditions and indicated that the 1:1 L+MK combination almost prevents the shrinkage deformations at sealed a chamber (RH 100%), and highly prevents it for RH 65%. For hemp fibre reinforced L+MK mortar (66%L+33%MK), drying shrinkage deformations decrease by about 60% (Wang et al., 2022) compared with lime mortar, smaller pore sizes and the enhancement in durability issues are other positive results. It is noted that the positive effect of coarse pumice aggregates (Akcay & Tasdemir, 2009) in cementitious binders to prevent the shrinkage cracks by gradual water release may be considered for fibre-reinforced L+MK composite in this study as well.

The fire resistance of fibre-reinforced lime-based composite is another issue to predict, and it depends on the ingredients. For lime- and blended mixtures (Pachta et al., 2018) L-mix has the lowest fire resistance and pozzolanic components significantly increase the fire resistance. By comparing with concrete, for a one-hour fire duration at 800°C (Hossain & Lachemi, 2007), the samples with coarse pumice aggregates maintain about 40% of the initial strength, that ratio is about 20% for normal-aggregate concrete; the melting of the PP fibres is below 400°C, however, some of the hemp fibres still present (Netinger Grubeša et al., 2018).

CONCLUSIONS

More importance should be given to sustainable design in buildings to reduce carbon footprint. In this study, the possibilities for more usage of sustainable resources in structural members have been explored. Lime and pumice aggregates were addressed as sustainable resources. Cellulosic fibres and macro synthetic fibres in lime-metakaolin-based matrix were studied experimentally. The coarse pumice lightweight aggregates were used in a lime-based matrix with those fibres. The results from this study are summarised below.

- In specimens with macro synthetic fibres, rather similar performances was observed. In 28-day specimens, a good mechanical adherence in the interface of hydrophobic polymeric fibres and matrix were observed, and debonding behaviour is dominant around peak load and beyond it. After aging, more smooth form of the P-Δ curve indicates the decline of mechanical anchorage and pull-out mode transforming to fibre slippage. The lime+metakaolin-based matrix positively affected the debonding behaviour of macro-synthetic fibres (Figure 7).
- CH removal through 50% metakaolin addition provides the pull-out mechanism in hemp-fibre reinforced specimens to maintain even after aging test which provokes CH release. The rather clean surfaces of the hemp fibres were also observed in optical micro photos (Figure 10). The mitigation of the degradation in cellulosic fibres was satisfied for hemp fibres successfully. There is an increase in deflection capacity over three times from Δ_p to Δ_u (Figure 8).
- Strain softening (Stage III, Figures 5c and 7) was observed in three fibre types as well. This stage points

out the toughness, and three fibre types seem to have suitable flexural performance in their own categories.

- As some suggestions; the hemp fibres can be alternative to polymeric fibres to prevent shrinkage cracks in mortar-based plasters, and the combination with coarse pumice aggregates may be used in RC slabs, composite decks of steel structures or timber structures to prevent drying shrinkage cracks for sustainable solutions. Pumice aggregates will also allow a more lightweight design and fire resistance.

Acknowledgment
The experiments in this study were carried out in the R&D Dept. of NUH Beton Inc. Material, employer and equipment support of the firm to this experimental research are greatly appreciated. The authors would like to thank Soylu Group for providing pumice aggregate and Kaolin EAD for providing metakaolin as well.

- *This article is based on the PhD Dissertation entitled as Enhancement of Acoustic and Flexural Characteristics for Steel and Wooden Composite Decks Using Sustainable Materials by Havva Merve Tuncer and completed under the supervision of Prof. Dr. Zehra Canan Girgin at YTU, Department of Architecture in 2023.*

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 98–111, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2023.57983

Article

Studio exercises within the intuitive and intellectual approach in basic design education

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ARTICLE INFO

Article history
Received: 03 August 2022
Revised: 22 March 2023
Accepted: 23 March 2023

Key words:
Afyon Kocatepe University; basic design education; interior architecture; learning styles; studio exercises

ABSTRACT

Basic design is a totally critical and authentic course for all disciplines related to designing. When designing is considered as a process of problem solving, the main purpose of the course can be regarded as conveying the conceptual, abstract thinking approaches to students. The type of education students received earlier as well as students' habits, mental memory and visual perception are all effective in the process of solving design problem. This study discussed design process managed with both intuitive and intellectual approach while solving design problem. The study was conducted as a two-stage experimental research to analyze the methods students use while solving design problems. First, a questionnaire was administered to students to gain information about their learning styles. Secondly, studio exercises were performed within the Basic Design course. The following was the question of this study: "What sort of problem-solving attitude did people display and what were these people's learning styles? Consequently, what sort of results were achieved?" At the end of the studio exercises, a second questionnaire form was administered to determine students' approaches to design problems and the methods they used in the solving process. The second questionnaire was administered to students who were divided into two groups according to the learning style they preferred based on result of the first questionnaire. According to results; the hypothesis developed in the context of the interaction between process and method of solving the design problem and learning style and prior education was confirmed with the relevant data.

Cite this article as: Okuyucu ŞE, Çoban G. Studio exercises within the intuitive and intellectual approach in basic design education. Megaron 2023;18(1):98–111.

INTRODUCTION

Jones (1992) defined the design process as a serious event that starts with the procurement of human made materials and components and ends with impacts on society. Therefore, the design discipline is applied not only in the fields related to artistic skills, but also in various disciplines ranging from natural sciences to social sciences. The Turkish educational system has two options for students who aim to be designers. The first is to take the annual exam conducted by the Student Selection and Placement Center, while the other option is to take the aptitude tests conducted by the institutions that provide

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undergraduate education in the fields of art and design. The student selection exam score where the qualitative and quantitative reasoning skills are assessed should be used to select a school for undergraduate education in Architecture, Landscape Architecture or Interior Architecture, regardless of the high schools, such as fine arts high school or another high school with math courses being dominant, attended by students. These departments accept the science-focused students who are successful on the student selection exam.

The first-year students receive design-based education in the Basic Design studio on the concept of design. Design is a major course for all design-related departments aimed at increasing visual sensitivity and raising design-related awareness. Basic Design is an unfamiliar course for students who are accustomed to studying with written texts and formulae (Günay, 2007; 93). According to Dikmen (2011), for students who start their undergraduate education following their success on the selection and placement exam, adaptation to design education is really challenging after abandoning the learning patterns that do not require questioning, that are based on rote learning, that only have one single correct answer, and that are focused on the instructor instead of the students. Atalayer (1993) stated that the visual skills of students whose verbal skills develop better than their visual skills could be improved and enriched with secondary education, which constitutes the focal point of Basic Design Education. Özkar and Steino (2012) noted that Basic Design, which is described as an abstract world with lines, surfaces, volumes, colors, and textures, includes learning by practicing, where hands are also used. Instead of the conventional methods of education, discussion through concepts and the process of asking questions with the efforts to develop ideas are more significant.

Accordingly, the purpose of this study was to determine the preferred design method of students, who were accustomed to scientific education, in the process of solving the design problem, based on their learning style, within the Basic Design course they received in the first term. Aspects related to determining the methods students used in the process of solving the design problem were accepted as follows:

- Students form the result-related composition with an intuitive approach by using their visual organization principles in a sensory context while solving the design-related problem.
- Students form their result-related composition with an analytical approach based on certain rules, propositions, and models and according to their educational habits in the process of solving the design-related problem.

In this study, after the Higher Education Institution's exam, the two-dimensional composition activity conducted within the Basic Design course with students who enrolled at the Department of Interior Architecture and Environmental Design within the Faculty of Fine Arts at the Afyon Kocatepe University was examined in the context of design methods associated with students' learning style scales. Subsequently, a questionnaire was given to students so that they could select scales regarding Kolb's (1984) learning styles' inventory. The learning styles selected by students formed the students' compositions and served as the basis for determining students' methods in the design process. At the end of the questionnaires, efforts were made to determine the relationship between the design method students preferred in perceiving and solving the design method and the learning style scales they preferred.

BASIC DESIGN EDUCATION

Design is lexically defined as "the form or thought imagined", "the first draft of an artistic work, structure or technical product", "design", "the frame specifying the route and procedures to follow in various periods of a research process," and "revealing a pre-perceived object or event through conscience later" (TDK, 2021). Moreover, Bayazıt (2004) defines design as the action of revealing and solving a problem that consists of the decisions made to fulfill goals, while Lawson describes the concept as follows: "Finding solutions to the needs within specific conditions" (2005; 7). The aim of design education is to provide a holistic perspective to students. This education provided in the disciplines of Painting, Sculpture, Ceramics, Graphics, Architecture, Interior Architecture etc. serves for the purpose of forming a common design language (Aslan, 2012). Despite the scale differences between these disciplines, Basic Design aims to help students acquire the habit of abstract and conceptual thinking, the most basic instrument of designing. Analyzing the problem, dividing the problem into parts, reaching the abstract plane through the concrete one, developing ideas, and returning to the concrete plane back become a possibility with Basic Design education.

There are a total of eighty-eight educational institutions in Türkiye that offer interior architecture education. Of these, twenty-nine are state universities and fifty-nine are foundation universities (Yökatlas, 2023). It is required to receive an adequate score on the Student Selection and Placement Exam conducted by the Higher Education Institution to receive education in the departments of interior architecture. Students are placed in their preferred educational institutions according to the scores they received on the Student Selection and Placement Exam. Consequently, there are students together in the interior architecture departments from both the high schools where students received mathematical education and the

high schools where students received fine arts education. It is aimed in the interior architecture departments that have two different student profiles together to constitute a shared design language with the Basic Design education.

The German Bauhaus movement with intellectual background based on Arts&Crafts movement and stylistic background based on Art Nouveau set a balance between technology and ideology, and constituted a significant triangulation for Basic Design Education (Aslan, 2012). The first implementer of Basic Design within Bauhaus was Johannes Itten who claimed that there were no major differences between the studies presented during the enrollment despite the difference between the profiles of students who enrolled, and that students needed to receive a preparatory course for a term so that instructors could have a better idea about students' skills (Itten, 2002). Through this course, students will gain basic information about the design process, before initiating the activity of designing, and their perspective regarding the topic of design will be broadened. In the Bauhaus doctrine developed with the Gestalt perception theory, the interaction between the student-instructor as well as the educational methods are significant. Bauhaus doctrine enables students to get free and learn by practicing, and abandon stereotypes by exploring the basic features of the instruments they use (Uluoğlu, 1990; Dikmen, 2010). Many institutions in the world that provide education in design and planning give compulsory basic design education in the first year. Generally, the education in this course, which is taught with the two and three-dimensional abstract representation methods, is based on the Gestalt design principles of the Bauhaus school. Other than these, different applications are also conspicuous. The Istanbul Bilgi University implements basic design education with the computational design methods (Yalınay Çinici, 2012), whereas the Middle East Technical University in Ankara is focused on space in the direction of certain concepts and focuses on technical drawings and rules of perspective together with this (Özgüner, 1966). Some educational institutions focus on concepts, such as materials and texture and to references from the concrete world. Students make design exercises with these by knowing the materials. Students at the Bursa Orhangazi University realize their course outside with clay and sand workshops (İstanbul Teknik University, 2014). According to Boucharenc' study (2006; 2), the Basic Design course is globally considered as a one-year activity and that the instructors of this course support one-year education for this course. The common point of this education is to teach students thinking, analyzing and developing themselves and the fact that students have difficulty understanding the course. Bauhaus doctrine effectively changed architecture and relevant disciplines. According to the study by Yıldırım (2018), the common point of the Basic Design course presented with different content in different institutions is the conveyance of Bauhaus-based information to students with different methods (Boucharenc, 2006; Yıldırım, 2018).

The Basic Design Education have courses where the conceptual frame and Bauhaus-based basic design principles are briefly instructed, but there are also opposing views that these courses are actually the presentation of studies conducted in previous years to students (Erdoğdu, 2016). Çubukçu and Dündar (2007) stated that presenting visual images to students during the course did not affect creativity, while showing the student studies performed in previous years as examples might cause students to incorrectly think that the design has only one correct approach and to create similar works. Relevant studies reflect that a process where students experience objects and events without limiting their own creativity should be followed, and that it would be a better method for students to gain information about the alternative solutions of problems considering the relevant studies as examples. In Demirkan and Afacan's study (2011), created an instrument to determine the criteria on which creativity depends in a first course design studio and tested this instrument in the evaluation of 210 result products. As a result of the study, the concept of creativity is related with;

- consists of the novelty and affective characteristics of artifact that are associated with its shape,
- the elaboration characteristics that are integrated with its geometric and figure ground relations and harmony of design elements
- consists of rhythm, repetition, unity, order and number of design elements.

Although the approaches regarding the Basic Design education differ, the main purpose here is as follows:

- Helping students gain the relevant layout perception by enabling them to understand that creating two or three-dimensional compositions is fundamental and by stressing the arrangement-related principles,
- Helping students develop abstract thoughts, gain the ability to represent, and acquire appropriate design language and skills,
- Helping students re-assess their environments through abstraction and conceptualization, and
- Helping students form designs and organizations by blending, organizing and changing the concepts of figure, form, color, pattern, material, scale and space (METU 2020, METU 2015).

According to Itten (1975; 62), the composition created with abstract forms helps consider the practices and develop new instruments of representation, whereas the Bauhaus doctrine contains the square partitions with the geometrical forms such as square, triangle or circle.

Practices of Basic Design education are conducted with the analogue instruments such as cut, fold or paste. Signs, symbols and similes should not be used in such practices. Use of basic geometrical forms directs students, and students who learned how to use these forms can create parametric and fluent designs (Erdoğdu, 2016). The Basic Design Education aims to present the basic two and three-dimensional principles, and it is generally supported by the principles of Gestalt doctrine shaped with reference to Bauhaus' perception psychology. The literature has various definitions of basic design education: creativity and problem-solving skills, visual perception and language (Beşgen et al. 2015, Denel 1981, Makaklı 2015). According to Zelanski and Fisher (1996), many people know much about the discipline of design but only a few of them are familiar with visual development. Therefore, Basic Design education aims to increase visual sensitivity and raise design-related awareness.

In the first year of education, no matter what the profession, it is expected that students will transform the learning habits coming from secondary education. Within the scope of the first year of education is giving up the learning method based on memorization in place of the learning method based on research. Whereas the design education with the subjects, such as acquiring different skills and creativity becoming part of the activity, makes it mandatory to have an approach that requires a somewhat more detailed evaluation in this process of transformation (Dural, 2000). Students in the existing educational system in Türkiye are used to working with written texts and formulas. Consequently, the abstract world formed of lines, surfaces, and volumes of design education is unfamiliar to students (Günay, 2007). The basic design course, which is the first place where the Interior Architecture Department students encounter design concepts, is of tremendous importance in design education from the aspect of providing for a permanent transformation in the forms of thought and a change in the habits of students coming from the past, who were used to an educational system based on memorization.

Each person shapes information in different forms. According to Türkyılmaz (2010), the methods people prefer in receiving and processing information are different. Some people learn about certain topics, such as mathematical models and theories, more easily while some understand schemes and graphs faster. According to the Experimental Learning Theory developed by David A. Kolb, who is one of the researchers that has many studies related to learning styles, the selection of experience indicates which form of learning style is preferred in the learning process of a person. Kolb, who shaped his studies on Lewin's Experiential Learning Theory, constituted a learning styles' model by also considering the views of Jung, Piaget, and Guilford (Veznedaroğlu & Özgür, 2005). According to Kolb's Experimental Learning Theory, it is constituted of the learning forms of concrete experience, reflective observation, abstract conceptualization, and active style of life phases. Although there are various educational theories regarding particular differences among learners and the role of experiential learning, few have been applied to design education (Chickering, 1977, Dunn and Dunn, 1975). In the study of Newland et al. (1987), there are four kinds of designers in relation to learning styles, these are common sense learners, dynamic learners, contemplative learners, and zealous learners. Demirkan (2016) investigated the relationship between the learning styles preferred by interior design students and their success levels in her study. Using Felder e Soloman's Index of Learning Styles in the study, Demirkan found that there are significant relationship between learning styles and achievement levels and the ranking is reduced in the form of Sensing/Intuitive, Visual/Verbal, Active/ Reflective and Sequential/ Global. In the study Kvan and Yunyan (2004) investigated the relationship between the learning styles and design studio performance of architecture students in China. According to study, there is a statistically significant correlation between learning styles and academic performance, As a result, convergers achieving significantly lower marks in one studio while assimilators succeeded in the other. This study emphasized that architectural studio programmes can advantage students with particular learning styles.

According to Kolb (1984), while acquiring information, people use all of the Concrete Experience, Abstract Conceptualization, Reflective Observation and Active Experimentation (Active Living) stages at different rates. During the Reflective Observation stage, students learn by watching and interpreting, but they use and transform their knowledge into a new case/product in the stage of Active Experiencing. In the Concrete Experience stage, learning is performed through intuitions and private experiences. The singularity and complication of the reality is preferred in place of theories and generalization, while an intuitive approach is prioritized over a systematical and scientific approach in the process of solving problems. In the Abstract Conceptualization stage, the rationale as well as concepts and thoughts have a more important place than emotions. Characteristics such as learning by thinking, analyzing, systematical planning and deduction are all important in this stage. Scientific approaches are important in terms of developing general rules and theories and solving a problems (Kolb,1984; Kolb, Baker and Dixon, 1985). The first-year design studio atmosphere of interior architecture education is a process where a major transformation is expected, especially for students. Students are confronted for the first time with design problems and learn to ask questions that would not define them and to seek suitable answers to this. Some of

the students who encounter this difficult process for the first time are attempting to find solutions with actions of thoughts and feelings, whereas some are attempting to find solutions with actions of following and doing. It was observed in the studies conducted that interior architecture design education, which has a different learning process from other disciplines, that students are displaying an intuitive (by feeling) or analytical (by thinking) approach and have a variable learning style with the experience they acquire in the perception, solution, and transformation to a final product (Demirbaş, 2001, Kvan & Yunyan, 2005). Kolb's four learning style models in the framework of design education (Aşkar & Akkoyunlu, 1993; Peker, 2003), even if they are used actively, only the concrete experience and abstract conceptualization phases from the learning forms by feeling or thinking, which are learning means, were evaluated (Table 1). Since the feeling and thinking learning actions were used more intensively within the scope of the basic design course in the process of solving the design problem, the reflective observation and active experience stages were not included in the study.

The concrete experience and abstract conceptualization stages, which are learning styles, were examined in the present study (Table 1).

In the design education, defining the information to be known and used for creating a design is critical. Cross (1982) emphasized that the discipline of design had its own particular information and learning methods. Accordingly, knowing much about how to create a design, rather than the concept of design itself, is more important. Two types of learning styles were examined in the present study according to Kolb's Learning Style Inventory. As noted by Chevrier et al. (Veznedaroğlu & Özgür, 2005), people's learning styles as well as their learning methods and ways are presented in Table 2.

In this study, the two types of learning styles were treated for the solution process of design problems within the scope of the basic design course according to Kolb's Learning Styles Inventory (KLSI). Within the scope of the study, it was thought that students having an established learning style, would solve the design problems with intuitive or artistic behaviors by using the experiences they acquired within the framework of "concrete experience" (learning by becoming experienced or by experimenting). In the study, at the stage of solving the design problem, in the context of providing a limited amount of time and the uses of codes learned, the Learning Styles Scale was used, placed on having attributes, such as being intuitive and providing harmony with the existing situation.

It was thought that within the scope of the study, students who had assimilated the learning style would solve the design problem with behaviors, which were analytical and systematic, by using abstract ideas and concepts, within the framework of the "abstract conceptualization" (learning by thinking) capability. In the study, at the stage of solving the design problem, in the context of there being rules and following a scientific approach, the learning styles scale was used that assimilated the attributes, such as organizing the knowledge in a good manner and extracting the inductive results.

Two scales were used as learning styles in the study, based on the assumptions from Kolb's learning style inventory. The reason for using "Accommodating" and "Assimilating" learning styles;

- Students display an intuitive (feeling) or analytical (thinking) approach while perceiving and solving the design problem and transforming it into a result product.

The characteristics and comparisons regarding the accommodating and assimilating learning styles defined according to Kolb's Learning Style Inventory are presented in Table 3.

The behaviors of the Interior Architecture Department students, who came from an educational formation based on science, displayed differences according to the learning styles in the process of solving the design problems in the first year

Table 1. The relationship between learning stages and styles and information type (Turkyılmaz, 2010)

Learning Stages	Learning Style	Information Type
Concrete Experience	Learning by Feeling	Descriptive Information
Perceiving the Information		
Abstract Conceptualization	Learning by Thinking	Descriptive Information
Perceiving the Information		

Table 2. The relationship between Kolb's learning styles, methods and ways (Veznedaroğlu & Özgür, 2005)

Learning Style	Learning Methods		Learning Ways	
Accommodating	Concrete Experience	Active Experimentation	Feeling	Doing
Assimilating	Abstract Conceptualization	Reflective Observation	Thinking	Watching

Table 3. Comparison of Accommodating and Assimilating Learning Style Characteristics

Accommodating Learning Style	Assimilating Learning Style
Acting with emotions rather than logical analyses	Valuing the logical soundness of theory rather than its practical value
Utilizing the experiences and gaining learning skills	Understanding information on a broad scale and organizing information and making it short and concise
Adaptation to conditions and flexibility	Planning, modeling, detecting the problems and developing theories
Being curious and intuitive	Being analytical, logical and systematical

of education. The findings obtained according to Demirbaş (2001) were in the direction of the different courses in the curriculum felt a need for different learning styles or in other words, students having different learning styles, became varied according to their academic performances and the contents of the course. When the data obtained were analyzed, it was observed that a great majority of the Architecture and Interior Architecture students were actively learning more than being verbal and more than learning visually and reflectively. It is stated that individuals who are in the profession of Architecture and Interior Architecture have mostly the Established and Factional learning styles according to Kolb's Experimental Learning Theory (Kolb, 1984). However, in the studies conducted on architectural education and learning styles, it was supported with evidence that students preferred different learning forms at different design phases. For example, persons who have assimilative learning styles, since they are interested in abstract ideas more than working with concrete products, are more successful in the first-year studies of architectural design education, which requires the capability of being able to perceive three dimensions in the design actions, such as depth, ratio and materials. Demirbaş (2001) considered the relationship between the learning preferences of students and the design performances they displayed by making different design studio exercises with first-year Interior Architecture Department students. When the comparative results of the design findings are studied thoroughly for the learning style determined with Kolb's Experimental Learning Theory, while students who had a certain learning style obtained advantages by the learning forms they preferred in different design style exercises, it was observed that individuals with the same learning style were at a disadvantage in different design exercises (Özdemir, 2013). Since there is a difference in the levels of success in the learning process of students, successful students reach the awareness of their own cognitive processes and know how they would learn. Accordingly, successful students can use different learning strategies that are suitable to their own learning styles (Nisbet & Shucksmith, 1986).

MATERIALS AND METHODS

This study aimed to reveal whether there was a relationship between the result product achieved by every student who used design-related knowledge with the intuitive or analytical approach and the learning methods students preferred to understand the development of designing within the interior architecture discipline. Accordingly, the relationship between students' design processes and learning methods was examined. A field study was conducted regarding the relevant examination covering the process where the freshmen in the Department of Interior Architecture and Environmental Design at the Faculty of Fine Arts of the Afyon Kocatepe University met the concept of design for the first time and solved the design problem assigned to them. The first year is particularly important for students in interior architecture education since students are supposed to transform their learning habits after secondary education. Students encounter the problem of designing in the first year. They learn to understand and solve the design problem, ask questions that will define the problem, and seek answers for that problem. In this study, an answer was sought for the following question: "What sort of problem-solving attitude did students display, and what were their learning styles? Consequently, what sort of results were achieved?" In this study, a hypothesis was developed for the interaction between the process and method of solving the design problem, learning style, and educational background (art-based or science-based educational background):

H 1. There is a strong relationship among the method of solving a design problem, preferred learning style, and educational background.

Definition of Design Problem

The study consisted of two stages: A questionnaire was administered to students to learn about their learning styles before the initiation of the study. The purpose was to determine whether students selected "accommodating learning style" or "assimilating learning style". In the second stage of the study, a design problem was assigned to students who were then asked to solve this problem however they liked and to present the result. The freshmen who took the basic design course for the first time were asked to extract a square piece with no predetermined sizes (sizes would be determined by the students themselves) from an A3 paper and to add their names and surnames to this piece. There were two problems forming the frame of the study: **extracting** a square piece from an A3 paper and **adding**

the name and surname. Students were expected to solve the design problem during the class period and were allowed a duration of four hours. Studio coordinators were present in the studio to answer students' questions. No study was shown as a model when conveying the design problem to students.

Study Method

A 5-point Likert type questionnaire (1: negative, 5: positive) was administered to students to collect data for determining their approaches towards the design problem and the method they followed in the process of solution. The second questionnaire was administered to 111 students who were divided into two groups according to the learning style (accommodating or assimilating) they preferred based on the results of the first questionnaire. The first two items of this questionnaire were demographic questions about students' gender and educational background. The questionnaires utilized were found to be valid and reliable in the studies conducted by Özgen et al. (2019). The Statistical Package for the Social Sciences (SPSS) version 22.0 was used to analyze the data collected. Cronbach's alpha reliability tests were performed on the data, and mean values as well as standard deviation figures were also determined. The alpha values were found to be 0.83 and 0.81 for both groups. In the studies by Cronbach (1951), Kaplan and Saccuzzo (2010), and Panayides (2013), Alpha coefficients over 0.60 indicate "reliability". Based on the study by Ural and Kılıç (2005), the t test and correlation analyses were performed to compare the data. The sub-scales of the questionnaire items were given in Table 4.

Table 4. Questionnaire Scales

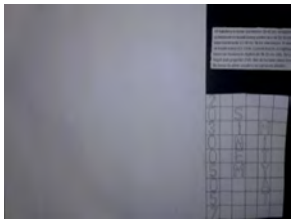
Questionnaire Scales Specified Based on Accommodating Learning Style		
Based on visual perception - intuitive		
Scales	**Acting with Emotions (AwE)**	**Utilization of Experiences (UoE)**
Statements	1. Adding-removing	1. Balance element on the surface
	2. Importance of A3 paper size	2. Visuality
	3. Size of the square	3. Integrity
Scales	**Adaptation to Conditions and Flexibility (ACF)**	**Intuitive Attitude (IA)**
Statements	1. Basic Design Principle	1. Stylistic similarity
	2. Symmetry	2. Coincidental location of square
	3. Central Orientation	3. Coincidental name and surname
Questionnaire Scales Specified Based on Assimilating Learning Style		
Based on analytical approach - intellectual		
Scales	**Logical Attitude (LA)**	**Organizing Information (OI)**
Statements	1. Adding-removing	1. Forming a rule while extracting a square
	2. Importance of A3 paper size	2. Special design to A3 size
	3. Size of the square	3. Integrity
Scales	**Planning-Modeling (PM)**	**Being Analytical (BA)**
Statements	1. Rule-based design	1. Mathematical expression
	2. Locking	2. Establishing relationship with name-surname and square
	3. Pattern	3. Accepting name-surname as a character

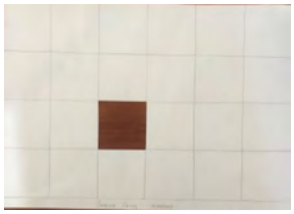
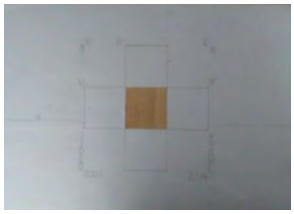
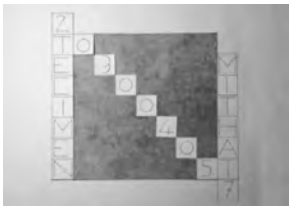
Table 5. Students' Demographic Data

	Education Type		**Learning Style**	
	Art-Based Education	**Science-Based Education**	**Accommodating Learning Style**	**Assimilating Learning Style**
Female	48	40	43	45
Male	10	13	13	10
Total	58	53	56	55

The design problem assigned within the Basic Design course were followed by 111 students who aimed to solve the problem with different methods. Students who preferred the accommodating or assimilating learning style displayed different approaches in the process of solving the design problem. The examples from students' studies are as follows (Table 6).

Table 6. Examples from students' studies

	Result Products			
	Student Study 1	**Student Study 2**	**Student Study 3**	**Student Study 4**
Assimilating Learning Style				
	The square that does not fit the A4 paper and that is the largest one to be drawn on an A3 paper is 22x22 cm. Implementing the fractals to 22x22 cm square, I constantly divided the square in the bottom right to four, and I cut and extracted the remaining square piece after I wrote my name-surname and number.	Folding the A3 papers, I managed to have the largest four squares that I could have. Then, I folded the papers on the corners to find the center of gravity. Auxiliary lines emerged on the paper, and a 45-degree square also appeared. I extracted the square in the middle which could only be extracted from an A3 paper. I added my name and surname in a parallel manner to 45-degree lines to lock and stabilize the square.	I considered the A3 paper as 30x42 cm; the largest square that I could extract from this paper was 30x30 cm. After drawing this square, I extracted the largest square (12x12cm) that I could extract from the remaining 30x12 cm area. The remaining area was 18x12 cm. Using the value of 2 which was the lowest common denominator, I formed a grid with 2x2 cm squares, and I added my name-surname and number within the square.	I started my activity by drawing the diagonal aspects of the A3 paper and finding the center of gravity. Using the value of 6 which was the lowest common denominator of 30 and 42, I drew a 6x6 cm square and extracted it later. I symmetrically added my name-surname and number to above and below of this square.

	Result Products			
	Student Study 5	**Student Study 6**	**Student Study 7**	**Student Study 8**
Accommodating Learning Style				
	To achieve balance in my study, I extracted a square from the middle of the A3 paper while leaving 2 cm spaces on the upper and lower sections. My name-surname and number reached 20 characters in total, and I wrote these characters symmetrically on four corners, with each corner containing five characters.	After finding the middle of the A3 paper, I marked this middle point in a manner that a corner of my square contacted this point. I formed 7x7 squares as they could be divided into 42. To achieve balance in my design, I extracted the square in the bottom left corner of the middle point. I wrote my name-surname and number on the middle of the 2-cm area below.	I drew a 18x18 square on the middle of the A3 paper using the number 18, the total character count of my name and surname. I divided this square into three pieces which are horizontally and vertically equal as I will write my name-surname and number. Extracting the square in the middle, I wrote my name-surname and number on the sides of 18x18 cm squares in a manner to ensure integrity.	I extracted a 16x16 square from the A3 paper using the number 16, the total character count of my name and surname. Then, I added my student number in a 45-degree form to the diagonal parts of the piece that I extracted.

RESULTS

The mean values of intuitive expressions forming the sub-scales of the accommodating learning style and intellectual expressions forming the sub-scales of assimilating learning style based on art and science-based education types are presented in the table below (Table 7).

According to the expressions on the accommodating learning style (intuitive expressions) in Table 7, the mean values for each dependent variable differed based on students' education types (art-based education or science-based education). The dependent variable of "Intuitive Attitude" received the highest (positive) value from students who had an art-based educational background, while it received the lowest (negative) value from students with a science-based educational background. According to the values of all dependent variables, all values received for art-based education were higher than those received for science-based education.

According to the expressions on the assimilating learning style (intellectual expressions) in Table 7, the mean values for each dependent variable differed based on students' education types (art-based education or science-based education). The dependent variable of "logical attitude" received the highest (positive) score from students with a science-based education. The dependent variable of "being analytical" received the lowest (negative) score from students with an art-based education. According to the values of all dependent variables, all values received for science-based education were higher than those received for art-based education.

According to the results of the questionnaire administered to the groups that were formed of the accommodating and assimilating learning styles based on students' preferences, a significant relationship was found between the preferred styles and variables (Table 8).

According to Tavşancıl (2006), the classifications in correlation analyses are generally as follows (0.00 – 0.30) weak, (0.31 – 0.49) moderate, (0.50 – 0.69) strong, and (0.70 – 1.00) very strong. Accordingly, there was a moderate and positive relationship between the independent variables on the scales of accommodating learning style and acting with emotions, and independent variables on the intuitive attitude scale. A strong and positive relationship was found between the independent variables on the scale of accommodating learning style and experimental learning, while a weak and positive relationship was found between the independent variables on the scale of adaptation to conditions and flexibility. According to these values, there was a moderate and positive relationship between the independent variables on the scales of assimilating learning style and planning-modeling, being analytical, and organizing information.

Table 7. Mean Values

Accommodating Learning Style Scales	**Art-Based Education**	**Science-Based Education**
Intuitive Expressions	**Mean Values**	**Mean Values**
Acting with Emotions	3.37	2.96
Utilization of Experiences	3.52	2.64
Adaptation to Conditions and Flexibility	3.46	3.01
Intuitive Attitude	4.02	2.16
Assimilating Learning Style Scales	**Art-Based Education**	**Science-Based Education**
Intellectual Expressions	**Mean Values**	**Mean Values**
Logical Attitude	2.76	4.06
Organizing Information	2.67	3.84
Planning-Modeling	2.08	3.44
Being Analytical	2.04	3.62

Table 8. Results of Correlation Analysis

	AwE-Mean		**UoE-Mean**		**ACF-Mean**		**IA-Mean**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Accommodating Learning Style	0.434	0.01**	0.549	0.00**	0.289	0.31**	0.434	0.02**
	LA-Mean		**OI-Mean**		**PM-Mean**		**BA-Mean**	
	r	**p**	**r**	**p**	**r**	**p**	**r**	**p**
Assimilating Learning Style	0.575	0.000**	0.390	0.003*	0.496	0.000**	0.466**	0.000**

* Correlation is significant at the 0.05 level (2-tailed); ** Correlation is significant at the 0.01 level (2-tailed).

Moreover, a strong and positive relationship was found between the independent variables on the scales of assimilating learning style and logical attitude.

Whether the relationships among the independent variables on the scales of art-based education and science-based education with education type were significant was assessed using the t-test analysis (Table 9).

According to results of the independent t test:

A significant relationship was found between *the visuality expression on the scale of utilization of experiences (UoE2)* that belonged to the intuitive attitude defining the accommodating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the basic design expression on the scale of adaptation to conditions and flexibility (ACF2)* that belonged to the intuitive approach defining the accommodating learning styles, and students' *education type (abe-sbe)*. A significant relationship was found between *the expressions of stylistic similarity and coincidental locations of name and surname on the intuitive attitude scale (IA1, IA3)* that belonged to the intuitive attitude defining the accommodating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the expression of creating composition according to A3 paper size on the scale of organizing information (OI2)* that belonged to the intellectual approach defining the assimilating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the mathematical expression on the scale of being analytical (BA1)* that belonged to the intellectual attitude defining the assimilating learning style, and students' *education type (abe-sbe)*.

DISCUSSION

Since the first step for design researchers is to examine the design processes (Uluoğlu, 2000), students were asked to perform a studio exercise to experience students' stages of solving design problem during "Basic Design" education. With Çetinkaya's (2011) statement, "perceiving the design problem, and understanding the cause-effect relationship is a significant step in solving the design problem", the design problem was clearly conveyed to the students of Interior Architecture. As expressed by Seylan (2004), no examples were shown to students who were asked to present specific studies based on their imagination. Students solved the design problem they perceived with the methods they knew or learned. The issues to be solved within the design problem are based on the roots of science, but as stated by Seylan (2004), intuitive approaches were emphasized as much as the scientific solutions in the process of solving the design problem. The systematical design methods developed according to various designers (Alexander, 1964; Archer, 1965; Asimov, 1962; Jones, 1980) were used to perceive how students considered solving the design problem as well as created designs. The learning styles students preferred prior to solving the design problem were divided into two groups as intuitive and intellectual. As noted by Uluoğlu (2000), according to the design process of students who preferred the intuitive approach, the process was not explainable or clear, even if the inputs and outputs were visible. Bayazıt (1994) stated that the design processes of students who preferred the intellectual approach were systematical with the explainable steps in mind, and these students' intellectual inputs as well as outputs and advancements were all clear. While starting to solve the design problem, the students who preferred either the accommodating or assimilating learning styles and who were divided into two groups, questioned the problem in mind and established, interpreted, and practiced relationships as stated by Tepecik and Toktaş (2014). The student group that preferred the accommodating learning style (with the intuitive approach) used creativity, visual perception, and stylistic similarity based on their educational backgrounds. The other student group that preferred the assimilating learning style (with the intellectual approach) used their knowledge and skills based on their educational statuses. The H1 hypothesis that

Table 9. Results of t test

	UoE2			ACF1		
	t	**df**	**p**	**t**	**df**	**p**
Art-Based Education	-2.156	23.292	0.042	-2.041	23.472	0.043
	IA1			**IA3**		
	t	**df**	**p**	**t**	**df**	**p**
	2.033	24.775	0.053	2.043	24.420	0.052
	OI2			**BA1**		
	t	**df**	**p**	**t**	**df**	**p**
Science-Based Education	2.991	36.019	0.050	2.551	53	0.014

p is significant at the 0.05 level.

was developed for the interactions among the process and method of solving the design problem, learning style, and students' educational background (art-based or science-based), "*A strong relationship is present between students' preferred learning style and their educational background (art-based or science-based)*" was supported by the data. As a result of the analyses:

Of the 56 students who preferred the accommodating learning style, 84% (47) had an art-based educational background, while 16% (9) received a science-based education. This result supports the hypothesis. Of the 55 students who preferred the assimilating learning style, 80% (44) had a science-based educational background, while 20% (11) received an art-based education. This result also supports the hypothesis. The other hypothesis (H2) "*There is a strong relationship among the method of solving a design problem, preferred learning style, and educational background*." was supported by the data. As a result of the analyses:

1. According to the expressions on the accommodating learning style (intuitive expressions), mean values for each dependent variable differed based on students' education types (art-based education or science-based education). According to the values of all dependent variables, all values received for the art-based education were higher than those received for the science-based education. Accordingly, students with art-based educational backgrounds used the intuitive approaches more extensively, utilized the concepts they learned, and displayed a more flexible approach in the process of solving design problems. While assessing students' studies, the digital data on the expressions that helped analyze the approaches students displayed while solving the design problem were given below:

Accommodating Learning Style	**Number of Students**	
	Art-Based Education	**Science-Based Education**
Using at least one basic design principle	42	1
Using symmetry	32	3
Having central orientation	29	2
Paying attention to visuality	50	4
Creating a stylistic similarity	34	0
Paying attention to the element of balance	28	6
Solving the design problem coincidentally	41	3

2. According to the expressions on the assimilating learning style (intellectual expressions), mean values for each dependent variable differed based on students' education types (art-based education or science-based education). According to the values of all dependent variables, all values received for the science-based education were higher than those received for the art-based education. Accordingly, students with science-based educational backgrounds used the intellectual approaches more extensively, had analytical thoughts, and displayed an approach that organized information in the process of solving design problems. While assessing students' studies, the digital data on the expressions that helped analyze the approaches students displayed while solving the design problem were given below:

Assimilating Learning Style	**Number of Students**	
	Art-Based Education	**Science-Based Education**
Forming rules	0	43
Paying attention to A3 size	8	37
Including mathematical expressions	1	38
Thinking about the problem systematically	5	44
Forming a relationship between name-surname and square	2	32
Performing an addition or subtraction	7	40
Locking the composition	0	7

3. According to the results of the questionnaire administered to the groups that were formed for the accommodating and assimilating learning styles based on students' preferences, a significant relationship was found between the preferred styles and variables. The data indicated that students managed the process of solving the design problem for the learning style they preferred.

4. A significant relationship was found between *the visuality expression on the scale of utilization of experiences (UoE2)* that belonged to the intuitive attitude defining the accommodating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the basic design expression on the scale of adaptation to conditions and flexibility (ACF2)* that belonged to the intuitive approach defining the accommodating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the expressions of stylistic similarity and coincidental locations of name and surname in*

the intuitive attitude scale (IA1, IA3) that belonged to the intuitive attitude defining the accommodating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the expression of creating composition according to A3 paper size on the scale of organizing information (OI2)* that belonged to the intellectual approach defining the assimilating learning style, and students' *education type (abe-sbe)*. A significant relationship was found between *the mathematical expression on the scale of being analytical (BA1)* that belonged to the intellectual attitude defining the assimilating learning style, and students' *education type (abe-sbe)*.

CONCLUSION

Modern design studios are environments that contain much more than pedagogical, sociological, ideological, and epistemological concepts and traditional classes (Demirbaş & Demirkan, 2003). Accordingly, it was observed that students used many conceptual backgrounds during their studio exercises. According to Hendrix (2017), who stated that the scope of studios, which always paid attention to conceptual approaches, and which conveyed these approaches to others, expanded with the terms from disciplines such as mathematics, literature, and cinema, and according to Hisarlıgil (2012), students utilized certain disciplines, such as mathematics and art, based on their educational backgrounds, while solving design problems. Kvan and Yunyan (2004) stated that students' different environments and educational backgrounds were effective in improving their conceptual relationships. The methods students used while solving design problem were related to their educational backgrounds, and they adopted their backgrounds into the new educational environments. It is a fact that studio exercises, which are a part of Basic Design, make contributions to the solution of problems and help students explore themselves with practical and theoretical methods. Evyapan's (2010) phrase, "developing certain basic conceptions instead of learning them" in basic design purposes was specifically emphasized with the Basic Design studio exercise. Consequently, this study may serve as the basis for different disciplines in the field of design, such as architecture, landscape architecture, urban, and regional planning.

ETHICS: There are no ethical issues with the publication of this manuscript.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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Megaron, Vol. 18, No. 1, pp. 112–125, March 2023

Megaron
https://megaron.yildiz.edu.tr - https://megaronjournal.com
DOI: https://doi.org/10.14744/megaron.2023.84704

Article

Relating environmental comfort conditions to student satisfaction with remote learning: A case on design students

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ARTICLE INFO

Article history
Received: 12 July 2022
Revised: 17 February 2023
Accepted: 23 March 2023

Key words:
Auditory comfort; remote learning; spatial comfort; thermal comfort; visual comfort

ABSTRACT

Remote learning applications have crucial importance in preventing education processes from being interrupted under extreme conditions such as a pandemic. Numerous studies on the field are being performed, as it is thought that remote learning will become even more critical in time. Notably, the variety of built environments in different regional, social, cultural, and technological aspects encourages researchers to investigate such differences and student performance and satisfaction relating to their conditions. Focusing on design students, who may have more distinct requirements since the nature of the education program they are subject to, this article aims to present the comfort conditions of students, as well as the relationship of such conditions with the level of student satisfaction with remote learning. The method of this study includes a comprehensive survey, which has been delivered to architecture and interior architecture students via online channels, questioning their spatial, visual, auditory, and thermal comfort. The multiple regression analysis, which has been used in connecting comfort conditions and satisfaction, has resulted that the built environment has a slight yet significant effect on satisfaction level (R=0.374). This result is substantial considering the variety and complexity of factors affecting satisfaction with remote learning. Findings of this study include that visual comfort conditions are the most influential on student satisfaction, indicating the inference that improvements relating to these conditions will be quite effective. The results of this study provide a perspective for improving remote learning processes and adapting living environments to remote learning, based on different student groups.

Cite this article as: Giresun Erdoğan B, Kutsal S. Relating environmental comfort conditions to student satisfaction with remote learning: A case on design students. Megaron 2023;18(1):112–125.

INTRODUCTION

Having affected 90% of the student population of the world (Unesco, 2020) the Covid-19 pandemic has led many countries to suspend face-to-face education and put compulsory remote learning processes into practice. Various researches have focused on remote learning, especially from 2006 and onwards, which was the subject of research before the Covid-19 epidemic (Salama & Wilkinson, 2017; Sun & Chen, 2016). The research of Allen and Seaman (2013) reveals that the global financial crisis in

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2008 had also been a driving factor for the improvement of remote learning. Several countries around the world have synchronously experienced a switch in education processes by necessity (Boca, 2021; Ibrahim et al., 2021; V.-H. Lee et al., 2021; Muthuprasad et al., 2021; Tleuken et al., 2022; D. Yang & Mak, 2020), to such a point that it can be inferred that the Covid-19 pandemic constitutes a breaking point in research and improvements in the field of remote learning.

Researches which have been initiated with Covid-19 pandemic (Arifiati et al., 2020; Boca, 2021; Jiang et al., 2021; V.-H. Lee et al., 2021; Muthuprasad et al., 2021; Oskaloğlu & Çatı, 2021; Özçiftçi, 2021; Tleuken et al., 2022) have focused on the effect of remote learning under compulsory situations. The factor of satisfaction, which has a substantial part in student motivation in terms of studying and learning, has been increasingly examined both before (Vilcekova et al., 2017; Z. Yang et al., 2013) and during the Covid-19 pandemic period. The increasing number of field researches and empirical studies focusing on this field indicates that remote learning will retain its important role in education processes.

Studies on student satisfaction with remote learning mainly focus on the psychological and psycho-social perceptions of students (Arifiati et al., 2020; Boca, 2021; Jiang et al., 2021; V.-H. Lee et al., 2021; Muthuprasad et al., 2021), while very few of the researches (Oskaloğlu & Çatı, 2021; Tleuken et al., 2022) have discoursed the effects related to the physical environment. In these researches, higher education students have been evaluated independently of their field of study. Teaching architecture in an online format is rare due to the nature of the discipline and student-instructor interaction (Ibrahim et al., 2021). Since design studio courses are involved in the course program, students of fields such as architecture and interior architecture have distinct and unique requirements (Karassowitsch, 2019). On the contrary of researchers who assert that online studio courses will not be able to substitute traditional studio courses (Salama & Wilkinson, 2017; Silva & Lima, 2008), Saghafi et al. (2012) propose a blended design studio that provides a combination of physical studio and virtual environment.

Teaching and learning strategies in design fields have drawn great interest due to their significance in the education of qualified architects and interior architects. Therefore, this study focuses on design students studying in the fields of architecture and interior architecture. The value of this research is based on the assessment of the relationship between environmental comfort factors and student satisfaction within the concept of remote learning, which lacks research on remote learning strategies in an adaptation of studio and design courses (Ibrahim et al., 2021) and psycho-social perceptions of students (Alnusairat et al., 2021).

Insufficient environmental comfort can have a substantial effect on the learning capacity of students (Haverinen-Shaughnessy et al., 2015). It has been widely recognized that a comfortable environment increases working productivity (M. C. Lee et al., 2012; Rosa-Jimenez & Jaime-Segura, 2021; Toyinbo et al., 2016), as this concept can be extended to the productivity level of students (Ricciardi & Buratti, 2018).

Environmental comfort is established through some factors like anthropometry, climate, sound, vibrations, light, and smell (Bouwens et al., 2018). Frontczak and Wargocki (2011) discuss thermal, visual, auditory, and spatial conditions. Nevertheless, rather than being solely based on objective parameters, environmental comfort is dependent on several factors which require detailed research in various fields (Ricciardi & Buratti, 2018).

In the literature review, it is seen that environmental comfort conditions are effective in education and learning. The general purpose of the research is how this situation will affect remote learning. The research problem is shaped in the context of design students and their differing needs from other students, which are one of the limits of the study. Accordingly, "*whether the environmental comfort conditions of design students affect their satisfaction with distance education*" is the main problem of the research. The theory that we created based on the literature review is that environmental comfort conditions will affect satisfaction with distance education linearly. We used a quantitative method, multiple regression analysis, to test the hypothesis. We analyze the data we collect from students through the questionnaire we developed specifically for this study with the SPSS program and prove it statistically.

BACKGROUND

Remote Learning and Environmental Comfort

Comfort can be defined as the consistency between the functional, technical and perceptive performance of a building and the user expectations (Giresun Erdoğan & Polatoğlu, 2021) and the psychological satisfaction of the user which is achieved through optimal performance in user activities (Oral et al., 2004).

The process of learning and training require students to spend a long time within the same interior space. Especially design students proceed to use the same space not only during course hours but also during their processes of design and production. Therefore, environmental comfort is directly related to providing the health and prosperity of students (Bluyssen, 2017; Fantozzi & Rocca, 2020; Lamberti et al., 2020).

The insufficiency in environmental comfort conditions may result in a negative effect on the learning capacities of students and their creativity in thinking in three dimensions.

Indoor environmental conditions are associated with triggering health and learning difficulties for students in a study conducted by Soccio (2016) in a school context. The author remarks that poor indoor environmental quality can trigger health and learning difficulties for students and adversely impact the well-being of educators and their students. Lee et al. (2012) observed strong relationships between spatial comfort in interior spaces and learning performance. Similar observations were made on the effects of comfort conditions on the student's performance by some other researchers, for example, Krüger and Zannin (2004). They concluded that auditory, visual, and thermal comfort also affect stress, concentration, and disturbance, respectively.

Bouwens et al. (2018) rank the environmental comfort factors from most important to least important: anthropometry, climate, noise, vibrations, light, and smell. Similarly, Tleuken et al. (2022) makes a definition like this without a hierarchy; light, a robust supply of electricity and internet, noise, technical resources, personal study space, and temperature and humidity. However, rather than being only an objective concept, human comfort is dependent on various factors and subfactors (Ricciardi & Buratti, 2018). Although conditions of built interior spaces have been examined within thermal, auditory, and visual aspects (Frontczak & Wargocki, 2011; Krüger & Zannin, 2004; Oral et al., 2004), an investigation regarding the spatial sufficiency of students is also required due to the obligatory and unprovided nature of the switch to remote learning.

Soccio (2016) relates the conditions that affect education and training as environmental, motivational, socio-economic & socio-cultural, and pegagogical & currcular factors. We approached the environmental comfort conditions constituting the working limits, spatial requirements, and competencies, generally within their dependence on ergonomic factors. Yet, physical measurements solely lack in achieving environmental comfort (Ricciardi & Buratti, 2018). Frontczak and Wargocki (2011) have stated that providing for requirements such as privacy and personal space (Allen & Seaman, 2013) also has a remarkable effect on human comfort. It is crucial to take the psychological conditions and requirements of students into consideration in shaping the space and equipment for studying. Figure 1 shows the conceptual scheme that we have created based on this information and the factors of Soccio (2016). According to this scheme evaluating environmental comfort with perceptual data can be considered a new approach.

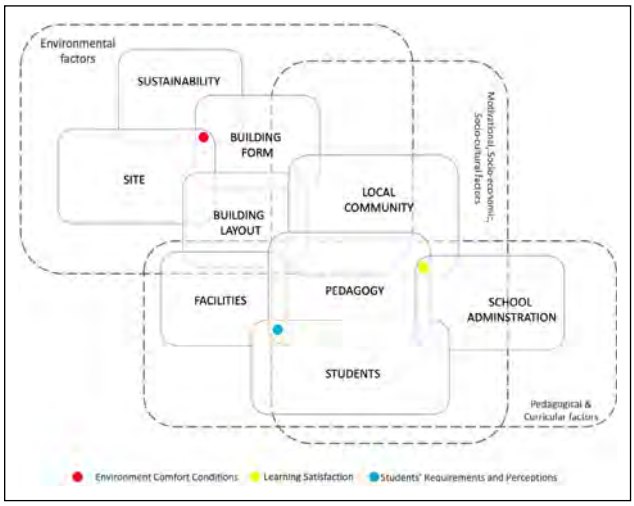

Figure 1. The relation between learning satisfaction with environmental comfort and students' perception.

Remote Learning and Satisfaction

As the success of remote learning is related to achieving student satisfaction (Jiang et al., 2021; Özçiftçi, 2021), the effect of the Covid-19 pandemic on student satisfaction with remote learning has been globally researched. A study by Aristovnik et al. (2020) has asserted that student satisfaction with remote learning during the Covid-19 pandemic has been lower in countries that have lower life standards compared to the other countries. Studies based in various countries have shown that students prefer online education during the pandemic, yet remote learning cannot substitute traditional face-to-face education (Boca, 2021; V.-H. Lee et al., 2021; Muthuprasad et al., 2021; Özçiftçi, 2021). While research-based in Jordan has emphasized the indecisiveness of students regarding their satisfaction with remote learning processes (Alnusairat et al., 2021; Ibrahim et al., 2021), Jiang et al. (2021) state a positive level of satisfaction in case of Chinese students. Also, a report by the Council of Higher Education has shown that Turkish students prefer face-to-face education (Council of Higher Education, 2021).

During remote learning processes, students become subject to more than one environmental factor. Various combinations of more than one interior environmental factor affect environmental perception (D. Yang & Mak, 2020). Categorizing perception types and determining the effect of such categories to overall perception are complicated processes (Jin et al., 2020; W. Yang & Moon, 2018, 2019). These constitute a valid base for the requirement to examine satisfaction with remote learning from various perspectives.

Yang et al. (2013) state that studies that focus on various aspects of learning environments and encourages the learning process of students started in the 1960s. According to these studies, learning environment-related perceptions of students can be categorized under three topics: "*perception of the psychosocial environment such as belongingness and connection with classmates; perception of the psychological environment such as motivation,*

self-efficacy, and achievement; and perception of the physical environment such as classroom size, lighting, and technology." In parallel, later studies have examined learning performance and satisfaction by focusing on psychosocial conditions (Alnusairat et al., 2021), psychological factors (Ibrahim et al., 2021) and conditions relating to the physical environment (Oskaloğlu & Çatı, 2021; Tleuken et al., 2022). This article distinguishes itself by analyzing the success in adapting to a different physical learning environment (transition from school to home) within the context of comfort conditions, and its relationship with satisfaction with remote learning focusing on design students.

Remote Learning in Design Fields

The basis of design education is constituted by practical courses which are conducted in special classrooms called "*studios*". Design studios provide students with a multi-dimensional and enriching learning experience. The education process in studio training is based on "*experimental learning*" or "*learning by doing*" (Nicol & Pilling, 2000). Therefore, as design education is distinguished from other undergraduate education programs by requiring creativity for design (Akin & Akin, 1996; Taneri & Dogan, 2021), design students have distinctive necessities compared to students working in other fields.

Although there had been various initiatives to digitize design education programs as online, remote processes before the Covid-19 pandemic (Saghafi, M.R., Franz, J. and Crowther, 2012; Salama & Wilkinson, 2017; Silva & Lima, 2008; Wojtowicz, 1995), researchers had reached a consensus that online education cannot substitute face-to-face training. This has led the effect of remote learning on architecture students to become a topic of discussion (Alnusairat et al., 2021; Ibrahim et al., 2021; Oskaloğlu & Çatı, 2021; Şekerci et al., 2021). As the digitization of design studios has started, students have lacked materials to present their works such as boards, drawing tables, cardboards, etc. (Alnusairat et al., 2021; Ibrahim et al., 2021). Besides, the research by Tleuken et al. (2022) had shown that students complain about their home environment not being reconciled for education and decent studying. Within this direction, this study includes spatial qualifications regarding distinct necessities of design students, alongside the factors which are examined within the context of research focusing on the comfort of students in the classroom environment (Ricciardi & Buratti, 2018; D. Yang & Mak, 2020; W. Yang & Moon, 2018; Z. Yang et al., 2013). Within the context of this article, conditions of architecture and interior architecture students such as having sufficient private space, storage spaces for design and working materials, computer tables, and ergonomically convenient chairs to use in following remote learning programs, have been examined as comfort parameters.

METHODS AND MATERIALS

The beginning of this article covers a literature review focusing on the factors affecting learning performance and education-related satisfaction of students. The study which has been conducted before the Covid-19 pandemic by Yang et al. (2013), proved that physical comfort conditions in the classroom have influential effects on learning and satisfaction. Based on that study the literature review of this article also focuses on physical comfort conditions.

This study is a case study that reveals the environmental comfort conditions of a certain student group in a certain period. The research is a descriptive study designed in a survey model and is used to detect an existing situation as it exists (Karasar, 2017). This study is valid only for the subject of study and does not aim to generalize. However, as Karasar (2017) stated, generalizability can be achieved by increasing the number of cases examined.

This study also makes use of a statistical method to indicate the impact of a wide range of comfort attributes on student satisfaction with remote learning. Figure 2 shows the steps of the developed methodology. According to these steps, we first determined various factors and subfactors to analyze the effect of comfort conditions in the housing environment on student satisfaction. However, not all of the factors coming from the literature are simple and clear for students to evaluate by themselves. As a solution, a pilot survey has been structured for students to eliminate vacillating while answering clear questions and conducted on 15 students who have also contributed to delimiting the diversity of questions.

The pilot survey, which included the concerns and suggestions relating to environmental comfort conditions,

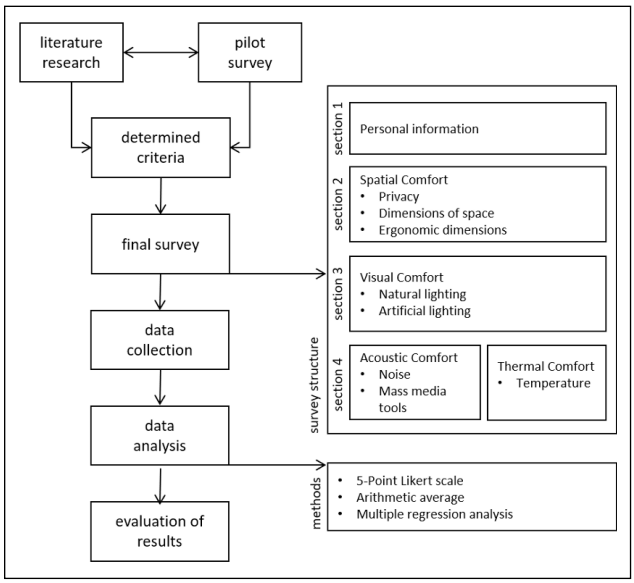

Figure 2. The structure of the research methodology.

aims to understand the potential aspects to be adapted by the satisfaction survey, as well as the problems of students. Following the feedback, simple and clear subfactors have been determined to be used by students in evaluating their studying environments. Other sub-measurements that are technically complex and require special equipment to determine, such as air quality, relative airspeed, sound level, auditory transmission, etc. have been excluded from the context of this study.

Surveys constitute important tools for analyzing physical comfort conditions (Ricciardi & Buratti, 2018). Although face-to-face interviews make room for instant feedback and clarification of certain doubts, they also require more time (Benoliel et al., 2021). Therefore, this study makes use of online surveys in order to collect more inputs in a shorter amount of time. Following the representative results of the pilot survey and the feedbacks, the updated survey has been delivered to the users.

The data obtained from students through the online systematic questionnaire have been analyzed via the SPSS program. Three techniques have been used in the analysis process: First, the findings transform qualitative verdicts into quantitative ones and obtain information on the comfort conditions of the students with the "*Likert scale*". The second technique is "*arithmetic average*". The last one is "*Multiple Regression Analysis*" (Allison, 1999). This method has been developed to relate more than one comfort condition to satisfaction with remote learning, as well as to present certain conditions and their precise effects on student satisfaction.

Survey Design

User survey provides evaluating the feasibility of comfort conditions in the home environment of students in both qualitative and quantitative manners, as well as relating the results regarding feasibility to satisfaction with remote learning.

In parallel with the goals of the survey, the approach to data collecting is based on the qualifications of the physical environment and the field that students are working in. We adopt to be understandable with quick and simple answers in survey design. For the first time, we propose the questionnaire we prepared specifically for this research to examine environmental comfort conditions from different perspectives and to obtain subjective data from students (Table 1). The most significant difference from the existing scales of this questionnaire is that it consists of questions without the need for technical measurement and technical tools that enable students to self-assess under pandemic conditions. In addition, another difference from the existing scales is that it was developed specifically for this research with the feedback from the pilot survey.

The survey has been divided into four sections to ensure students focus on one comfort parameter at a time. To determine whether an individual student is suitable for the survey, the first section covers special criteria including personal information, such as school, the field of study, age, and years spent in the program. Besides, the first section includes information on whether an individual student attended a remote learning program for at least two terms and the general satisfaction level with such program.

The second section questions the spatial sufficiencies of

Table 1. Survey Structure

Sections	Criteria	Sub-Criteria	Data
1	Personal Information	Indicators	• School, year, field
			• Regular attendance to remote learning
			• Satisfaction with remote learning
2	Spatial Comfort	Privacy	• Private/shared/co-shared working space
		Dimensions of space	• Size of working space
		Ergonomic dimensions	• Ergonomy of working desk
			• Ergonomy of working chair
3	Visual Comfort	Natural lighting	• Sufficient sunlight
			• Total window area in working space
		Artificial lighting	• Sufficient lighting fixtures
			• Artificial lighting level of working desk
4	Auditory Comfort	Noise	• Noise level
		Mass media tools	• Tv, radio, mp3 player, etc.
	Thermal Comfort	Temperature	• Evaluation for Fall term
			• Evaluation for Spring term

the students. For evaluating privacy, students have been requested to provide information on whether they have a private space for studying and, in case of lack of such space, whether they use a shared or alternate space for studying. This section assesses the sufficiency of the dimensions of the studying environment from where the student is attending to remote learning and makes perceptive evaluations, such as comfort and sufficiency of the working desk and chair, which students use for hours while studying.

The third section evaluates the visual comfort conditions of the students by assessing the ratio of window dimensions to wall surface areas, the sufficiency of lighting fixtures, and level of natural and artificial light.

The fourth section includes questions towards evaluating both auditory and thermal comfort conditions. In terms of auditory comfort, the survey aims to qualify the level of noise with qualitative expressions such as "*quite noisy*" or "*quiet*", for students who naturally lack technical equipment to measure the sound level. Besides, students have been requested to evaluate the sound of mass media tools in their working space, if any, of their own accord or not, with expressions such as "*distracting*", "*contributes* in *focusing*", etc. Students with no mass media tools (music, television, radio, etc.) in their working environment have been excluded from this question.

As the effective thermal comfort conditions are expected to differ during different seasons, the students have been requested to make qualitative assessments for fall and spring terms with expressions such as "*very cold*", "cool" or "*muggy*". All answers have been grouped into five options.

Respondent Characteristics

Having been conducted in Turkey, the survey covers undergraduate students from fields of architecture and interior architecture of various universities located in Istanbul. In order to participate in the survey, the students have been required to have regularly attended online lessons within remote learning for at least two terms (fall and spring). Answers from students who do not meet these criteria have been sorted out from the dataset.

The self-administered survey has been prepared and shared with online student groups, and then collected online. Among approximately 170 students who have participated in the survey, 110 students have been evaluated for data analysis. While 38.1% of the participating students are studying in public universities, the ratio of students studying in private universities is 61.9%. 46% of the participating students study in the field of Architecture, while 54% of them study Interior Architecture. The ratio of students registered in the program for 1, 2, 3, and 4 or more years is 40.0%, 29.1%, 18.2 and 11.8%, respectively. In terms of gender, the female/male ratio of respondent students is 57% to 43%.

Analysis of Data

Descriptive Analysis

The data collected through the online questionnaire has been analyzed through the SPSS program. As the data included qualitative assessments, the reliability of the survey questions has been tested through Alpha (Cronbach) Reliability Analysis (Cronbach, 1951).

The comfort conditions of the students have been evaluated through the questions corresponding to the subcriteria of the survey. The survey which aims to evaluate the subcriteria makes use of the 5-Point Likert scale. According to the scale, values of "5", "4", "3", "2" and "1" correspond to "*quite sufficient*", "*sufficient*", "*neither sufficient nor insufficient*", "*insufficient*" and "*quite insufficient*", respectively. In interpreting the weighted average of the answers, this study makes use of the "*Gap width = Serie width / Group count*" formula (Oral Erbaş, 2018) and determines the score intervals as 4/5 = 0.80. According to this value, structured score intervals are presented in Table 2.

The arithmetic average obtained from the subcriteria provides a basis for the quantitative assessment of the comfort conditions. Evaluation of comfort condition ($\bar{X}$) requires averaging evaluations (x) of subcriteria which are N in number (Formula 1).

$$\bar{X}=\frac{\sum_{i=1}^{n} Xi}{N}=\frac{x1+x2+\cdots+xn}{N} \quad (1)$$

Following this operation for each comfort condition, the visual, spatial, auditory, and thermal comfort of the students have been evaluated and interpreted according to the intervals given in Table 2.

Multiple Regression Analysis

Multiple Regression Analysis is a method that has been used for measuring the relationship between more than one independent variable (possible factors) and a dependent variable (possible outcome) (Allison, 1999). Required reliability and consistency tests have been conducted before the analysis. Formula 2 demonstrates a linear relationship between a dependent variable Y and two or more independent variables (x1, x2, x3 . . . , xk).

$$\boldsymbol{Y} = \alpha + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k \quad (2)$$

In the formula given above, Y represents the dependent

Table 2. Evaluation table

Score	Evaluation	Interval
1	Quite insufficient	1,00-1,80
2	Insufficient	1,80-2,60
3	Neither sufficient nor insufficient	2,60-3,40
4	Sufficient	3,40-4,20
5	Quite sufficient	4,20-5,00

variable, while the X1,… ,Xk corresponds to the independent variables. α and β parameters (unknown parameters) have been used in weight calculation. The multiple regression model of this study consists of four independent variables. In the model, the dependent variable (Y) corresponds to the level of student satisfaction with remote learning, while independent variables represent spatial comfort conditions (X1), visual comfort conditions (X2), and auditory comfort conditions (X3), and thermal comfort conditions (X4). The weight of effect for all subcriteria has been accepted as equal within the context of this study. Figure 3 demonstrates the regression relationship of the subcriteria.

RESULTS

Descriptive Findings

Reliability analysis, regarding the answers of students on level of satisfaction for remote learning and comfort conditions, has demonstrated that the scale is quite reliable (α=0,758) (Table 3).

The arithmetic average of the values corresponding to the answers regarding the comfort subcriteria has been calculated ($\bar{X}$) to evaluate the general state of comfort conditions. Values regarding the number of answers (valid), missing data (miss.), averages ($\bar{X}$), and standard deviation (σ) have been demonstrated in Table 4.

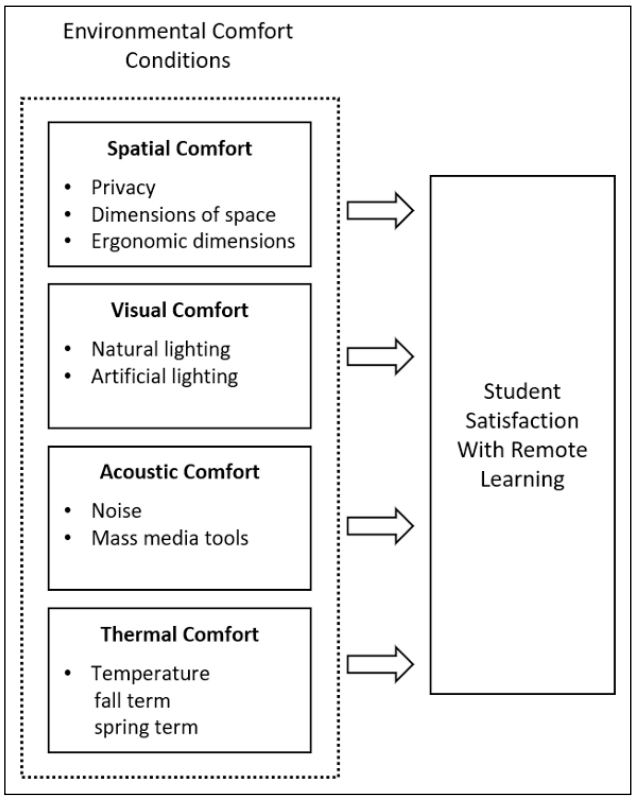

Figure 3. Conceptual framework of the multiple regression.

Table 3. Reliability analysis

Reliability Statistics		
Cronbach's Alpha	**Cronbach's Alpha Based on Standardized Items**	**N of Items**
.758	.776	17

Table 4. Descriptive findings regarding sub-criteria

Criteria	N		$\bar{X}$	σ
	Valid	Miss.		
Privacy	110	0	4,45	1,00
Dimensions of Space	110	0	2,94	1,15
Ergonomy of Fittings 1	110	0	3,24	1,24
Ergonomy of Fittings 2	110	0	3,44	1,10
Window Dimensions	110	0	2,92	1,18
Natural Light	110	0	3,64	0,89
Lighting Fittings	110	0	3,18	1,12
Artificial Light	110	0	2,10	0,56
Noise	110	0	2,91	0,96
Mass Media Tools	97	13	2,54	1,09
Temperature (Spring)	110	0	2,71	1,09
Temperature (Fall)	110	0	3,62	1,06

Findings related to spatial comfort have proven that privacy ($\bar{X}$=4,45) of participating students is quite sufficient where a majority of participants study in a private working space. Dimensions of working space ($\bar{X}$=2,94) have been expressed as "*neither sufficient nor insufficient*". Ergonomy of fitting 1 ($\bar{X}$ =3,24), which corresponds to dimensions of the working desk, has been defined as "*neither sufficient nor insufficient*", while ergonomy of fitting 2 (dimensions, height, and comfort of the working chair) ($\bar{X}$=3,44) has been expressed as "*sufficient*".

In terms of visual comfort, window dimensions ($\bar{X}$=2,92), have been defined as "*neither sufficient nor insufficient*" when comparing the window area to the base area. The level of natural light ($\bar{X}$=3,64), on the other hand, has been stated as "*sufficient*". While lighting fittings in the studying environment have been expressed as "*neither sufficient nor insufficient*" ($\bar{X}$=3,18) in terms of count and quality, the artificial lighting level of the space has been found as "*insufficient*" ($\bar{X}$=2,10).

By means of auditory comfort, the noise in the studying space has been stated as "*neither sufficient nor insufficient*" ($\bar{X}$=2,91). A certain number of students have noted that noisy media devices exist in their studying environment and evaluated such devices as "*distracting*", which corresponds to "*insufficient*" ($\bar{X}$=2,54).

Thermal comfort findings, obtained from students' evaluation of the disturbance level of the temperature of

the studying environment, have been collected separately during spring and fall terms. According to the evaluation, room temperature has been found to not affect satisfaction during the spring term ($\overline{X}$=2,71), while it has a positive effect ($\overline{X}$=3,62) during the fall term.

Following the data, the arithmetic average of subcriteria has been gathered under the related criteria which have been covered by the survey. Table 5 demonstrates a general evaluation of comfort conditions.

Information to a certain level regarding the comfort conditions of participant students has been obtained from the calculations. Accordingly, spatial comfort is sufficient ($\overline{X}$ =3,52), while visual comfort ($\overline{X}$=2,96), auditory comfort ($\overline{X}$ =2,72), and thermal comfort ($\overline{X}$=3,16), have been evaluated as "*neither sufficient nor insufficient*". These data indicate that the comfort conditions of students are at medium level.

Statistical Findings

Participating students stated their level of satisfaction with remote learning as "*quite dissatisfied*" (%21,8), "*dissatisfied*" (%28,2), "*neither satisfied nor dissatisfied*" (%29,1), "*satisfied*" (%18,2), and "*quite satisfied*" (%2,7). Besides, 67.3% of the participant students have expressed that they prefer face-to-face learning over remote learning, within the context of specified comfort conditions. According to this information, it has been found that the satisfaction of the sample group with distance learning is negative. To analyze the relationship between satisfaction level and comfort conditions, multiple regression analysis has been applied to the data which have been obtained from the descriptive analysis of comfort conditions. Before analysis, normality tests have been performed on the data, to test if the data has distributed normally. The number of samples which were greater than 50 allowed for checking the significance values via the Kolmogorov-Smirnov Test. Since the P-value is less than 0.05, it has been determined that data has not been distributed normally. However, it has also been found that kurtosis and skewness values regarding the data are between -1.5 and +1.5, therefore it has been accepted as an indicative for normal distribution of data (Tabachnick & Fidell, 2011). Taking these values into consideration, it has been accepted that data has been distributed normally, allowing the analysis to proceed (Table 6).

Table 5. General evaluation of comfort conditions

Criteria	N		$\overline{X}$	σ
	Valid	Miss.		
Spatial Comfort	110	0	3,52	0,70
Visual Comfort	110	0	2,96	0,55
Auditory Comfort	110	0	2,72	0,89
Thermal Comfort	110	0	3,16	0,80

In multiple regression analysis, high correlation relations within more than one variable cause a problem of multiple linearities. Therefore, before evaluating the results, the Pearson correlation of independent variables in Table 7 has been analyzed and found as no greater than 0.700.

As another indicator that the variables do not correlate, Durbin-Watson parameter, which has been Table 8, has been found as 2.00 approximately (Durbin & Watson, 1971). In parallel, VIF coefficients, which have been asserted in Table 9, be under 2.5 and therefore have indicated the absence of multiple linearities (Allison, 1999). Following the multiple linearity check, the results of the findings have been evaluated.

The results have demonstrated the multiple correlation coefficient value between satisfaction with distance learning and comfort conditions, which has been presented with "R" as 0.374 (Table 8). The mentioned value indicates a weak relationship between the dependent variable and all independent variables. Adjusted R_2, which can be explained as the level of interpretation of the dependent variable by the interdependent variables, has been found as 0.107 (Table 8), which means that the ability of comfort conditions of students to explain their satisfaction level is 10.7%.

In order to determine the existence of a linear relationship between satisfaction with remote learning (dependent variable) and spatial, visual, auditory, and thermal comfort (independent variables), hypotheses of H_0 and H_1 have been determined as follows:

H_0:$\beta_1=\beta_2=\beta_3=\beta_4=0$

H_1: *at least one of* β_1, β_2 β_3 ,*or* β_4 *explains Y*

Table 6. Results of Normality Test

Statistics	Satisfaction	Spatial Comfort	Visual Comfort	Auditory Comfort	Thermal Comfort
N					
Valid	110	110	110	110	110
Missing	0	0	0	0	0
Skewness	.181	-.423	-.085	.516	-.211
Std. Error of Skewness	.230	.230	.230	.230	.230
Kurtosis	-.875	-.099	-.102	-.784	-.367
Std. Error of Kurtosis	.457	.457	.457	.457	.457

Table 7. Correlation findings

Correlations	Y	X1	X2	X3	X4
Pearson Correlation					
Y	1.000	.235	.327	.137	.085
X1	.235	1.000	.208	.269	.324
X2	.327	.208	1.000	.123	.051
X3	.137	.269	.123	1.000	.236
X4	.085	.324	.051	.236	1.000
Sig. (1-tailed)					
Y	.	.007	<.001	.077	.190
X1	.007	.	.014	.002	.000
X2	.000	.014	.	.100	.297
X3	.077	.002	.100	.	.006
X4	.190	.000	.297	.006	.
N					
Y	110	110	110	110	110
X1	110	110	110	110	110
X2	110	110	110	110	110
X3	110	110	110	110	110
X4	110	110	110	110	110

The variance analysis has proven that the level of significance is 95% (Sig. =P=0.003 which translates into the rejection of H_0. Therefore, the result of this test demonstrates that a linear relationship exists between the satisfaction with distance learning and at least one of four independent variables (spatial, visual, auditory, and thermal comfort) entering the model (Table 10).

Including B, standard error of B, β (Beta), t, and sig. values, Table 9 gives the effect of each independent variable on the dependent variable. Within the chosen level of significance (%95), it has been found that spatial, auditory, and thermal comfort variables do not have a significant effect on regression (Sig.>0.05), while the visual comfort variable affects regression significantly (Sig.=0.03 <0.05).

Taking the variation coefficient into consideration, placed in the unstandardized column B of Table 9, it has been found that the coefficient value of the relationship between the visual comfort variable and satisfaction with distance learning is 0.574. This can be translated as a change of 1 unit in the visual comfort conditions of students may correspond to a linear change of 0.574 units to their satisfaction levels with remote learning (Formula 3).

$$\boldsymbol{Y} = -0.274 + 0.574X_1 \quad (3)$$

DISCUSSION

A part of the design students studying in Turkey are dissatisfied with remote learning. The results of this study include that 20.4% of participating students are satisfied or quite satisfied with distance learning. It is expected that, since the Covid-19 pandemic has forced a switch to remote learning while every country has had different levels of preparedness to such change in education processes (Aristovnik et al., 2020), similar studies from different countries have different results (Arifiati et al., 2020; Boca, 2021; Jiang et al., 2021; Realyvásquez-Vargas et al., 2020). Several parameters may affect student satisfaction. As stated by Yang and Moon (2019), dividing satisfaction into

Table 8. Model findings

Model Summary[b]											
Model	R	R^2	Adjusted R^2	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R^2 Change	F Change	df1	df2	Sig. F Change	
1	.374[a]	.140	.107	1.04577	.140	4.259	4	105	.003	1.946

[a] Predictors: (Constant), thermal comfort, visual comfort, auditory comfort, spatial comfort; [b] Dependent Variable: satisfaction.

Table 9. Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Tolerance	VIF
1									
a	-.274	.729		-.376	.708	-1.719	1.171		
X1	.249	.157	.158	1.590	.115	-.061	.559	.827	1.209
X2	.574	.186	.287	3.092	.003	.206	.943	.951	1.052
X3	.072	.118	.058	.610	.543	-.162	.306	.898	1.114
X4	.006	.134	.005	.048	.962	-.259	.272	.870	1.149

Table 10. Variance analysis

ANOVA[a]						
Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	18.631	4	4.658	4.259	.003[b]
	Residual	114.832	105	1.094		
	Total	133.464	109			

[a] Dependent Variable: satisfaction; [b] Predictors: (Constant), thermal comfort, visual comfort, auditory comfort, spatial comfort.

categories and determining the effect of such categories on general satisfaction is a complex process. It has been known that in traditional education, the classroom environment has a significant effect on student satisfaction (Frontczak & Wargocki, 2011; Krüger & Zannin, 2004; M. C. Lee et al., 2012). Therefore, it is possible to relate physical comfort in home environments to satisfaction with remote learning (Oskaloğlu & Çatı, 2021).

One of the most recent studies (Tleuken et al., 2022) reveals that there is a significant relationship between physical environmental conditions and students' satisfaction with remote learning. However, it also mentions that their field of study can have an additional effect on such relationships. Students' field of study may determine their expectations by means of physical comfort conditions. A study conducted with agricultural faculty students (Muthuprasad et al., 2021) has shown that 70% of the students attent remote distance learning only with smart cell phones, while another study which has been conducted with architecture faculty students have emphasized that students lack certain technical equipment and requirements (Ibrahim et al., 2021).

Due to its nature containing concepts of creative thinking and learning by doing (Akin & Akin, 1996; Taneri & Dogan, 2021), it is possible for design education to require different requirements and comfort-related expectations compared to other study fields. This has constructed the base for this article, which has limited the frame of work with design students. The students who have participated in this study stated their spatial comfort conditions as "*sufficient*" ($\overline{X}$=3,52), while they also expressed their visual ($\overline{X}$=2,96), auditory ($\overline{X}$=2,72), and thermal conditions ($\overline{X}$=3,16) as "*neither sufficient nor insufficient*". Having evaluated these results to relate them with their general satisfaction, this study has shown that, as the correlation between comfort perceptions of students and their level of satisfaction with remote learning has demonstrated, the direct effect of the built environment on student satisfaction is relatively low (R=0.374). This result can be explained by the consideration that alongside physical comfort conditions, students are subject to more than one factor (V.-H. Lee et al., 2021). Similar studies which have specifically focused on architecture students have proven the existence of psychological (Ibrahim et al., 2021) and psychosocial (Alnusairat et al., 2021) factors. It is obvious that various combinations of more than one comfort factor affect general satisfaction. Hence, it can be inferred that the power of at least one of the comfort conditions of the findings is quite sufficient (Adjusted R^2= 0.107).

The findings of multiple correlations indicate that spatial, auditory, and thermal comfort do not have a significant effect on student satisfaction. This result is notable since it goes against the studies which have asserted that thermal and auditory comfort has a significant effect on satisfaction (Buratti et al., 2018; Frontczak & Wargocki, 2011; Krüger & Zannin, 2004; Realyvásquez-Vargas et al., 2020; W. Yang & Moon, 2019). However, the difference in findings can be explained with the fact that previous studies have been conducted focusing on the classroom environment and that they have covered not only architectural students. This may translate into the perceptions and expectations of the students that differ between the classroom and home environments.

Multiple regression analyses have shown that there is a positive significant correlation between visual comfort and satisfaction (B=0.574) (sig.=0.003). This finding makes this study in accordance with other related research along with the result which indicates that visual comfort has a significant effect on student satisfaction. And also shows that a change of 1 unit in visual comfort conditions corresponds to a change of 0.6 units in student satisfaction with remote learning.

Discussions related to the significance of comfort factors on learning performance and student satisfaction with remote learning remain. While Yang and Mak (2020) have found that thermal comfort is more effective compared to other comfort factors, Yang and Moon (2019) assert that auditory comfort has more significance. On the other hand, the findings of Ricciardi and Buratti (2018) support the findings of this study by demonstrating visual comfort is more effective on learning performance and satisfaction.

It has not been possible to compare the findings of this study with other research, since the number of studies focusing on design students and home environment is very few. The limitations of this study can be accepted as its national scale and regional coverage. It would be possible to obtain comparable and generalizable results in case of repetition of this study on different cities and countries with wider participation.

CONCLUSION

This study has been done during the period when higher education students were educated completely online, during the period of full closures in line with the Covid-19 restrictions. Since 2022, higher education continues within the boundaries of the hybrid education model. The study

aims to investigate and evaluate the effect of a home-built environment on satisfaction with remote learning during the Covid-19 pandemic. Limited to the focus on architecture and interior architecture design students, this study measures the effect of comfort conditions in increasing student satisfaction with remote learning. And shows that comfort conditions have a relatively low direct impact on student satisfaction. Because there are various parameters affecting satisfaction (academic success, accessibility to resources, socioeconomic conditions, etc.).

Focusing on Turkey, this article has evaluated the spatial, visual, auditory, and thermal comfort conditions of design students attending remote learning programs. It has been found that the spatial comfort conditions of the students are at a better level compared to other comfort conditions, and visual comfort conditions have more effect on satisfaction with remote learning compared to other comfort conditions. It is intelligible that students emphasize natural and artificial lighting while their basic requirements include drawing, modeling, and working on project details. The effect of visual comfort is more powerful than the single effect of the built environment on student satisfaction. This change could include very simple improvements such as a change in the location of the working desk, improvement in lighting fittings, or applying desktop lighting equipment. Performing general notifications to students regarding comfort conditions could constitute a simple yet very effective solution to increase student satisfaction with remote learning.

Remote learning offers a great opportunity for achieving continuous, uninterrupted education during the Covid-19 pandemic or possible obligatory limitations. To achieve healthier education processes, it is important for decision-makers to focus on living areas and for researchers to investigate student performance and satisfaction within the context of remote learning, which might remain permanent in various study fields. This article contributes to the literature by performing a systematic analysis of the comfort perceptions and qualitative assessment of the students.

In the remote learning process, there are sub-factors such as student dimension, instructor dimension, course content, and environmental comfort conditions that affect the student's attendance and learning level. The mutual positive interaction of all these factors improves students' satisfaction with remote education positively. Examining the relationships between instructors and environmental comfort conditions, which is not referred to in this study, maybe a subject of future studies. Because the high comfort conditions in the place where the instructor is located can positively increase work performance and the level of knowledge transfer. This situation can directly increase satisfaction with remote education by affecting students' interest in the course.

The approach of this study can be applied to different student groups which have specific requirements in terms of studying. By this means, this study leads the way for future studies. For future studies, this article suggests investigating the opportunities and limitations affecting the design talents and creativity of students during remote learning processes. Another research topic that we think is important to examine in future studies is the improvement of the hybrid education process. A comparative study to evaluate the learning satisfaction of students receiving remote education and students receiving face-to-face education will reveal important information in the field of educational studies. In this way, it can be provided to understand the new challenges produced by the remote education process and how these can be addressed to increase students' learning satisfaction. Such a study can make a positive contribution to the development of the relationship between student satisfaction and environmental comfort conditions in the hybrid education process.

ACKNOWLEDGEMENTS: We acknowledge all the participating students for spending their valuable time on filling our questionnaire. We also acknowledge and thank Ahmet Çetindaş for reviewed the statistical analysis and for comments.

ETHICS: The survey questions have been formed to ensure the highest possible credibility of answers and have been approved by the Yıldız Technical University Ethics Committee on date 25th of May. 2022 with the report number 20220500483. Signed informed consent was obtained from participants before answering the questionnaire.

PEER-REVIEW: Externally peer-reviewed.

CONFLICT OF INTEREST: The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this arcticle.

FINANCIAL DISCLOSURE: The authors declared that this study has received no financial support.

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