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**Tel:** +90 (0)212 383 25 85

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**Article**

# Perspectives on Urban Lighting: Pedestrian Safety and Visual Comfort Preferences

**Lanlan WEI[1,*], Grega BIZJAK[1], Matija SVETINA[2], Matej KOBAV[1]**

*[1]Faculty of Electrical Engineering, University of Ljubljana, Ljubljana, Slovenia*
*[2]Faculty of Arts, University of Ljubljana, Ljubljana, Slovenia*

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Pedestrian environmental psychology; pedestrian's perception of safety; urban lighting; visual comfort.

## ABSTRACT

This study investigates pedestrian preferences regarding outdoor public lighting, specifically examining their impact on the perception of visual comfort, safety and reassurance in different urban settings. Despite extensive research on lighting parameters and pedestrian safety perception in recent years, gaps remain in understanding how users perceive different lighting scenes in real nighttime environments.

The laboratory study comprised 130 participants under 30 years old. Using real location data, we simulated four distinct urban lighting conditions using Dialux software and examined them in a dark laboratory setting. Participants viewed generated images of urban nighttime scenes of a well-known Ljubljana district and answered the questionnaire. The questions were about participants' walking habits in a nighttime environment and about their perception of safety and reassurance based on viewed images. All together nine different scenes were evaluated by participants.

Our study employed various analytical approaches to examine the effects of height (low vs. high) of lighting poles and lighting uniformity (better vs. worse) on participants' perceptions of safety, visual comfort, reassurance and orientation ease. The results demonstrate a preference for lighting with good uniformity, particularly in areas with higher lamp posts, suggesting its vital role in enhancing visual comfort. These findings emphasize the significance of continuous lighting design in promoting pedestrian safety and visual comfort in urban environments.

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## INTRODUCTION

Outdoor public lighting plays a critical role in influencing pedestrians' decision to walk after dark (CIE, 2019). Compared with an unlit road, a well-lit road enhances the reassurance that it is safe to walk (Fotios et al., 2015), and encourages walking activity (Fotios et al., 2019). Proper lighting environment improves pedestrians' obstacle detection ability (Fotios et al., 2020) (Uttley et al., 2017), and fosters a sense of security, which is particularly important in urban environments where uneven pavement, street furniture, and other pedestrians may increase the risk of accidents.

***Corresponding author**
*E-mail adres: lanlan.wei@fe.uni-lj.si

The prospect-refuge theory further emphasizes the role of lighting in shaping perceptions of safety, particularly in natural environments such as parks (van Rijswijk & Haans, 2018). This theory suggests that people feel safer in environments where they can both see potential threats (prospect) and have the option to seek shelter if needed (refuge). Adequate lighting supports this by enhancing visibility and reducing the feeling of entrapment in dark, secluded areas, especially in natural outdoor public environments (Dosen & Ostwald, 2016).

Under consistent lamp and optical fixture conditions, increasing the height of lamp posts typically leads to more uniform illumination of the road surface. However, this increased height also raises the potential for light spillage (Bennie et al., 2016) (Kyba et al., 2017). To achieve better uniformity, also reducing the distance between lamp posts might help. Proper management of these factors, ensuring that uniformity is maintained within an optimal range, is crucial. Therefore, understanding user preferences for lamp post height and spacing is essential for designing effective and satisfactory lighting scenarios.

Traditional lighting design has often focused on factors such as illuminance levels and uniformity. However, this study adopts an approach by examining the effects of uniformity of illuminance and pole height. Higher poles generally offer better light distribution, enhancing visibility, while lower poles can create a more intimate atmosphere, albeit with potentially reduced visibility. A shorter distance between lamp posts usually results in more uniform lighting conditions, especially with higher poles, which improves spatial orientation and overall visual comfort—crucial for pedestrians navigating unfamiliar areas.

This study explores how lamp post distance and pole height affect pedestrians' perceptions of safety and visual comfort in urban outdoor public spaces during nighttime hours. Specifically, it investigates the effects of pole heights (lower vs. higher) and lamp post distances (closer with better illuminance uniformity vs. farther apart with worse uniformity) on participants' perceptions of safety, visual comfort, reassurance, and ease of orientation in public squares during nighttime hours.

The study seeks to address two key questions:

1. Do pedestrians have a clear preference for pole height and uniform illuminance settings, and what is the preference?
2. How do the height and continuity of the lamp posts in the public square affect the perception of pedestrians?

## METHODOLOGY

### Participants

The experiment took place in the Lighting and Photometry Laboratory at the University of Ljubljana in the spring of 2022. A total of 130 participants, all from the Faculty of Electrical Engineering, were involved in the study. Of these, 16 (12%) were female and 114 (88%) were male, all under 30 years old with normal or corrected-to-normal vision. All participants confirmed familiarity with the location and surroundings before the experiment.

Due to COVID-19 safety protocols, the darkroom could only accommodate 25 participants at a time, with a required 1.5-meter distance between them. As a result, each trial involved 8 to 10 participants, and the same procedure was repeated for each group.

Participation was voluntary, with no financial compensation provided. The study was reviewed and approved by the University of Ljubljana's Ethics Committee, and informed consent was obtained from all participants before their participation.

### Photo Stimuli

The experiment utilised rendering images of night-time cityscapes and photometric datasets. Using Dialux software, we created a complex 3D model that simulated four different street lighting scenarios in front of the central train station in Ljubljana, as shown in Figure 1. Notably, all the participants confirmed that they were familiar with the locations of the stimuli in real. Building on the lighting paradigm described in previous research (Nasar & Bokharaei, 2017), our stimulus repertoire included subtle variations in light consistency. The images were displayed on a 300 cm × 230 cm screen, and the luminance was adjusted using computer and projector settings to maintain an average luminance of approximately 1.0 cd/m² across the visual area on the road surface.

An experimental paradigm with a 2×2 configuration was adopted, encompassing lamp-post height (low vs. high at 4.5 m vs. 12 m, respectively) and illuminance uniformity (uniform with 24 m lamp-post distance and less uniform with lamp-post distance of 48 m). These independent variables were operationalised through a quartet of rating reports. The survey aimed to assess the participants' subjective evaluations of their perceptions of safety, visual comfort, ease of discerning distances between pedestrians and street objects, and ease of orientation.

### Experimental Procedure

To maintain consistent illumination and mitigate the influence of external lighting, the use of mobile phones was prohibited throughout the presentation phase. This standardised protocol was meticulously adhered to across

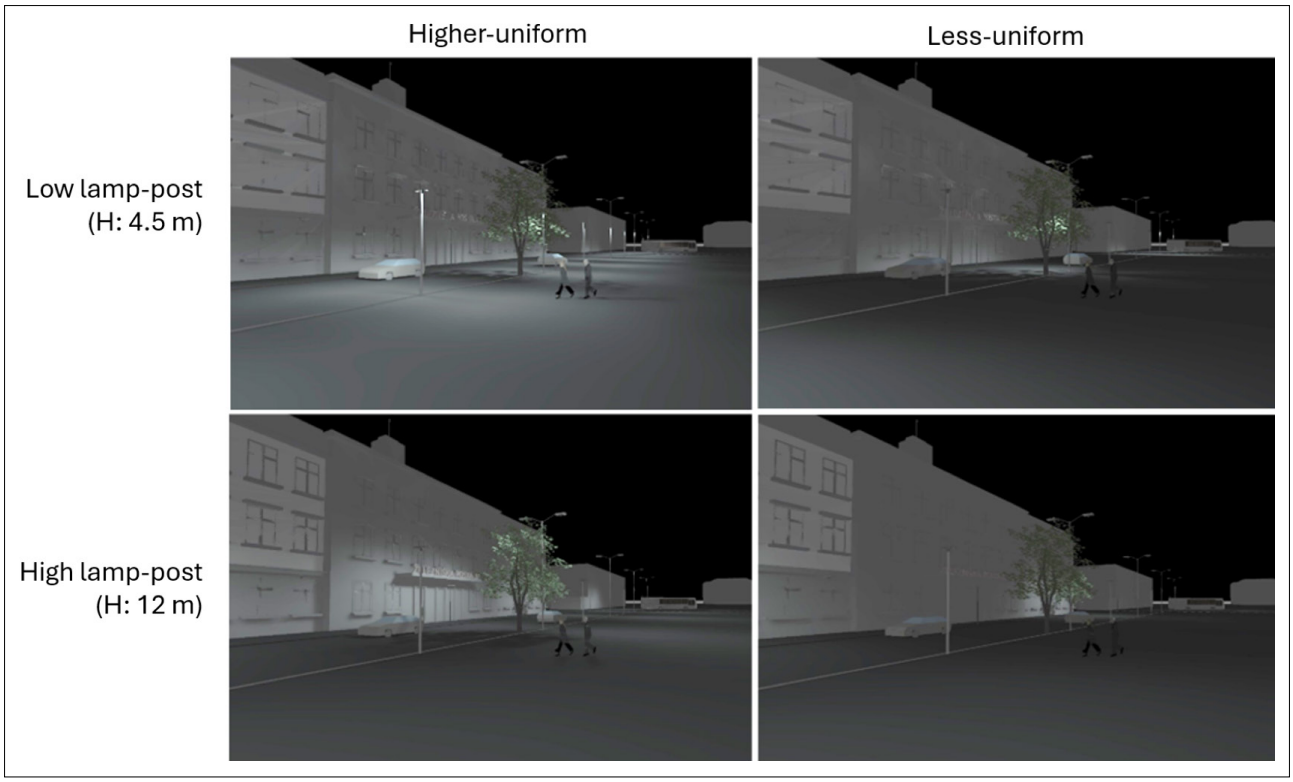


**Figure 1**. Example of the 3D Dialux rendering images used in the experiment.

all experimental groups, as illustrated in Figure 2.

The procedure began by displaying each image to participants for 3 seconds. To ensure robust perceptual engagement, the same set of comparative images was presented twice. During the questionnaire phase, pairs of images were shown simultaneously for an average duration of 105 seconds, allowing participants to compare and rate them. Participants were required to evaluate the images based on specific questions, and their responses were recorded using a five-point scale, ranging from 1 (not at all) to 5 (very much). The order of both images and questions was randomized. The questions were formulated as follows.

Question 1 (Q1), visual comfort: Do you notice a difference between these two images? How comfortable do you feel with Figure A? How comfortable do you feel with Figure B?

Question 2 (Q2), confident: How confident do you feel with Figure A? How confident do you feel with Figure B?

Question 3 (Q3), orientation: To what extent does lighting help you become oriented with Figure A? To what extent does lighting help you become oriented with Figure B?

Question 4 (Q4), distance estimation: How much does the lighting help you estimate the distance to other pedestrians and objects with Figure A? How much does the lighting help you estimate the distance to other pedestrians and objects with Figure B?

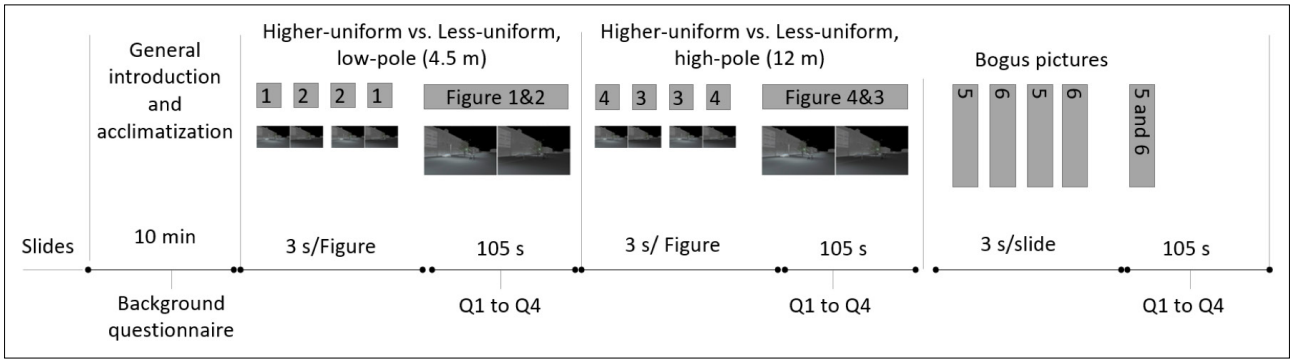


**Figure 2**. Timeline and order of the pictures in the experimental procedure.

## RESULTS AND CONCLUSION

For questions regarding whether there was a noticeable difference between the two images, participants consistently indicated that a difference was present. This suggests that participants were able to perceive variations in the images, despite only changes in the pole distance and height parameters.

First, we examined the mean rating results. As shown in Figure 3, the mean ratings span from 2.2 to 4.1, at a 95% confidence interval. Environments featuring uniform illuminance from high lamp posts had the highest mean scores, whereas those featuring less uniform illuminance from high lamp posts had the lowest scores. This observation suggests a preference among the participants for environments characterised by better uniformity of illuminance from high lamp posts. The standard deviation within this range varied from 0.9 to 1.1 across all means.

Subsequently, two-way ANOVA was employed to investigate the impact of lighting uniformity and lamp-post height on the four subjective rating indicators. Post-hoc analyses were conducted using the Bonferroni–Dunn method, with the significance threshold set at $p<0.05$. The full factorial ANOVA design consisted of higher and lower lamp post heights and higher uniform and less uniform lighting conditions.

The results are summarised in Table 1. Significant effects were observed for both uniform and less-uniform lighting environments for all four questions. Moreover, the lamp-post height did not demonstrate any significant effect, regardless of uniformity. Analyses comparing the low and high lamp post settings across all questions revealed no statistically significant differences.

Overall, the collected data suggested a consistent participant preference for lighting with better uniformity of illuminance over one with worse uniformity that persisted across both higher- and lower-lamp-post environments.

This study explored the effects of lamp post distance and height on pedestrians' perceptions of safety, visual comfort, and ease of distance and orientation in public spaces at night. The findings indicate that continuously installed lamp posts which provide good illuminance uniformity and higher poles are preferred over lower ones providing worse illuminance uniformity. Specifically, the results demonstrate that higher lamp posts with higher illuminance uniformity significantly enhance visual comfort and instil a greater sense of reassurance among pedestrians, further improving visibility and spatial orientation. This may be attributed to the fact that higher and continuous light posts create a wider and brighter space, enabling pedestrians to navigate with greater confidence.

Overall, these findings suggest that incorporating higher lamp posts and ensuring continuity and uniformity in lighting design can contribute to a safer and more visually comfortable nighttime environment for pedestrians in public spaces. On the other hand, we have found in practical project applications that high lamp posts are more prone to casting unnecessary (spill) light on surrounding non-target areas so producing light pollution. Effective lighting design must take into account a broad range of technical parameters to ensure the efficient use of light while minimizing light pollution. These parameters include the optical form, the distribution of luminous intensity, and the design of shading elements, all of which are critical for controlling the direction and reach of the light. By carefully balancing these factors, it is possible to develop lighting solutions that are not only functional but also aesthetically pleasing, contributing to safer and more enjoyable public spaces.

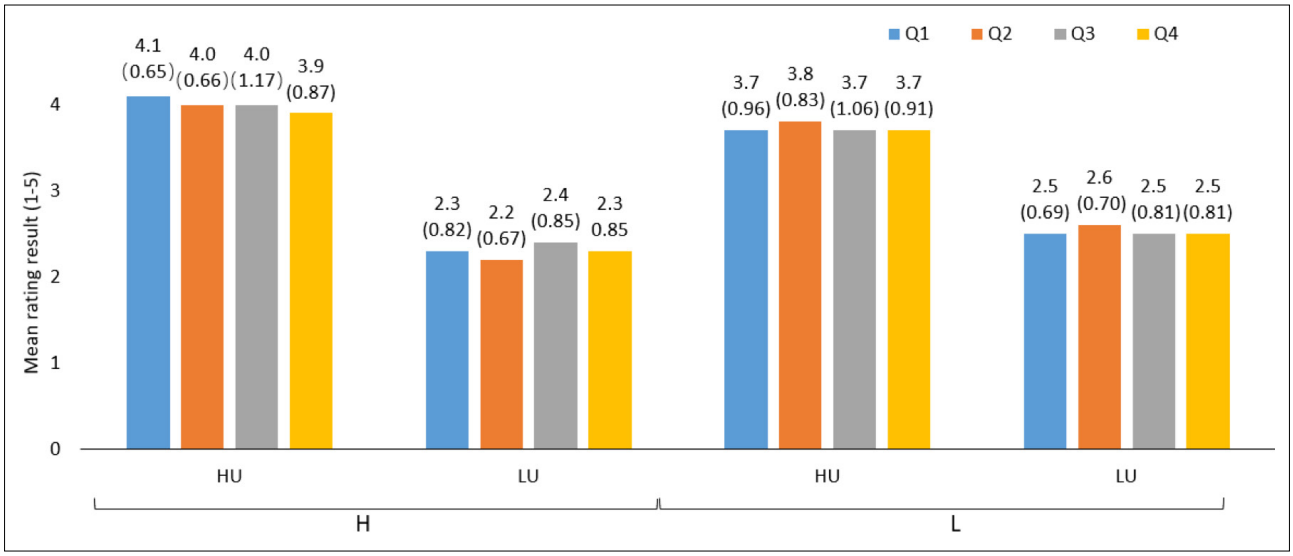


**Figure 3**. Mean rating results and variations (the number in parentheses) for all lighting scenes, categorized as higher uniform (HU), lower uniform (LU), high lamp-post (H), and low lamp-post (L). The ratings are based on four questions: visual comfort (Q1), confidence (Q2), ease of orientation (Q3), and ease of perceiving distances (Q4).

**Table 1.** Results of statistical analyses (ANOVA) for uniformity and lamp-post height

| Factors | df | Sum of Squares | F-ratio | Sig. |
|---|---|---|---|---|
| Visual Comfort | | | | |
| High street lamp-post (H), Low street lamp-post (L) | 1 | 0.95 | 1.23 | 0.2689 |
| Higher-uniform (HU), Less-uniform (LU) | 1 | 297.57 | 383.49 | <0.0001 |
| (H), (L)*(HU), (LU) | 1 | 10.02 | 12.91 | 0.0004 |
| Confidence | | | | |
| (H), (L) | 1 | 1.11 | 1.55 | 0.2137 |
| (HU), (LU) | 1 | 286.53 | 400.91 | <0.0001 |
| (H), (L)*(HU), (LU) | 1 | 6.47 | 9.05 | 0.0028 |
| Ease of Orientation | | | | |
| (H), (L) | 1 | 0.277 | 0.28 | 0.5940 |
| (HU), (LU) | 1 | 252.01 | 258.9 | <0.0001 |
| (H), (L)*(HU), (LU) | 1 | 6.92 | 7.11 | 0.0079 |
| Perceived distances | | | | |
| (H), (L) | 1 | 0.03 | 0.04 | 0.8499 |
| (HU), (LU) | 1 | 243.72 | 283.9 | <0.0001 |
| (H), (L)* (HU), (LU) | 1 | 4.8 | 5.6 | 0.0183 |
| All | | | | |
| (H), (L) | 1 | 0.10 | 0.12 | 0.7313 |
| (HU), (LU) | 1 | 1077.95 | 1301.06 | <0.0001 |
| (H), (L)* (HU), (LU) | 1 | 27.73 | 33.48 | <0.0001 |

The significant differences are bolded.

**Appendices:** *https://tinyurl.com/yjz9kffe*

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**Article**

# The effect of the pandemic period on residence and residential environment preferences: The example of Istanbul

**Aysel YAVUZ*[1], Halide Candan ZÜLFİKAR[2], Habibe ACAR[1]**

*[1]Department of Landscape Architecture, Faculty of Forestry, Karadeniz Technical University, Trabzon, Türkiye*
*[2]Department of City and Regional Planning, Faculty of Architecture, Istanbul University, Istanbul, Türkiye*

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Covid-19; Istanbul; residence preference; social distance; urban open space; user satisfaction.

## ABSTRACT

In late 2019, Covid-19 emerged as a global crisis threatening the entire world. The first case in our country was announced on March 11, 2020. Governments carefully monitored the epidemic process from the first months and took the necessary measures in all areas of public life. Significant increases have been recorded, especially in the use of urban open spaces. Whether this process leads to permanent changes in recreation models and areas, residence and residential environment, remains among the debated issues. For this purpose following the questions "Have people's housing preferences in urban areas changed compared to the pre-pandemic period?" and "How effective are the social, physical, cultural, perceptual and economic opportunities of the residential environment in residence choice?" constitute the starting point of the research. Taking Istanbul as a case study, this article presents the results of an online survey administered to 263 people in December 2020. The results showed that resident and residential environment preferences changed during the pandemic period, and the perceptual, physical, functional and social features of the resident and its environment were most decisive in this change. Research results suggest parameters that may be effective for planning cities that are more resilient to future pandemics.

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## INTRODUCTION

Throughout history, pandemics have had social, economic, and cultural impacts on societies (Başeğmez & Aydın, 2021). The Covid-19 outbreak was described as a "pandemic" by the World Health Organization (WHO) in January 2020 and has turned into a global crisis that threatens the whole world. Therefore, governments imposed strong restrictions to their populations such as keeping physical distance, stopping non-essential activities and limiting the movements of people. This global "lockdown" resulted in almost two thirds of the world population being asked to stay at home and placed under a confinement by April 2020 (Vimal, 2022). While social distancing has been shown to be an effective alternative to reduce the spread of the virus, it is predicted that other health problems may develop due to extended

***Corresponding author**
*E-mail adres: ayavuz75@hotmail.com

time spent at home. Since then, in many parts of the world, such drastic measures have also been reactivated to face the second and third waves of the pandemic (Vimal, 2022). The Covid-19 pandemic has had severe negative effects on populations worldwide (Olszewska-Guizzo et al., 2021). In the first months of 2020, the increase of patients needing medical assistance and intensive care, forced governments all over the world to take remedial actions to rapidly stop the spread of the disease. In particular, social distancing and home confinement were widely used to contrast the diffusion of the virus SARS-CoV-2 (Theodorou et al., 2021).

As of May 28, 2023, more than 767 million confirmed cases and more than 6.9 million deaths have been reported worldwide (WHO, 2023). The rapid spread and high mortality rate of Covid-19 has increased the need to have a healthy living environment to escape infection and has begun to appear as one of people's main concerns. Quarantine measures implemented during the pandemic period led to changes in the use of public spaces. Significant increases have been recorded, especially in the use of urban open spaces. Therefore the question of whether this process leads to permanent changes in preferences regarding housing and the housing environment has been added as a new topic to the discussed topics. On the other hand, it is estimated that staying at home for a long time may have negative consequences in terms of physical, social and psychological aspects. Researchers around the world while investigating the dynamics of the epidemic also have examined the effects of the epidemic on people and society in many areas such as economy, finance, education, tourism and the evolution of Covid-19 and the parameters of the epidemic. It also investigated what can be done to respond to Covid-19, prevent its spread and create healthier environments. Some of them: the important role of gardening activities on psychopathological distress during the days of austere lockdown in Italy, in the course of the first wave of Covid-19 (Theodorou et al., 2021), the impact of the stay at home on the neuro-psycho-physiological functioning of healthy adults during the pandemic period (Olszewska-Guizzo et al., 2021), the critical roles of residential gardens in cities, the spatial distribution of housing types and the degree of self-sufficiency of housing (Ghosh, 2021), the role of both public and private green space in subjective health and wellbeing during and after the first peak of the Covid-19 outbreak that took place in the UK (Poortinga, 2021).

The purpose of this study is to determine whether housing and residential environment preferences have changed after Covid-19. Within the scope of the study, answers were sought to the following questions:

- Have people's "housing" and "residential environment" preferences in urban areas changed compared to the pre-pandemic period?
- What features should a healthy home and residential environment have to be protected from the pandemic?
- How effective are the social, physical, cultural, perceptual and economic opportunities of the house environment in housing preference?
- What should be the parameters that can be effective in "residential environment" preferences for the planning of cities that are more resilient against future pandemics?

With the global spread of the Covid-19 pandemic in the world, domestic spaces have become dramatically important in terms of controlling pandemics and as an environment that must meet the needs of residents during the quarantine period (Zarrabi, Yazdanfar & Hosseini, 2021). Home gardens provide direct contact with nature and gardening activities which reduce stress, anger, fatigue, depression and anxiety (Marques et al., 2021). For this reason, the spaces that constitute "housing" and "residential surroundings" need to have some features to survive both this pandemic process and possible pandemics in the future. In summary it can be said that a healthy environment provides a healthy life opportunity and in this context it is thought that the pandemic process will have permanent effects on housing selection and housing purchase. In conclusion; the pandemic has made all actors related to housing and the city, including politicians, attach importance to a healthy "residential" and "residential environment" for a healthier life. After the pandemic, factors related to architectural design such as light, sun, heating, ventilation, water and energy, as well as factors such as access to gardens, green areas or open areas, began to be questioned in the selection of residence and residential environment. In other words, it is thought that the coronavirus causes people to change residence and residential environment preferences and therefore lifestyle, and increases efforts to improve the living environment. In this context, it can be said that green areas belonging to the residence or close surroundings of the residence have started to gain importance.

According to the results of a research conducted during this period, people are moving out of major cities of Australia to suburbs and beyond, households' choosing a lifestyle shift and settling down in regional towns and cities (Ghosh, 2021). In another study, during the pandemics, people who had access to greenery kept better mental health and had more social interactions. Also the sole presence of a view of vegetation outside the window had positive a effect on residents well-being, but it could scarcely make up for the direct possibility of a urban green spaces visit (Ugolini et al., 2020; Sikorska et al., 2023).

**Residence and Residential Environment**

The need for shelter, which was initially met by the use of caves and cavities, is now met with structures defined as residence produced by the human mind, which are one

of the important dynamics of cities (Asasoğlu, 2013). Residence is one of the basic elements that make up the city. Residence as a general definition; "It is defined as place, dwelling, residences, houses, apartments, etc. that people live in (Türk Dil Kurumu sözlükleri, 2024). Residence is also "a place where one or more people reside, a dwelling" (Hasol, 2010); It is defined as "a shelter built for one or more household members to live in, providing facilities such as sleeping, feeding, protection and cleaning that are necessary for human life."

Residence is shaped within the framework of the socio-cultural, socio-economic and demographic structure of the user like other functional areas. Residence has constantly changed throughout the historical process, according to the influence of daily life, working style, climate and topography, and economic and technological possibilities. In recent years, this need for change has been observed much more rapidly. As a result of external factors such as climate change and the Covid 19 pandemic, which have global and regional effects, and newly developed ways of working and living from home according to the developments in technology; the formation and transformation of residence (number of rooms, number of bathrooms, air conditioning solutions, etc.) have accelerated. The question for whom the residence will be produced affects the location selection, spatial formation and the characteristics of the environment in the urban dimension. (Kellekci & Berköz, 2006; Salihoğlu, 2012a; Mazıcıoğlu & Yenice, 2019).

The area that near the residence, where creates people's first positive or negative perceptions about the environment can be defined as the "residential environment". Residential environment; is the first space where a person connects with the city and directly affects his/her daily life and it is the basic living space at the closest distance where physical, psychological and social needs are met. The neighborhood unit, which is the basic building block of the spatial pattern in the urban area, that is, the meaningful part of the urban whole, constitutes the residential environment. Preferability of the neighborhood or neighborhood unit where the daily life functions of resicence, rest, transportation and (according to post-modern planning approaches) work are located; varies according to its capacity to respond to the social, psychological and spatial expectations of its inhabitants.

While the economic structure is effective in housing choice in cities, the social, cultural and spatial opportunities of the inear surroundings of the house, as well as the physical features of the house, and the equal accessibility of these opportunities to everyone are also effective (Türkoğlu & Kısar Koramaz, 2012; Kellekci & Berköz, 2006; Salihoğlu, 2012a; Yakın et al., 2019). Open and green areas around residences positively affect the perception of environmental quality and emerge as an important factor in housing preference. Especially green areas and home gardens near residences provide opportunities for psychological and physical health benefits (Chalmin-Pui, 2021). Additionally, home gardens are considered a platform for social participation, recreation, and human-nature interactions. Residence are privately owned areas where residents share their daily interactions with nature. A home garden connects to a household's cultural identities, memories, and traditional practices (Ghosh, 2021).

People always seek the most suitable home for choosing, buying, or renting. So, residential preferences are significant to designers, planners, and sociologists. Preferences point to a wide range of inclinations and desires to meet the basic and transcendent human needs. In other words, residential preferences reflect both the mental and ideal individual images and what can actually happen. Therefore, it is the preferences that guide an individual's goals in choosing a home (Zarrabi, Yazdanfar & Hosseini, 2021). Since the outbreak of the Covid-19 pandemic, as a result of the adoption of worldwide lockdown measures, the home environment has become the place where all the daily activities are taking place for many people. Stay-at-home mandates have transformed houses into places where to spend the entire day while working, home-schooling, taking care of families, nourishing, training, socializing, and finally resting (Torresin et al., 2021). This process increased the importance of residence and the residential environment for people's physical and mental health. In this study, it was aimed to evaluate the perception of residence and the resiential environment in relation to the new activities carried out at home, as well as the basic functions of the home, along with the changing social context. It is aimed to evaluate people's feelings of satisfaction with the environment they live in with psychological, mental and social context.

**Urban Life Quality**

Quality of life is a broad concept that aims to evaluate life in all its aspects. Urban quality of life is effective in the development of the individual and society and it is the interaction of the social, economic, health and environmental conditions of the city in which one lives (Shookner, 1997). Urban quality of life has been one of the important topics since the efforts to improve the negative health conditions that emerged as a result of the rapid and unplanned change in urban areas after the industrial revolution. Quality of life was first proposed as "livability" under the title of objective qualities in order to achieve a good settlement within the scope of the Habitat II Human Settlements Conference. Accordingly, for livability in the Habitat II Türkiye National Report and Action Plan various criteria have been determined these can be listed; adequate infrastructure, ensuring that women and children are safe everywhere in the urban area, adequate and accessible

housing, which is a basic need and human right, ensuring equitable services, especially a balanced distribution between open green areas and the built environment, sufficient space for recreation and sports purposes, especially ensuring easy and equitable accessibility of facilities, balanced structure and population density ets (Salihoğlu, 2012b). Urban quality of life is expressed as the reflection of human rights on urban life and is associated with the level of satisfaction of urban rights and the equal and accessible urban services for everyone.

In places where the quality of urban life is low, individuals tend to relocate (Türksever & Atalık, 2001). On the other hand, if individuals meet their physical, social, economic and psychological needs in the city they live in, they will be satisfied with the places they live in, their perception of quality of life will be positively affected and the quality of life in that city will be evaluated positively (Aydemir, 2008). In other words, urban quality of life can be measured by the satisfaction individuals derive from the city and their capacity to meet their needs. The basic determinants of quality in the urban environment are formed and developed by the mutual interactions of natural environmental elements, social environment elements and built environment elements, and change over time under mutual interaction (Çolakoğlu, 2005). Quality of urban life is evaluated through the provision of public services, neighborhood quality, crime, security, housing, natural environment and built environment (Bingöl, 2006). In short, quality of life is affected by all the elements that make up the urban environment and urban life (Kısar Koramaz, 2010).

Green areas, which are effective in evaluating the quality of urban life, contribute to the city in many ways. To list these: improving the urban climate and protecting natural life and natural resources are ecologically, directing and limiting the development of the city by balancing the structure and population distribution are developmentally; adding aesthetic value to the city is phycically; and providing social interaction and undertaking social and recreational functions with opportunities to develop social relations are socially contribute to improving the quality of life in urban environments (Kısar Koramaz, 2010). Green spaces as a component of urban green infrastructures are known to be important for the mental health of the urban population and the Covid pandemic has strengthened such awareness. Urban green infrastructure includes parks, home gardens, street trees and any other form of greening that is embedded in the urban matrix which has an ecological function and provides ecosystem services (Marques et al., 2021). Green areas enable users to establish relationships with their near surroundings and to develop the sense of belonging and ownership of urban people (Dunnet et al., 2002).

Researchers who have been dealing with space design for many years have determined that the users' perception of the quality of life and livability of that city increases in direct proportion to the facilities, quality and accessibility of the residential environment. Many factors such as the city's transportation system, the quality of public spaces, the green network system, land use decisions and the changing population and building density accordingly, the diversity, accessibility and fair distribution of the services offered are effective in determining the satisfaction and quality of life of the users in the urban area. The general approach to measuring urban quality of life is to evaluate the built and natural environmental conditions in cities and individuals' satisfaction together (Yakın İnan & Özdemir Sönmez, 2019). In this context, within the scope of the research, the relationship between users' satisfaction levels, expectations and quality of urban life regarding residence and its residental environment was discussed by comparing before and after the pandemic period.

**Determinants of Residence and Residential Environment Selection**

In its most general form, housing choice is a function of the socio-economic characteristics of the users, the features offered by the existing housing stock and the transportation network facilities (Pagliara & Wilson, 2010). Users' housing selection methods are determined on the axis of the socio-economic structure of the family, the structural and environmental characteristics of the existing house, and the characteristics of the house lived in before the current house (Alkay, 2017). It is not possible to consider the changes in the socio-economic profiles of users independently of social changes. Changes such as flexible working models that allow working at home depending on production styles and the increase in free time spent at home are reflected in the socio-economic profile and emerge as developments that create a need for more housing space, especially observed in recent years (Pagliara & Wilson, 2010; Friedrich & Piesch, 2007; Rossi, 2007).

There are two parties in residence selection. The first of the parties are the users who make the choice and constitute the demand side. The second is the presentation side that produces alternatives for selection. They show diversity and stratification in parallel with the social and economic structure on both sides (Pagliara & Wilson, 2010). The selection structure needs to be laid out in a way that takes into account not only user characteristics and expectations, but also macroeconomic conditions, residence market conditions and central and local government residence policies. The response of the supply side against the demand side, which exhibits an extremely dynamic and constantly changing structure, becomes important (Alkay, 2017). The main problem at this point is that new production is always less than the stock and the existing housing stock, due to its structure, has a weak ability to quickly adapt to changes in the socio-economic profile (Clark & Dieleman, 1996). It is clear

that this diversity and stratification cannot be independent of global changes and developments. Therefore, it is possible to talk about a structure that is constantly affected by internal and external changes (Alkay, 2017).

Clark, Deurloo, and Dieleman (2006) stated that when choosing residence, people do not only make their choice based on the suitability of socio-economic conditions, but also take into account factors such as low density in the environment, the presence of open-green areas, the opportunities and recreation opportunities offered by the residential environment and neighborhood relations. This shows that the perception of urban quality of life is an effective factor in choosing a residential location.

When the factors affecting the choice of residence and its environment are examined, it is seem that users' satisfaction also changes as a result of their different perceptions and different evaluations of the environment in connection with the different charecteristics of users such as age, gender, marrial status -married, single, having children or not-, education level, profession, income level, duration and ownership of residence. Knowing which criteria are effective in people's residence preferences in urban areas is important for creating livable and preferred cities and has always attracted the attention of researchers. Many valuable results have been obtained from the research conducted to date. However, pandemic conditions have brought the importance of this issue back to the agenda, literally returning researchers back to the point where they started. Because it is an expected result that there may be changes in people's residence preferences after the pandemic.

In this context, based on the research questions, the study aims to measure the status and level of change in people's residence and location preferences compared to before the pandemic, and also to determine the criteria and priorities that cause this change.

## MATERIALS AND METHOD

### Material

The research was conducted within the scope of the Istanbul Metropolitan Area. Istanbul Metropolitan Area, as a metropolitan city with 19% of Turkey's population (15,519,267/83,154,997 depending on the province of residence and place of birth) (Turkish Statistical Institute, 2023), is thought to have a potential to determine the changing perceptions of people and the population of our country. It was chosen because it is the most populous city in terms of urbanization and the city where the pressure of urbanization and its accompanying problems are felt the most. Istanbul has been an important cultural, social and economic center in every period of history, and has been a city where urban, social, economic and cultural transformations have occurred from the Ottoman Empire to the present day. Today Istanbul, is one of the most crowded metropolises in the world with a population of approximately 20 million, contains differences in housing areas, housing production styles and housing types with very different dynamics. In this context, the main material of the research consists of the thoughts and evaluations of people residing in Istanbul on the subject.

### Method

This research, which aims to measure people's thoughts about residence and residence preferences during the pandemic period, was conducted in December 2020, while the pandemic process was still ongoing. It was thought that it was important to get the opinions of the users while the problems caused by the pandemic continue. In the research, answers were sought to the following questions by comparing the pre-pandemic and pandemic period.

1. Will Covid-19 have an impact on changing the type of residence people live in?
2. What are the factors affecting users' preferences regarding recidence and residential environments before and after Covid-19?
3. How effective are the social, physical, cultural, perceptual and economic opportunities of the residential environment in residence choice?
4. What is the level of relationship between life satisfaction and factors affecting residence and residential environment preferences due to the pandemic?
5. What are the effective factors on the user satisfaction scale in choosing residence and its near environment?

For the determined research questions, users' opinions on the subject were questioned using the online survey method. The ease of participants expressing their opinions on a certain issue and the difficulty of working face to face with users, especially during the Covid-19 pandemic period that affected the whole world, were influential in the selection of the method. It is seen that the same method is preferred in similar studies (Ugolini et al., 2020; Ugolini et al., 2021; Lehberger, Kleih & Sparke 2021; Blasco-Belled et al., 2020; Poortinga et al., 2021; Theodorou et al., 2021).

The first part of the survey includes demographic evaluations. This section included 8 questions evaluating gender, age, profession, education level, status, total household income, type of residence they live in and type of residence they want to live in. The second part of the survey includes 29 statements (Q1, Q2, …, Q29) compiled from the conceptual framework of the research, reflecting the factors affecting users' residence and residential environment preferences and their views before and during the pandemic. These expressions include physical, functional, cultural, perceptual, social and psychological

criteria. These statements were placed randomly on the survey form, regardless of group order. The aim here was to develop a valid and reliable measurement tool to measure satisfaction in residential environment choice. In creating this scale;

- Physical criteria were measured with eight questions (Q1, Q2, Q 4, Q5, Q6, Q7, Q9, Q14). Here, locational features, security, earthquake and accessibility criteria were evaluated.
- Functional criteria were measured with eight questions (Q11, Q12, Q13, Q17, Q18, Q21, Q23, Q24). In this context, mandatory and optional activities were evaluated.
- Cultural criteria were measured with four questions (Q15, Q19, Q20, Q26). Under this heading, criteria related to being together or in close relationships with family members and friends were evaluated.
- Perceptual criteria were measured with four questions (Q3, Q10, Q16, Q22). The quality of basic elements representing nature, such as air, water, soil and trees, was evaluated.
- Social criteria were measured with two questions (Q8, Q25). With these questions, the criteria that enable humans to establish bonds with other living creatures were evaluated.
- Psychological criteria were measured with three questions (Q27, Q28, Q29). Measures were evaluated for sensory health, mental health, and life satisfaction.

In this context, participants were asked to read each statement and make two separate evaluations, taking into account the period before the pandemic and the period during the pandemic. Participants were evaluated their agreement for each statement using a five-point Likert attitude scale. Here, 1 indicates that the level of agreement with the statement is close to the least (I strongly disagree) and 5 indicates that the level of agreement with the statement is the highest (I strongly agree). Survey questions were answered via internet access.

**Statistical Evaluations**

Statistical analyzes were performed using SPSS version 23. First of all, findings regarding demographic variables were obtained by looking at descriptive statistics. Then the effect of Covid-19 on changing the type of residence people live in was analyzed by frequency analysis, the factors affecting users' preferences regarding residence and residential environments before and after Covid-19 were evaluated by arithmetic average, the effect of the social, physical, cultural, perceptual and economic opportunities of the residential environment on residence choice was evaluated with the arithmetic average and the relationship level between the variables was evaluated with the correlation test.

The level of relationship between factors affecting residence and residential environment preferences due to the pandemic and life satisfaction was determined by correlation test. Inquiries were made using factor analysis to group the factors affecting user satisfaction in the choice of residence and residential environment. The reliability of the data was tested with Cronbach Alpha analysis, and the suitability of the research data for factor analysis was tested with Kaiser Mayer Olkin (KMO) and Bartlett tests.

## FINDINGS

**Participants**

In the research, survey data from a total of 263 people living in different districts of Istanbul were evaluated. According to the data obtained, it was determined that 64% of the participants were women, 36% were men, and 43% of them were individuals between the ages of 46-55. It was determined that 24% of the participants in the total sample worked in the private sector. In addition, when the education level of the participants was evaluated, it was determined that 62% of them were university graduates. It was observed that 73% of the participants owned property and 48% of the household's total income was between 0-10,000 TL. One of our research questions was whether Covid-19 would have an impact on changing the type of residence people live in. With this question, we determined that 65% of the participants lived in an apartment, but when asked about the type of residence they wanted to live in during the pandemic, 71% preferred the house with a garden option (Table 1).

Within the scope of the study, the distribution of participants by districts was examined, it was determined that participants participated from a total of 33 districts: Kadıköy 18%, Üsküdar 11%, Ataşehir 7%, Bakırköy 6% (Fig. 1). Considering that there are a total of 39 districts in Istanbul, it is important to ensure participation from 33 districts in the research.

**Findings on Factors Affecting Residence and Residential Environment Preference**

The arithmetic averages and factor loadings of the participants' residence and residential environment preferences before the pandemic and during the pandemic period were determined. The aim here is to develop a valid and reliable measurement tool to measure satisfaction in residential environment choice. The six criterion groups that were effective in creating this scale were first evaluated within themselves (Table 2).

Accordingly, when looking at the total arithmetic averages of the participants' opinions before the pandemic and during the pandemic process;

**Table 1.** Percentage (%) distribution of the data regarding the demographic characteristics of the participants

| | Percentage (%) |
|---|---|
| Gender | |
| Men | 64 |
| Woman | 36 |
| Age | |
| 18-25 | 9 |
| 26-35 | 11 |
| 36-45 | 24 |
| 46-55 | 43 |
| 56-65 | 11 |
| over 65 years old | 3 |
| Educational background | |
| Primary school | 1 |
| High school | 17 |
| Üniversity | 62 |
| Postgraduate | 15 |
| Doctorate | 6 |
| Type of residence live in | |
| Apartment | 65 |
| House with a garden | 7 |
| Residence | 3 |
| Villa | 3 |
| Site | 22 |
| Total household income | |
| -10 000 | 48 |
| 11 -15000 | 28 |
| 16-25 000 | 18 |
| 26 000- | 6 |
| Job | |
| Student | 8 |
| Housewife | 10 |
| Officer | 11 |
| Private sector | 24 |
| Retired | 11 |
| Engineer | 13 |
| Doctor | 2 |
| Teacher | 15 |
| Landscape architect | 4 |
| Unemployed | 1 |
| Household status | |
| Owner | 73 |
| Tenant | 27 |
| Type of housing you want to live in | |
| Apartment | 7 |
| House with a garden | 71 |
| Residence | 3 |
| Villa | 10 |
| Site | 10 |

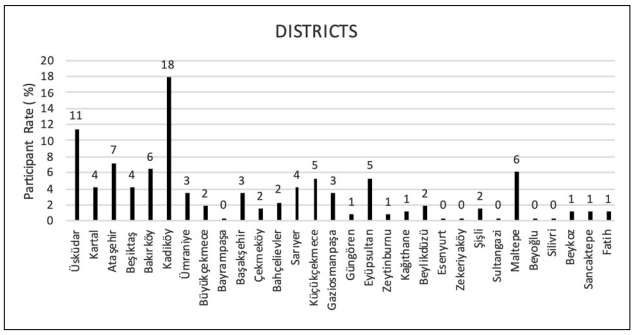


**Figure 1**. Percentage (%) distribution of participants by districts.

From the expressions in the physical criteria before the pandemic, respectively; While the statements "proximity to forests is an important criterion" ($\bar{X}$ 2.97) and "proximity to the city center is an important criterion" ($\bar{X}$ 2.88) stood out, during the pandemic period, "proximity to forests is an important criterion" ($\bar{X}$ 2.91) and "accessibility" "It is an important criterion" ($\bar{X}$ 2.76) statements came to the fore.

From the expressions among the functional criteria, before the pandemic and during the pandemic period, respectively; While the statements "sports activities are an important criterion" ($\bar{X}$ 2.95) and "proximity to educational buildings is an important criterion" ($\bar{X}$ 2.92) stood out, a decrease in these rates was detected during the pandemic period.

From the expressions among the cultural criteria, before the pandemic and during the pandemic period, respectively; While the statements " closeness to friends and associates is an important criterion" ($\bar{X}$ 2.98) and "neighbourhood relationship is an important criterion" ($\bar{X}$ 2.93) stand out, for the pandemic period a decrease was detected in statement "neighbourhood relationship is an important criterion" ($\bar{X}$ 2.88) as was of the functional critaria

From the expressions in the perceptual criteria, during the pandemic period compared to the pre-pandemic period, while an increase observing in the expression "proximity to water resources such as the sea or a lake is an important criterion" (BP: $\bar{X}$ 2.81, PP: $\bar{X}$ 2.86) a decrease was observed in the expression "open green area is an important criterion" (BP: $\bar{X}$ 2.64, PP: $\bar{X}$ 2.44).

From the expressions in the psychological criteria, there was a decrease in the statement "providing vital support (such as the presence of social facilities, sports fields, recreation areas) is an important criterion" during the pandemic period compared to before the pandemic (BP: $\bar{X}$ 2.849, PP: $\bar{X}$ 2.73).

From the experessions among the social criteria, there was a decrease in the statement "socializing/establishing social ties is an important criterion" (BP: $\bar{X}$ 2.84, PP: $\bar{X}$ 2.77) during the pandemic period compared to before the pandemic.

**Table 2.** Factor groups affecting housing and housing environment preferences

| EXPRESSIONS | Before the Pandemic | | Pandemic Period | |
|---|---|---|---|---|
| **In residence preference (RP)**<br>**Residential environment (RE)** | **Arithmetic average** | **Factor loadings** | **Arithmetic average** | **Factor loadings** |
| Physical criteria | | | | |
| 1. (RP) Region/district/neighborhood is an important criterion. | 2.52 | 0.66 | 2.52 | 0.51 |
| 2. (RP) Proximity to the city center is an important criterion. | 2.88 | 0.54 | 2.71 | 0.59 |
| 4. (RP) Proximity to forests is an important criterion. | 2.97 | 0.57 | 2.91 | 0.57 |
| 5. (RP) Security is an important criterion. | 2.47 | 0.66 | 2.44 | 0.63 |
| 6. (RP) Accessibility is an important criterion. | 2.86 | 0.59 | 2.76 | 0.69 |
| 7. (RP) Proximity to the workplace is an important criterion. | 2.87 | 0.56 | 2.71 | 0.57 |
| 9. (RP) Earthquake resistance is an important criterion. | 2.14 | 0.53 | 2.16 | 0.66 |
| 14. (RP) Suitability for use by disabled individuals is an important criterion. | 2.62 | 0.40 | 2.62 | 0.63 |
| Group average factor loadings | | 0.56 | | 0.60 |
| Functional criteria | | | | |
| 11. (RP) Proximity to health services is an important criterion. | 2.87 | 0.50 | 2.67 | 0.57 |
| 12. (RP) Proximity to educational buildings is an important criterion. | 2.92 | 0.56 | 2.83 | 0.60 |
| 13. (RP) Proximity to shopping centers is an important criterion. | 2.64 | 0.58 | 2.50 | 0.62 |
| 17. (RP)The existence of hobby gardens is an important criterion. | 2.86 | 0.57 | 2.79 | 0.59 |
| 18. (RP) Swimming pool is an important criterion. | 2.41 | 0.58 | 2.41 | 0.66 |
| 21. (RP) Parking is an important criterion. | 2.70 | 0.68 | 2.69 | 0.71 |
| 23. (RP) Children's playground is an important criterion. | 2.78 | 0.44 | 2.68 | 0.59 |
| 24. (RP) Sports activities are an important criterion. | 2.95 | 0.48 | 2.90 | 0.48 |
| Group average factor loadings | | 0.54 | | 0.6 |
| Cultural criteria | | | | |
| 15. (RP) Other living residents and the general cultural structure are important criteria. | 2.65 | 0.60 | 2.62 | 0.51 |
| 19. (RP)Proximity to relatives is an important criterion. | 2.90 | 0.77 | 2.84 | 0.66 |
| 20. (RP) Closeness to friends and associates is an important criterion. | 2.98 | 0.74 | 2.98 | 0.63 |
| 26. (RP) Neighbourhood relationship is an important criterion. | 2.93 | 0.52 | 2.88 | 0.54 |
| Group average factor loadings | | 0.65 | | 0.58 |
| Perceptual criteria | | | | |
| 3. (RP) Proximity to water resources such as the sea or a lake is an important criterion. | 2.81 | 0.54 | 2.86 | 0.72 |
| 10. (RP) Clean air is an important criterion. | 2.39 | 0.45 | 2.29 | 0.59 |
| 16. (RP) The existence and quality of trees is an important criterion. | 2.64 | 0.55 | 2.51 | 0.55 |
| 22. (RP) Open green area is an important criterion. | 2.64 | 0.63 | 2.44 | 0.68 |
| Group average factor loadings | | 0.54 | | 0.63 |
| Psychological criteria | | | | |
| 27. (RP) Providing vital support (such as the presence of social facilities. sports fields. recreation areas) is an important criterion | 2.89 | 0.62 | 2.73 | 0.47 |
| 28. (RE) Positively affects the physical and psychological health of individuals. | 2.75 | 0.57 | 2.63 | 0.59 |
| 29. (RE) User satisfaction is essential for children. young people. adults and the elderly. | 2.87 | 0.58 | 2.78 | 0.57 |
| Group average factor loadings | | 0.59 | | 0.54 |
| Social criteria | | | | |
| 8. (RP) Socializing/establishing social releations is an important criterion. | 2.84 | 0.50 | 2.77 | 0.59 |
| 25. (RP) Suitability is an important criterion for pets. | 2.88 | 0.36 | 2.83 | 0.55 |
| Group average factor loadings | | 0.43 | | 0.57 |

It was determined that the changes that emerged in response to these statements during the pandemic period were physical needs at the basic level of Maslow's hierarchy of needs, and then other needs predominated. It has been observed that perceptual, physical, functional and social features are the most determining factors in the selection of residence and residential environment during the pandemic period. Therefore, people's residence and residential environment preferences are very important for designers, planners and sociologists (Zarrabi, Yazdanfar & Hosseini, 2021).

**Evaluation of the Relationships Between Factors Affecting Residence and Residential Environment Preferences and Life Satisfaction**

A correlation test was conducted to determine the factors affecting the participants' preferences of residence and residential environment (taking into account the pre-pandemic period and the pandemic period). The element for which a relationship will be sought is called the dependent variable, and the elements that may be related are called independent variables, and a correlation test was applied. With this approach, the dependent variable "user satisfaction is essential for children, young people, adults and the elderly in public housing areas." (Q29) and the independent variables consisting of expressions reflecting users' perceptions of residence and residential environment preferences, usage and expectation levels were evaluated with a correlation test. Two separate correlations were calculated before the pandemic period and during the pandemic period. According to the correlation test, the expressions that are related to each other are correlations that are significant at the $p<0.01$ level and are indicated with ** (Table 3). Accordingly, the functions that were most correlated with the expression of satisfaction in people's preferences of residence and residential environments before the pandemic period are, in order:

- Positively affects the physical and psychological health of individuals (n=263, $r^2=0.518$, $p<0.01$),
- Providing vital support (such as the presence of social facilities, sports fields, recreation areas) is an important criterion (n=263, $r^2=0.465$, $p<0.01$)
- The existence and quality of trees is an important criterion (n=263, $r^2=0.418$, $p<0.01$)
- Clean air is an important criterion (n=263, $r^2=0.367$, $p<0.01$)
- Suitability for use by disabled individuals is an important criterion (n=263, $r^2=0.365$, $p<0.01$).

During the pandemic period, the functions that correlate most with the expression of satisfaction in people's preferences of residence and residential environment are, in order:

**Table 3.** Correlation of life satisfaction with other expressions in residence and residential environment before the pandemic and during the pandemic period

| **Q29. In public housing areas. user satisfaction is essential for children. young people. adults and the elderly.** | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **Physical** | | | | | | | | | | | | **Functional** | | | | | | | | | |
| **Q29** | **Q1** | **Q2** | **Q4** | **Q5** | **Q6** | **Q7** | **Q9** | **Q14** | **Q11** | **Q12** | **Q13** | **Q17** | **Q18** | **Q21** | **Q23** | **Q24** | | | | | | | |
| BP | 0.207** | 0.167** | 0.146* | 0.264** | 0.291** | 0.310** | 0.165** | 0.365** | 0.291** | 0.231** | 0.012 | 0.302** | 0.095 | 0.112 | 0.356** | 0.320** | | | | | | | |
| PP | 0.142* | 0.138* | 0.221** | 0.227** | 0.269** | 0.269** | 0.211** | 0.387** | 0.223** | 0.302** | 0.140* | 0.324** | 0.064 | 0.133* | 0.402** | 0.258** | | | | | | | |
| | | **Cultural** | | | | | **Perceptual** | | | | **Psychological** | | | **Social** | | | | | | | | | |
| | | **Q15** | **Q19** | **Q20** | **Q26** | **Q3** | **Q10** | **Q16** | **Q22** | **Q27** | **Q28** | **Q29** | **Q8** | **Q25** | | | | | | | | | |
| BP | | 0.313** | 0.134* | 0.262** | 0.275** | 0.176** | 0.367** | 0.418** | 0.309** | 0.465** | 0.518** | 1 | 0.307** | 0.300** | | | | | | | | | |
| PP | | 0.345** | 0.181** | 0.242** | 0.248** | 0.181** | 0.307** | 0.429** | 0.273** | 0.440** | 0.485** | 1 | 0.272** | 0.322** | | | | | | | | | |

- Positively affects the physical and psychological health of individuals (n=263, $r^2$=0,485, p<0.01),
- Providing vital support (such as the presence of social facilities, sports fields, recreation areas) is an important criterion (n=263, $r^2$=0,440, p<0.01),
- The existence and quality of trees is an important criterion (n=263, $r^2$=0,429, p<0.01),
- Children's playground is an important criterion (n=263, $r^2$=0,402, p<0.01)
- Suitability for use by disabled individuals is an important criterion (n=263, $r^2$=0,387, p<0.01).

When comparing the correlation of life satisfaction in residence and residential environment with other questioned expressions before the pandemic and during the pandemic period, the strongest correlations belong to the psychological criteria group, respectively; the expressions residence and the residential environment "positively affects the physical and psychological health of individuals (Q28)" and "providing vital support (such as the presence of social facilities, sports fields, recreation areas)" is an important criterion (Q27). The value of these expressions during the pandemic period decreased compared to the pre-pandemic value.

These results also showed that when the participants' thoughts before the pandemic period and during the pandemic period were compared, the first three statements did not change, but children's playgrounds also gained importance during the pandemic period. In addition, it has been determined that the expressions "the importance of the existence and quality of trees" and "suitability for use by disabled individuals" have gained importance during the pandemic period.

In the research, it was observed that some expressions were responded to at a lower rate during the pandemic period than before the pandemic. These expressions are: (Q22) "Open green space is an important criterion", (Q24), "Sports activities are an important criterion", (Q26), "Neighborhood relations are an important criterion", (Q27) "Providing vital support (such as the presence of social facilities, sports fields, recreation areas) is an important criterion and (Q28) "Positively affect the physical and psychological health of individuals" It is thought that the reason for the decrease in these statements may be due to the fear and anxiety that people experience in developing the sense of confidence that is essential for going to open spaces and doing outdoor activities. Thus, it was once again understood how effective the need for protection and security defined by Maslow in hierarchy of needs in the Covid-19 pandemic.

**Analysis of Factors Related to User Satisfaction Scale in Preference of Housing and Housing Environment**

In the study, it was aimed to determine the factors that the participants took into consideration when determining their housing and location preferences and to determine which factors were more related to the satisfaction of the users. It was also wanted to determine whether these factors changed with the pandemic period. For this purpose, factor analysis was performed to determine the statements that affected the satisfaction of the participants, taking into account the pre-pandemic period and the pandemic period. By grouping and interpreting many variables in factor analysis, understanding and interpreting the relationships between variables were facilitated. In this context, all expressions (variables) queried within the scope of the research were grouped by bringing together the related ones using Varimax rotation (Table 4). As a result, factor groups were named by determining the common point between the variables within the same group and looking at the variable with the highest loading.

The suitability of research data for factor analysis was evaluated by Kaiser Mayer Olkin (KMO) and Bartlett tests. From the 29 statements evaluated, statements Q4, Q13, Q18, Q19, Q21, and Q29 were removed before the pandemic period and a scale consisting of 23 statements that were found to be related to each other at the **level was used in the correlation analysis. Before the pandemic period, the KMO value was found to be 0.870 and the Bartlett test result was $X^2$=1514.408 (p≤ 0.0001).

From the 29 statements evaluated, during the Pandemic period, the statements Q1, Q2, Q13, Q18, Q21, Q29 were removed and a scale consisting of 23 statements that were found to be related to each other at the **level was used in the correlation analysis. KMO value was found to be 0.851, and Bartlett test result was found to be $X^2$=1437.621 (p≤ 0.0001). The fact that the KMO value determined for the pre-pandemic and pandemic periods was in the range of $0.80 < \alpha < 1.00$ showed that the data was highly reliable and the Bartlett test was significant, indicating that the data was suitable for factor analysis.

According to the data obtained from the pre-pandemic period, five factors with eigenvalues above 1.0 explain a total of 49.630% of the variance in the scale scores. The total variance of the 1st factor is 26.548%. These results (Table 4) reveal that the statements under the 1st factor group (natural and cultural values) that meet the satisfaction levels of all user groups with housing and its immediate surroundings are more important than the statements under other groups. The total variance of the 2nd factor group (Proximity to Services) was determined as 6.985%, the total variance of the 3rd factor group (Security) was determined as 5.971%, the total variance of the 4th factor group (Location) was determined as 5.511%, and the total variance of the 5th factor group (Earthquake) was determined as 4.615. These factor groups are listed in Table 5. According to this,

**Table 4.** Factor analysis results evaluating the satisfaction levels of participants with housing and residential environments before the pandemic and during the pandemic period

| **Before the pandemic** | | | |
|---|---|---|---|
| **Factors** | **Factor eigenvalues** | **Variance explained %** | **Cumulative variance %** |
| 1 | 6.106 | 26.548 | 26.548 |
| 2 | 1.606 | 6.985 | 33.533 |
| 3 | 1.373 | 5.971 | 39.504 |
| 4 | 1.268 | 5.511 | 45.015 |
| 5 | 1.061 | 4.615 | 49.630 |
| **Pandemic period** | | | |
| **Factors** | **Factor eigenvalues** | **Variance explained %** | **Cumulative variance %** |
| 1 | 5.776 | 25.059 | 25.059 |
| 2 | 1.597 | 6.860 | 31.918 |
| 3 | 1.395 | 6.112 | 38.030 |
| 4 | 1.302 | 5.570 | 43.601 |
| 5 | 1.097 | 5.215 | 48.816 |
| 6 | 1.048 | 4.690 | 53.506 |

- In the pre-pandemic period, the headings that most affected the level of satisfaction in the house and its immediate surroundings in terms of natural and cultural values were determined as "Presence of trees", "Open green area" and "Cultural structure".
- In terms of proximity to services, proximity to "Educational buildings", "Health services" and "Workplace" comes to the fore.
- “Security” and “Accessibility” come to the fore as separate categories in terms of satisfaction.
- The most important headings affecting the level of satisfaction in terms of location were determined by the "Importance of the region/district/neighborhood", "Proximity to water resources" and "Proximity to the city center" criteria.
- The earthquake factor presented itself as a separate group.

According to the data obtained from the pandemic period, six factors with eigenvalues above 1.0 explain a total of 53.506% of the variance in the scale scores. The total variance of the 1st factor is 25.059% (Table 4). These results reveal that the expressions under the 1st factor group (natural and cultural values) that meet the satisfaction levels of all user groups with housing and its immediate surroundings are more important than the expressions under other groups. The total variance of the 2nd factor group (Proximity to Services) is 6.860%, the total variance of the 3rd factor group (Security) is 6.112%, the total variance of the 4th factor group (Communication) is 5.570%, and the total variance of the 5th factor group (Location) is 5.215.6%. The total variance of the factor group (Earthquake) was determined as 4.690%. According to the distribution of these factor groups (Table 6),

- During the pandemic period, the parameters "Open green space", "Presence of trees" and "Clean air" come to the fore among the natural and cultural values that most affect the level of satisfaction.
- Regarding proximity to services, the parameters "Proximity to the workplace", "Socialization" and "Neighbourhood relationship" were evaluated as among the most important headings.
- “Accessibility” and “Security” come to the fore as separate categories in terms of satisfaction.
- In terms of location, proximity to "Water resources" and "Forests" has been determined as separate and important groups.
- The earthquake factor presents itself as a separate group.
- Additionally, unlike the pre-pandemic period, the parameters "Closeness to relatives" and "Closeness to friends" were separated from the other groups and appeared as the 4$^{th}$ Factor group.

The differences detected when comparing the participants' thoughts before the pandemic period and during the pandemic period are summarized below.

- While the statements "security is an important criterion in housing preference" and "region/district/neighborhood is an important criterion in housing preference" were important before the pandemic period,

**Table 5.** Factor groups that met the participants' satisfaction levels with their housing and immediate surroundings in the pre-pandemic period (BP)

| BP | | Factor loadings | | | | |
|---|---|---|---|---|---|---|
| **Expressions** | **Concept** | **Natural and cultural** | **Proximity to services** | **Security** | **Location** | **Earthquake** |
| Q16 | Presence of trees | 0.674 | | | | |
| Q22 | Open green field | 0.625 | | | | |
| Q15 | Cultural structure | 0.596 | | | | |
| Q17 | Hobby gardens | 0.590 | | | | |
| Q24 | Sportive activity | 0.554 | | | | |
| Q27 | Vital support | 0.515 | | | | |
| Q23 | Children's play area | 0.485 | | | | |
| Q28 | Health | 0.478 | | | | |
| Q25 | Suitability for pets | 0.410 | | | | |
| Q10 | Fresh air | .376 | | | | |
| Q5 | Security | | | 0.769 | | |
| Q6 | Accessibility | | | 0.675 | | |
| Q14 | Suitability for individuals with disabilities | | | 0.412 | | |
| Q1 | Importance of region/ district/neighborhood | | | | 0.745 | |
| Q3 | Proximity /closeness to water sources | | | | 0.600 | |
| Q2 | Proximity /closeness to the city center | | | | 0.593 | |
| Q12 | Proximity /closeness to educational buildings | | 0.652 | | | |
| Q11 | Proximity /closeness to healthcare services | | 0.572 | | | |
| Q7 | Proximity /closeness to workplace | | 0.561 | | | |
| Q20 | Proximity /closeness to friends | | 0.517 | | | |
| Q26 | Neighborly relations | | 0.506 | | | |
| Q8 | Socializing | | 0.478 | | | |
| Q9 | Earthquake resistance | | | | | .661 |

- During the pandemic period, the expressions "proximity to water resources such as the sea or lake is an important criterion", "open green areas are an important criterion", "proximity to relatives is an important criterion" have gained importance.

Therefore, based on these data, while crowded and lively city centers were preferred in housing preference before the pandemic, on the contrary, after the pandemic, people moved to natural, calm and healthy environments such as the sea, lake and forest, away from the crowd, people and the city center, as well as to relatives. It has been observed that the attractiveness of houses in easy-access areas has increased. In other words, before the pandemic period, entertainment, shopping and the social environment were the determining factors of people's housing preferences, but with the pandemic period, protection from the pandemic and healthy living have become the determining factors.

## DISCUSSION

This study primarily focused on whether there was a change in the user satisfaction scale in people's preference for housing and residential surroundings in urban areas before and during the Covid-19 pandemic. At the same time, it aimed to raise awareness about the importance of urban open spaces during epidemic periods. In this context, the study conducted specifically in Istanbul focused on the characteristics of a healthy residence and its close environment (home in order to be protected from pandemics in the future and the impact of the social, physical, cultural, perceptual and economic opportunities of the residential environment on housing choice.

Results clearly show that we need to pay more attention to the contribution of residential gardens and urban open spaces to people and the city during the epidemic period. When the effect of Covid-19 on changing the type of housing people live in was questioned, it was revealed that 65% of the participants lived in an apartment, but with

**Table 6.** Factor groups that met the participants' satisfaction levels with their housing and immediate surroundings during the pandemic period (PP)

| PP | | Factor loadings | | | | | |
|---|---|---|---|---|---|---|---|
| **Expressions** | **Concept** | **Natural and cultural** | **Proximity to services** | **Security** | **Communication** | **Location** | **Earthquake** |
| Q22 | Open green field | 0.795 | | | | | |
| Q16 | Presence of trees | 0.691 | | | | | |
| Q10 | Fresh Air | 0.606 | | | | | |
| Q27 | Vital support | 0.533 | | | | | |
| Q15 | Cultural structure | 0.532 | | | | | |
| Q28 | Health | 0.477 | | | | | |
| Q24 | Sportive activity | 0.469 | | | | | |
| Q23 | Children's play area | 0.421 | | | | | |
| Q17 | Hobby gardens | 0.349 | | | | | |
| Q25 | Suitability for pets | 0.329 | | | | | |
| Q7 | Proximity /closeness to workplace | | 0.615 | | | | |
| Q8 | Socializing | | 0.605 | | | | |
| Q26 | Neighborly relations | | 0.585 | | | | |
| Q11 | Proximity/closeness to healthcare services | 0.562 | | | | | |
| Q12 | Proximity/closeness to educational buildings | 0.498 | | | | | |
| Q14 | Suitability for individuals with disabilities | 0.407 | | | | | |
| Q6 | Accessibility | | | 0.770 | | | |
| Q5 | Security | | | 0.696 | | | |
| Q19 | Closeness/proximity to relatives | | | | 0.790 | | |
| Q20 | Closeness /proximity to friends | | | | 0.767 | | |
| Q3 | Proximity /closeness to water sources | | | | 0.796 | | |
| Q4 | Proximity /Closeness to forests | | | | | 0.540 | |
| Q9 | Earthquake resistance | | | | | 0.650 | |

Covid-19, 71% of the participants wanted to live in house with a garden. In a study examining the change in people's perspectives on the city and housing during the pandemic period, it was found that city centers lost their attractiveness, apartment life limited people and was described as unhealthy, those with the means preferred detached houses away from the crowd, surrounded by nature, and those with less means preferred their current living conditions. It has been determined that they transform their areas into more livable areas. In a study examining the change in people's perspectives on the city and housing during the pandemic period, it was found that city centers lost their attractiveness with the epidemic, apartment life limited people and was described as unhealthy, and those with the means preferred detached houses away from the crowd and surrounded by nature. It has been determined that those with fewer opportunities can transform their existing living spaces into more livable ones. It has also been observed that sales of houses with gardens have increased and the rents of these houses have also increased (Tayanç, 2022). Residential or home gardens or yards are the places where residents share everyday interactions with nature and are under private ownership (Ghosh, 2021). In a study conducted with residents of Rio de Janeiro during the Covid-19 epidemic, it was emphasized that although urban parks and green landscapes are important for people, residential gardens are the most effective factor in reducing mental distress (Marques et al., 2021). Another study confirmed that participating in gardening activities reduced psychological distress during isolation (Theodorou et al., 2021). In a study with similar results, the reasons for gardening during the pandemic period were investigated. Among the responses received, giving life satisfaction, especially liking gardening activities and enjoying seeing plants/flowers grow stood out as the most frequently mentioned expressions (Chalmin-Pui, 2021).

Using nature, including residential gardens and public green spaces, is known to be positively correlated with measures of subjective well-being (Lehberger, Kleih & Sparke, 2021).

It also shows that engaging in gardening activities is important for some people and can be creative and have the opportunity for self-reflection (Chalmin-Pui, 2021). On the other hand, it is known that a private garden can partially compensate for the lack of access to public green space, but in times of crisis, nearby public green spaces are especially important for households without a private garden (Poortinga et al., 2021). This supports the results of many studies that having open space and a garden has potential benefits and contributions to life satisfaction (Lehberger, Kleih & Sparke, 2021; Corley et al., 2021; Poortinga et al., 2021; Hanson, Eckberg & Widenberg, 2021).

Our research findings, as in similar studies, emphasized that the presence and quality of trees in the immediate vicinity of residences in urban areas are important during the pandemic period, and also emphasized the role of open green spaces (Olszewska-Guizzo et al., 2021; Poortinga et al., 2021). A study conducted by Chalmin-Pui (2021) revealed that the generally open and green prevalence of houses and the perception of environmental quality are an important factor in positive credit and housing preferences. In addition, the benefits of green structures in residences and residential gardens for psychological and physical health have been expressed (Chalmin-Pui, 2021). It is also clear that private gardens provide opportunities for daily nature experiences (Hanson, Eckberg & Widenberg, 2021). This is a result consistent with previous findings.

Another study supporting our research findings was conducted among apartment residents in Tehran. This study, which examines the effectiveness of factors related to mental health, physical health and socio-economic lifestyle in determining priorities in housing selection after the COVID-19 crisis, shows that the view from the window to the open space reaches the highest average among other preferences. The study also recommended the use of plants in the immediate vicinity of residences due to their calming effects on stress reduction, as well as their effects on improving air quality, reducing noise and creating favorable views. Determining the depth of appropriate private open or semi-open spaces per capita in line with the socio-cultural context of each region has been suggested as a strategy that will positively affect the mental health of urban residents (Zarrabi, Yazdanfar & Hosseini, 2021).

In this article, the statement "proximity to water sources such as the sea or lake is an important criterion", which is among the perceptual criteria regarding the house and its environment, stands out and suggests that spending time here can be an important source of health. Similarly, in a different study, people described the coastal area as an integral part of their extended home networks (Jellard & Bell, 2021). In this context, our research supports previous studies and contributes to the literature showing that water is beneficial for people's health.

According to our research results, the statements "proximity to forests is an important criterion" and "accessibility is an important criterion" came to the fore among the physical criteria during the pandemic period. According to the results of a study conducted with real estate agents in Italy, where Guglielminetti et al. (2021) investigated the impact of the pandemic on housing preference, the pandemic caused a large increase in the demand for houses located in areas with lower population density. Accordingly it has been determined that a significant shift in home preferences towards larger, single-family homes with outdoor areas. Therefore, it is possible to say that there is a tendency towards natural areas with low population, away from crowds. Again, in a study on housing purchasing preferences, it was observed that with the pandemic, homeowners started to prefer houses surrounded by greenery where they could get fresh air. Therefore criteria such as having a garden terrace or balcony and proximity to the forest directly affected the housing purchasing process. In addition, the criterion of proximity to the forest in housing preference was determined as the least important criterion in both pandemic and non-pandemic situations. Online education and online working situations arising from the pandemic have caused users to pay more attention to the interior features of the house. For this reason, there has been no change in the importance of the proximity to forest criterion (Çalık & Ergülen, 2023). A study conducted in Izmir also showed that the epidemic had an impact on housing preferences. While preferences are changing from gated communities and residences to detached houses, personal pools and walking areas and, if possible, nature and sea views have also been determined as preferred factors. In addition, due to the effect of the epidemic, the demand for housing increased, but due to limited land, construction increased in locations further from the city center (Diyadin Lenger, 2023).

In addition, along with various studies indicating that crowded environments cause negative health problems, the World Health Organization has also stated the characteristics of healthy housing. It is stated that in such epidemic situations, completely detached houses with a reasonable amount of garden space in the surrounding area, providing better opportunities for social distance and food production, having the healing effects of light, air and nature, would be a good solution. It is clear that the idea of creating indoor garden areas even in multi-storey buildings should now be considered. Research areas and questions on architecture and urbanization were defined in a study that included lessons to be learned about built environments after the Covid-19 pandemic. Accordingly, under the title of post-pandemic housing, the layout of houses, indoor air quality, flexible use and transformation are stated as the subject of this study. One of the research questions related

to these topics is “Should our terraces, balconies, and roofs be planted?” Therefore, it seems that it is important for the house to have as much plant presence as possible in terms of what the pandemic has taught us (Megaheda & Ghoneim, 2020).

While the statements "sports activities are an important criterion" and "proximity to educational buildings is an important criterion" were prominent among the functional criteria before the pandemic, a decrease in these rates was detected during the pandemic period. Similarly, Akbari et al.'s (2021) study showed that environmental factors are the first priority in residents' housing preferences compared to space and activities, and the most important priorities are air quality, daylight quality and view quality, respectively. Air quality and natural light are among the priority criteria for healthy homes when choosing housing. In the research that determines the level of satisfaction and preference regarding the residence, the lowest indicators are seen in "activities and functions", and the highest indicators are in "terrace", "green area" and "exercising outdoors". In the research, a decrease was observed in the statement "providing vital support (such as the presence of social facilities, sports fields, recreation areas) is an important criterion" among the statements among the psychological criteria. While healthy socialization in terms of psychological health and recreational activities in terms of physical health define vital support during the pandemic, a healthy diet and access to food can also be discussed under this heading. From this perspective, Megaheda and Ghoneim (2020) stated that we need physical interaction with living plants for our mental health and that we should also grow what we eat to reduce the risk, especially during self-isolation. For this reason, they state that we should focus on green again, especially from what the pandemic has taught us, and that we should consider planting options and green roof system applications in our gardens and terraces.

In the research, a decrease was observed in the statement "providing vital support is an important criteria"(such as the presence of social facilities, sports fields, recreation areas) which among the psychological criteria While healthy socialization in terms of psychology and recreational activities in terms of physical health are defined as vital support during the pandemic, a healthy diet and access to food can also be discussed under this heading. From this perspective, Megaheda and Ghoneim (2020) stated in their study that we need physical interaction with live plants for our mental health and that we should also grow what we eat to reduce the risk, especially during self-isolation. They also stated that we should focus on green again, especially based on what the pandemic has taught us, and that we should consider planting options and green roof system applications in our gardens and terraces.

It is known that being in contact with green areas positively affects psychological health. This relationship can be achieved in public spaces. However, when public spaces cannot be accessed or used, the role of green spaces within or in the immediate surroundings of the home is important (Spano et al., 2021). As a result of the online surveys conducted by Akbari et al. (2021) with 421 people during the pandemic period, it turns out that environmental factors have a higher mean in housing preferences than space, functions and activities, and that optimal mental health is associated with a very high level of satisfaction with indicators of roof, green space and outdoor exercise. Findings regarding housing type revealed that people living in private homes had better mental health than those living in low-rise or high-rise housing.

As a result of the research, there was a decrease in the statement "socializing/establishing social ties is an important criterion" among the statements among the social criteria. Among the cultural criteria, the statements "closeness to friends and acquaintances is an important criterion" ($\overline{X}$ =2.98) and "neighbourhood relationship is an important criterion" stand out, while a decrease in the statement "neighbourhood relationship is an important criterion" was detected during the pandemic period. Different from these results, a study showed that a living environment that allows the establishment of social relationships is important. While security is determined as the most important factor in housing and residential environment preferences, people prefer safe living spaces that allow neighborly relations. In terms of construction type, low-rise buildings are more preferred. The vast majority prefer living spaces in a site layout. Security, perception of exclusivity, common areas, social facilities and integrated building layout are effective in this decision. As a result of the study, it was revealed that the Covid-19 epidemic affected people's priorities regarding housing and the residential environment to a limited extent (Levend & Sağ, 2023).

Although our study provides important information about the factors affecting the choice of housing and the housing environment, this study has some limitations. The number of women among the participants is significantly higher than the number of men, meaning that the imbalance in gender distribution may change the results. New studies with a larger number of participants will be fundamental to better understand how effective factors in the selection of housing and residential environments can help reduce possible problems during a possible epidemic period. Since only the parameters of the residential environment were evaluated in this study, it is recommended that the parameters of the building structure and interior design should also be taken into account in the future.

## CONCLUSION

The COVID-19 pandemic has revealed the necessity of planning cities in the face of possible future global health crises. Developing new approaches within the scope of housing, business and social life activities has become vital and many disciplines have evaluated the issue through field studies. Our study was conducted to reveal how the COVID-19 epidemic affects people's housing and immediate surroundings and quality of life preferences. In this context, preferences and satisfaction levels are discussed under physical, functional, cultural, perceptual, psychological and perceptual criteria. Together with the evaluations made, it is possible to discuss the results based on the research questions stated at the beginning of the study.

- Will Covid-19 have an impact on changing the type of housing people live in? What are the factors affecting users' preferences regarding housing and residential environments before and after Covid-19? Considering both this research and other research conducted during the pandemic, it is seen that people's housing preferences have changed. These changes seem to be influenced by the location and quality of the house, the physical opportunities offered by the housing environment, the presence of opportunities such as interior space/balcony/terrace/garden/roof garden, neighborhood relations and socialization with other people, security, access to the city center and therefore to crowded places. In addition to changing preferences, there are also situations where economic conditions are not possible to change the house and its surroundings. In this case, people made some changes to their existing homes, at least within their means. With this result, these demands of users should be prioritized in the residential areas that will be planned and designed from now on.
- How effective are the social, physical, cultural, perceptual and economic opportunities of the residential environment in housing choice? Among the physical criteria affecting housing choice during the pandemic period, proximity to forests and accessibility were determined as important criteria. Many studies have shown that having accessible green areas in people's living spaces has positive effects. This research also shows that users demand this. When we look at the functional criteria, it is seen that it is not as prominent as it was before the pandemic. On the other hand, research shows that during the pandemic period, environmental factors such as air quality, light, etc. are considered before the diversity of places and activities. The importance of a healthy social life in the development of an individual is an undeniable fact. However, this situation remained in the background during the pandemic period. Although restricting people's social activities and environments is a requirement of isolation measures, it has also produced negative consequences. This situation has been the subject of different research. When we look at the choice of housing and its immediate surroundings, establishing social relationships during the pandemic was not a desired situation. It has been observed that there are also studies that show the opposite. Therefore, although the probability of recurrence of pandemics is low, it is also an important consequence that people have to stay away from social life in a possible situation.
- What is the level of relationship between factors affecting housing and housing environment preferences due to the pandemic and life satisfaction? In this inquiry, the functions that are most correlated with the expression of satisfaction in people's preferences regarding housing and residential environments before the pandemic period are, respectively, positively affecting the physical and psychological health of individuals and providing vital support (such as the presence of social facilities, sports fields, recreation areas). These results also showed that children's playgrounds gained importance during the pandemic period. In addition, the expressions "The importance of the existence and quality of trees" and "Suitability for use by disabled individuals" gained importance during the pandemic period.
- What are the effective factors on the user satisfaction scale in choosing housing and its immediate surroundings? During the pandemic period, natural and cultural values affected the level of satisfaction the most, and within this factor group, the parameters "Open green space", "Presence of trees" and "Clean air" came to the fore the most.

As a result, our study clearly showed the contribution of residential gardens and urban open spaces to people and the city during the epidemic period. With Covid-19, it has been revealed that the type of housing people wants to live in is a house with a garden. For adaptation and resilience cities against to the effects of the pandemic such as Covid-19, managers should consider a flexible and sustainable urban development strategy. It is thought that the evaluations made with the results obtained from this study for possible future pandemics can form the basis for the physical and social resilience of cities and contribute to finding solutions.

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**Article**

# Evaluation of plasterboard partition wall sections in terms of requirements for noise control

**Zeynep SAVCI ÖZGÜVEN*, Neşe YÜĞRÜK AKDAĞ**

*Department of Building Science and Technology, Yıldız Technical University Faculty of Architecture, Istanbul, Türkiye*

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## ABSTRACT

Building acoustics is known as one of the main indoor environmental conditions which holds utmost importance while considering the design, construction, and operation of buildings. Furthermore, it has gained greater importance together with the growing awareness of the adverse effects of noise on human health and psychology. As a result of these pertinent findings, the "Regulation on Protection of Buildings Against Noise (RPBAN)" was published in the Official Gazette on May 31, 2018, and was officially enforced. Under this regulation, the criteria related to architectural acoustics, such as sound insulation, background noise levels, and reverberation time, are evaluated using an acoustic performance classification system divided into six categories. Newly designed buildings are expected to achieve at least Class C acoustic performance, while existing buildings undergoing renovation are required to meet a minimum of Class D.

Achieving the sound insulation values specified for different acoustic performance classes in buildings is dependent upon various factors such as the inclusion of material properties of different densities and thicknesses, variations in the joint details of building components, and application conditions. Consequently, significant differences often arise between airborne sound insulation values obtained under laboratory conditions and those recorded in the field. Within the scope of this study, 10 different wall variations that were formed into dry wall systems were applied and measured for airborne sound insulation values at the Turkish Standards Institution's Tuzla Building Materials Fire and Acoustic Laboratory. These applications were conducted at various times, using different inner materials, wall types, and gypsum board densities.

To make calculations with the simulation program, the Rw values obtained from laboratory measurements were assigned as the sound transmission loss values of the partition wall sections defined between the rooms. The laboratory-measured results were then simulated within a controlled digital environment under three different scenarios, and the resulting $D_{nT,w}$+C ($D_{nT,A}$) values were compared with the standards outlined under formal regulations. The results obtained from the three different evaluated hypothetical scenarios showed that as the volume of the receiver room increases, i.e., as the V/S ratio increases, the calculated $D_{nT,w}$+C value rises.

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***Corresponding author**
*E-mail adres: zeynepsavci@gmail.com

## INTRODUCTION

The construction sector holds a significant place in our economy and is one of the largest and most dynamic industries in Turkey. In recent years, with the increase in the export of both construction materials and contracting services, the importance of the sector and its direct involvement with international competitiveness has consecutively grown. In order to assist with the improvement of general comfort for indoor usage and amenities of the like, to avoid undesired situations that are directly correlated to the rights of acoustic privacy and the effects of standardized conditions, these new policies came into effect as an official regulation to directly address acoustic requirements in Turkey on May 31, 2018.

The sound insulation classes defined by regulation are crucial criteria for determining the quality of sound insulation provided by the building elements. Neubauer's study, commonly utilized throughout Europe, is used to examine how parameters such as DnT,w and Rw, are used to create sound insulation classes and explores the relationship between these parameters. This study reveals that a difference of approximately ±2 dB may occur between these two measurements dependent on the geometric properties of building elements and rooms. These findings emphasize the importance of considering specific boundary conditions when evaluating the acoustic performance of building elements (Neubauer, 2023).

Another study evaluates the acoustic performance of residential buildings in terms of legislation and its subjective effects by conducting field measurements of acoustic performance. This study also compares the threshold values defined in Turkey's regulations and the evaluation methods of building acoustic performance with socio-acoustic surveys, which helps to determine residential user satisfaction, disturbances caused by other various noise pollution and the levels of negative impact experienced by those affected (Şentop, 2020).

In the process of building acoustics, the design of partition walls and the selection of materials are of great importance, particularly in densely urbanized areas, which help to ensure acoustic privacy. In the study conducted by Uris et al., it was observed that due to the presence of an internal gypsum layer in double-framed partition walls, the sound insulation at low frequencies decreases even if the number of plaster panels in the wall section, the thickness and density of the gypsum panel layer do not change. The study further concludes that placing such layers in the middle of the partition wall decreases sound insulation at additional resonance frequencies, particularly in the 100-200 Hz range. These findings highlight the need for particular selection of material combinations for the purpose of building internal wall systems (Uris et al., 2006).

The sound insulation performance of building elements should be meticulously evaluated, not only in laboratory environments, but also under actual field conditions. Goretti and Cotana's study investigates the variations in sound insulation performance exhibited by the same building elements when constructed in different building designs. This study reveals how design parameters such as wall thickness and surface density lead to differing results in sound insulation, especially in small and irregularly shaped rooms. These findings underscore the importance of considering field conditions in the acoustic design of partition walls (Goretti & Cotana, 2014).

The study by Schäfers and Grethe examines the pros and cons of the KS Schallschutzrechner simulation program, which allows the modeling lateral or separating structural components of multi-layered lightweight structural elements in multi-storey residential buildings where sound insulation is designed in accordance with DIN 4109-2 (Schäfers & Grethe, 2015).

Aksoylu et al. conducted a comparative analysis of sound reduction index models in terms of sound transmission using four different simulation programs (Bastian, Akuzoft, Insul, and dBKAisla). Their analyses calculated the effectiveness and accuracy of the models for the weighted sound reduction index (RW), which reflects the degree of effective performance by the usage of proper materials, based on experimental data. With the usage of 11 materials, the average accuracy of the models was determined as follows: Insul model 90%, dBKAisla model 86%, Bastian model 84%, and Akuzoft model 82% (Aksoylu et al., 2016).

Tan and Sin analyzed the sound transmission values of four different construction materials (autoclaved aerated concrete, laminated glass, expanded polystyrene, and rock wool) using an impedance tube. These results can suggest that autoclaved aerated concrete provides more sound insulation than other materials. The sound insulation values of various combinations of these materials were also examined, with the combination of autoclaved aerated concrete and expanded polystyrene which proved to be more efficient than other alternative materials (Tan and Sin, 2018).

A similar study evaluated the sound insulation performance of single and double-panel structures using analytical and experimental findings based on mass law. The study calculated and compared sound insulation values using materials such as glass, steel, and concrete. While the analytical model was effective for sound insulation, differences between experimental and analytical results were observed at low frequencies (Tadeu et al., 2003).

In addition to simulation studies, on-site sound insulation measurements hold significant importance. In residential buildings in Macedonia, the sound transmission loss values of different types of partition walls, measured through field studies, were compared by Samardzioska T., and various

interventions were implemented to improve these results. Gypsum board cladding combined with mineral wool was applied to perforated brick walls of varying thicknesses. For a 160-mm-thick perforated brick wall, the sound transmission loss value increased by 11 dB, rising from 38 dB to 49 dB. Similarly, for a 250-mm-thick perforated brick wall, the sound transmission loss value increased from 46 dB to 53 dB. (Samardzioska, 2014).

Crispin et al. (2008) examined the efficiency of flexible connectors for sound insulation according to EN ISO 12354-1(2021e). Their study focused on airborne sound insulation in masonry buildings built with brick content. Measurements were conducted on a constructed building using different types of flexible connectors for walls and floors. The results offered solutions for improving sound insulation based on the geometric conditions of the building and the complete separation of walls from the structure using flexible connectors (Crispin, 2023).

This study aims to evaluate the data obtained from sound transmission loss measurements (RW) conducted on 10 different gypsum board partition wall types within the compliance and standards of 10140-2 at the Turkish Standards Institution (TSE) laboratory (International Organization for Standardization [ISO], 2021). The DnT,A values are determined through simulations in modeled spaces and compared with regulatory values. In order to achieve this, the following is applied:

- The variables causing differences in the sound insulation levels of various gypsum board partition wall types obtained in accredited laboratories are identified, and design details to be considered during the planning stage are determined.
- The targeted sound insulation levels for wall types measured in laboratory conditions are compared using simulation software.
- The sound insulation levels of gypsum board partition walls in newly designed buildings are evaluated for compliance with the standards outlined in the regulation.

## METHOD

Applications of gypsum board partition walls were conducted using 10 different wall typologies based on two different construction methods with varying density and thickness characteristics. The airborne sound insulation values of these wall types were measured at the Turkish Standards Institution's Tuzla Building Materials Fire and Acoustic Laboratory (TSE) according to the procedures outlined in ISO 10140-2 (2021b). The weighted standardized sound reduction index was calculated in accordance with ISO 717-1 (2013).

The Rw values obtained at the TSE Laboratory based on ISO 717-1 (2013) were converted into $D_{nT,w}$+C values for modeled spaces using the KS-Schallschutzrechner 8.03 Simulation Program. The weighted sound reduction index results ($D_{nT,w}$+C) derived from 10 partition wall types that were placed between a source room and three different receiver rooms were then evaluated under the "Regulation on Protection of Buildings Against Noise," published in the Official Gazette on May 31, 2018 (Ministry of Environment, Urbanization and Climate Change, 2018). As the modeled spaces were designed as office spaces the results were assessed within the office category as defined by the regulation.

The workflow followed by this study are presented below:

✓ Identification of gypsum partition wall section options

✓ Development of section details

✓ Determination of sound transmission loss values (RW) according to the TSE Laboratory

✓ Evaluation of results under the regulation are determined by:

- Design of modeled spaces
- Selection of simulation software
- Transfer of section options to the simulation program and obtaining results ($D_{nT,w}$+C)
- Assessment of results within the scope of RPBAN

## GYPSUM BOARD PARTITION WALL TYPES EVALUATED WITHIN THE SCOPE OF THE STUDY

This section provides an overview of the material and application details of the gypsum board partition wall types studied, as well as information on the measurement equipment and its relevant standards.

### Gypsum Board Partition Wall

The 10 types of gypsum board partition wall systems addressed in the study are divided into two categories based on their application methods.

### Single-Frame Gypsum Board Partition Wall Systems

Gypsum board partition wall systems constructed using a single-frame carrier with a C100 galvanized profile were manufactured in the laboratory at various times, incorporating gypsum boards with varying panel densities. The details of the single construction gypsum panel partition wall type are shown in Figure 1.

### Double-Frame Gypsum Board Partition Wall Systems

Double-frame gypsum board partition wall systems manufactured with C50 galvanized profiles were produced in the laboratory at various times using gypsum boards with varying panel densities. In the double-frame gypsum board

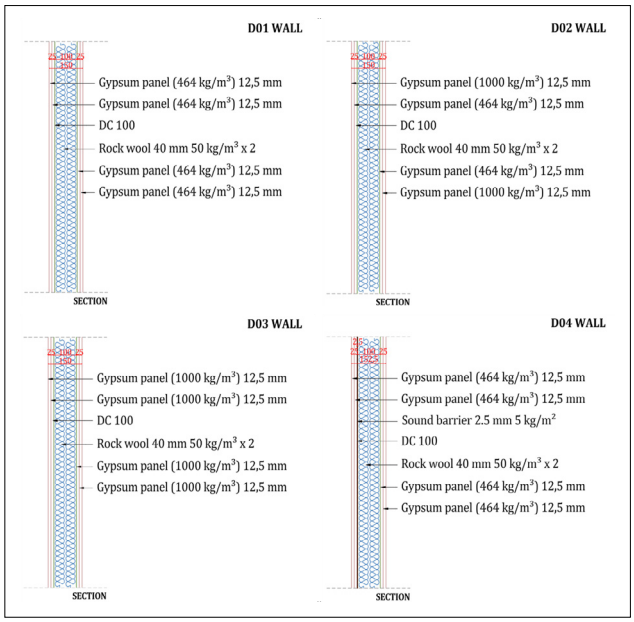



**Figure 1**. Single-Frame Gypsum Board Partition Wall Systems Manufactured at TSE (Credit to authors).

partition wall application, the air gap between the frames was increased to evaluate its effect on sound transmission loss values. In the double-frame gypsum board partition wall applications, the air gap between the frames was varied, a sound barrier was added to the gypsum board, and a flexible connection profile was utilized. The changes in measured sound transmission loss values were analyzed and compared, as illustrated in Figure 2.

### Technical Application Details

In accordance with TS EN ISO 10140-5 (2021c), DU profiles were affixed to the floor, ceiling, and wall surfaces of the test frame by gluing 5 mm thick acoustic strips made from recycled rubber to the back and securing them with screws (ISO, 2021). DC profiles were placed within the 3060 mm x 4060 mm test frame at intervals of 60 cm. Double layers of gypsum boards were staggered and applied on both surfaces of the construction. The construction cavity was filled with two layers of stone wool, each 40 mm thick and with a density of 50 kg/m³. The second layer of gypsum boards were patched with mesh tape and joint filler. Fire-resistant sealant was applied around the perimeter of the frame on both sides to ensure airtightness. The installation of the test frame between the source and receiver rooms was carried out by the laboratory team. Relevant technical details can be viewed in Figure 3 through the following photographs:

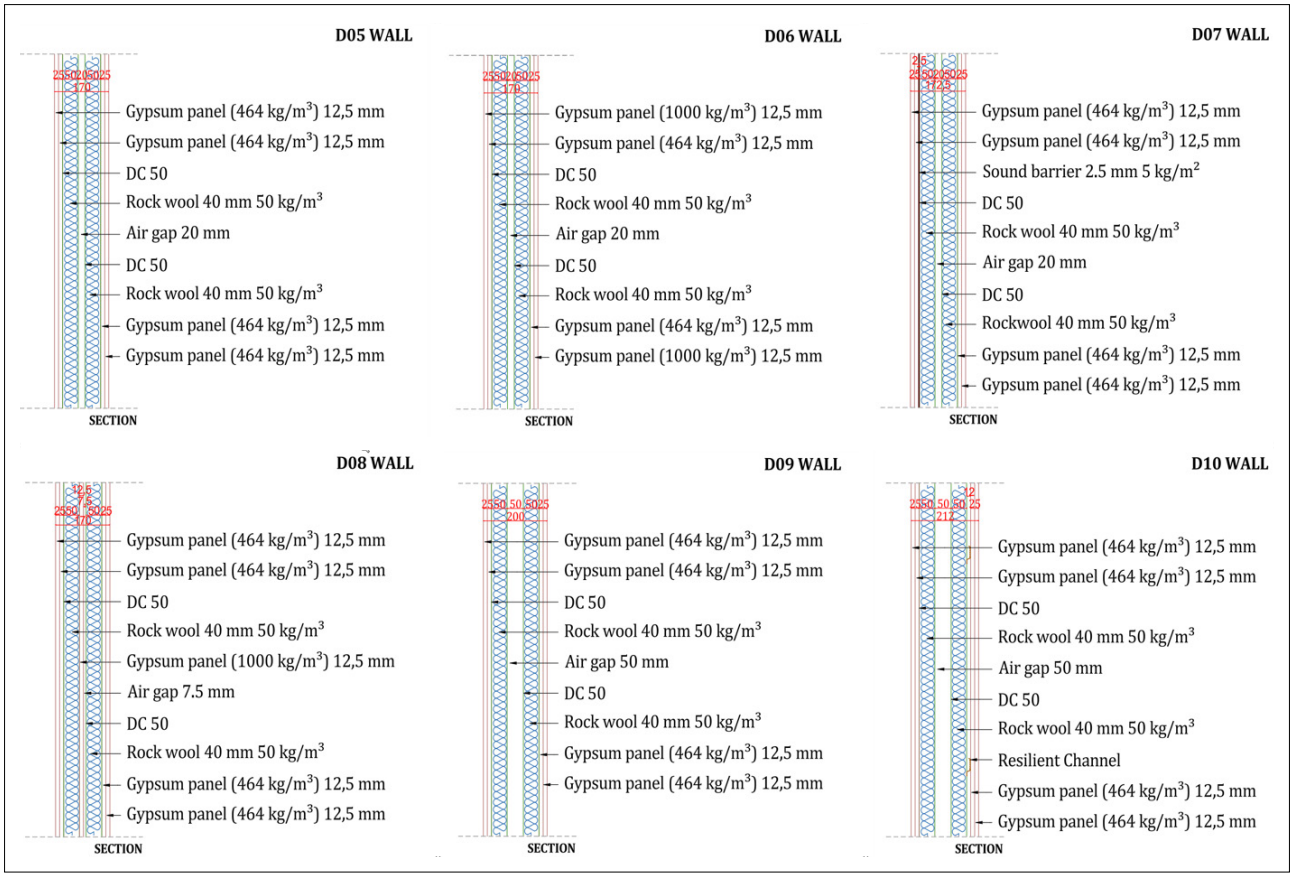



**Figure 2**. Double-Frame Gypsum Board Partition Wall Systems Manufactured at TSE (Credit to authors).

**Figure 3**. Gypsum Board Partition Wall Systems Manufactured at TSE.

## LABORATORY CONDITIONS AND MEASUREMENT METHODS

### Laboratory Conditions

The measurements were conducted at the Turkish Standards Institution (TSE) Testing and Calibration Center Presidency and Building Materials Fire and Acoustic Laboratory Directorate, both of which are located in Tuzla. The dimensions and specifications of the source and receiver rooms, as well as the environmental conditions of the laboratory where the measurements were carried out, are provided in Table 1.

Two adjacent rooms, one designated as the source room and the other as the receiver room, were used for the measurements. Loudspeakers and microphones were positioned at predetermined measurement points in accordance with TS EN ISO 10140-2 (2021b) and TS EN ISO 10140-5 (2021c) standards, which prepared the system for measurement (ISO, 2021). Before and after the measurement, calibration of the microphones was performed. For measurements using a mobile microphone, the sound pressure levels were recorded with a measurement duration and a full rotation time of the moving microphone set to 60 seconds. According to TS EN ISO 3382 (2021d), 12 measurements were performed for each frequency band to determine the reverberation time in the receiver room (ISO, 2021). Background noise was measured in the receiver room, and necessary corrections were made to the sound pressure level calculations. The section and plan views of the test rooms are provided in Figure 4:

Images of the test rooms containing specimens measured at varying times are presented in Figure 5. The laboratory tests were conducted using the following equipment:

- Power amplifier used specifically for the sound source, Norsonic, Nor280

**Table 1.** Environmental Characteristics of the Measurement Setup at TSE

| Room name | Length (m) | Width (m) | Height (m) | Volume ($m^3$) | Test wall area ($m^2$) |
|---|---|---|---|---|---|
| Source room | 6.39 | 5.29 | 3.56 | 114.90 | 12.40 |
| Receiver room | 7.75 | 5.48 | 4.30 | 174.42 | |
| **Room Name** | **Temperature °C** | **Pressure (kPa)** | **Moisture %** | | |
| Source room | 21.4±0,8 | 102.5±1 | 34.9±5 | | |
| Receiver room | 21.9±0,8 | 102.3±1 | 32.2±5 | | |

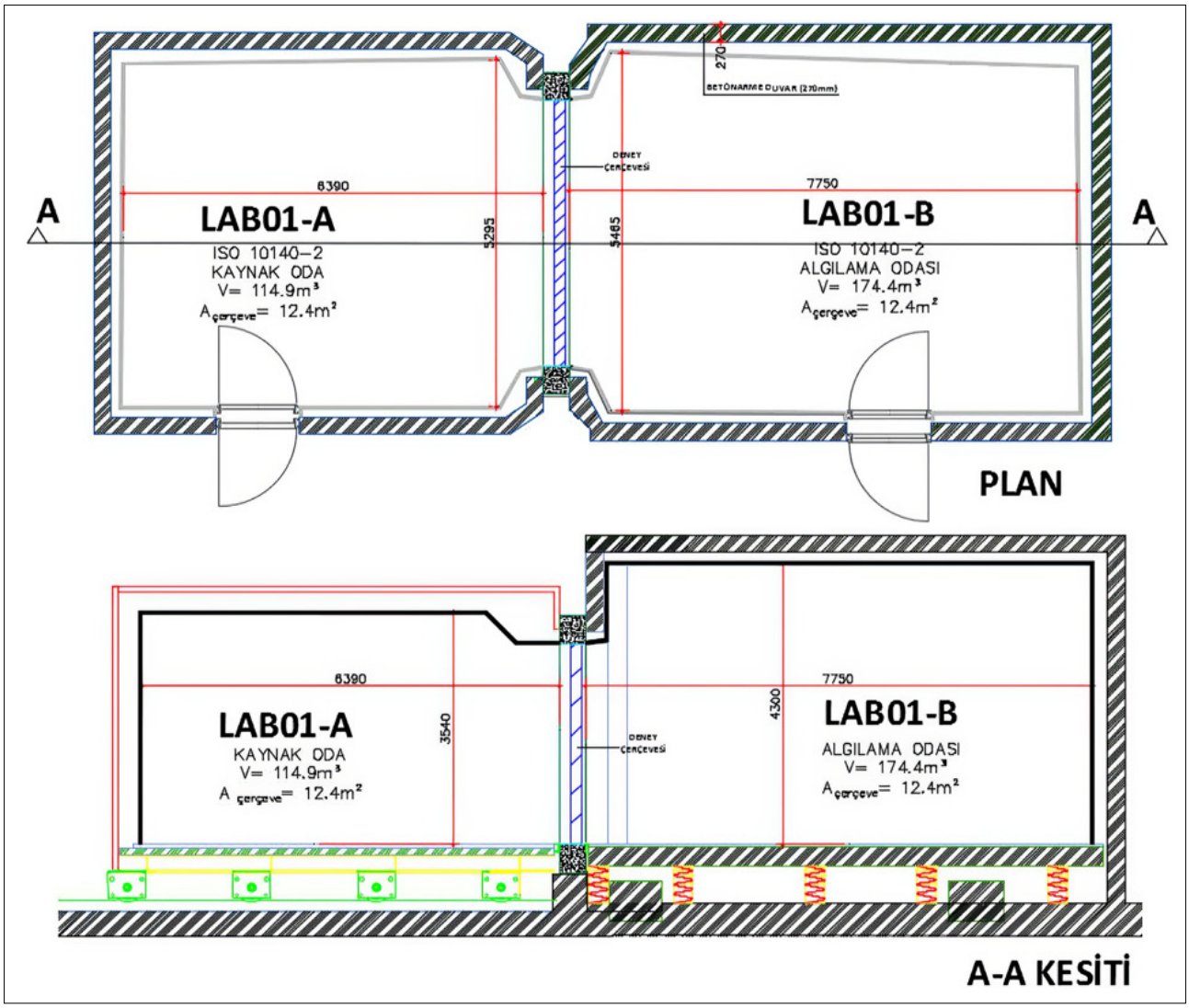



**Figure 4**. Section and Plan Views of the Test Room.

**Figure 5**. Measurement of the Test Specimen Under Laboratory Conditions.

- 12-faced omnidirectional sound source, Norsonic, Nor276
- 10-channel sound level analyzer
- ½-inch diffuse field microphone, Gras, Gras40ar
- Microphone boom and accessories
- Subwoofer, Davinci, Code 12S
- Calibrator, Norsonic, Nor1255

**Measurement Method**

To determine the Rw values of the wall sections, sound transmission loss measurements were conducted as a function of frequency in accordance with the TS EN ISO 10140-2:2021b standard. The results were calculated using the following Formula 1. The Rw values were obtained through single-number evaluation as per the TS EN ISO 717-1 standard (2013).

$R = L1 - L2 + 10\log(S/A)$ (1)

$A = 0.16V/T$

L1: Energy-averaged sound pressure level in the source room, dB

L2: Average sound pressure level in the receiver room, dB

S: Area of the free test opening where the test element is placed, $m^2$

A: Equivalent sound absorption area in the receiver room, $m^2$

V: Volume of the receiver room, $m^3$

T: Reverberation time in the receiver room, s

## LABORATORY MEASUREMENT RESULTS AND EVALUATIONS IN TERMS OF THE RELEVANT REGULATION

**Laboratory Results**

The first wall construction, featuring a C100 single-frame structure, double-layer Intreme Fit® panels on both sides, and double-layer stone wool with a density of 50 $kg/m^3$, was carried out on January 22, 2024, under standard-compliant conditions in the laboratory of the Turkish Standards Institution (TSE) in Tuzla. Following this, all constructions were sequentially performed using different construction types and panels of varying densities, covering 10 walls in total, and were completed on September 5, 2024. The sound reduction index values (RW), measured in the frequency range of 100-3150 and 50-5000 Hz in 1/3 octave bands, along with the technical specifications of the wall types, are provided in Table 2.

In the RPBAN Regulation, requirements for insulation based on room function are provided using the weighted standardized level difference ($D_{nT,A}$), which takes into account factors such as the area of the receiver room, the surface area of the partition element, and lateral transmissions (ISO, 2021). Therefore, the Rw value determined through laboratory measurements is required to be converted into the DnT,A metric. The measurement values of the wall types tested in the laboratory indicate the Rw ($C;C_{tr}$) values belonging to the sound reduction class, which considers only direct sound transmission and excludes lateral transmission. In field applications of these wall types, factors such as lateral transmissions, the volume of the room, the surface area of the applied wall, and the reverberation time of the environment become critical. This is due to the fact that the regulation evaluates values based on $D_{nT,A}$. Using the Formula 2 and Formula 3 provided below, the weighted standardized level difference ($D_{nT,w}$) value can be calculated by substituting R'W.

The formulas from TS EN ISO 12354-1(2021e) which enable the conversion of Rw to DnT,A, are provided below as Formula 2 and Formula 3 (ISO, 2021):

$$D_{nT,W} + R'_w + 10\log\left(\frac{0.16V}{T_0 S_s}\right) = R'_w + 10\log\left(\frac{0.32V}{S_s}\right)\ dB \quad (2)$$

$DnT,A = D_{nT,w} + C$ (3)

C: Correction Factor

T0: Reference Time

R'w: Weighted Sound Reduction Index

V: Volume of the receiver room ($m^3$)

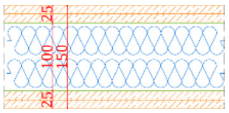
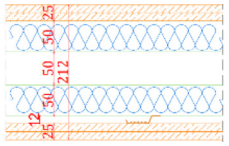
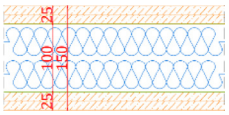
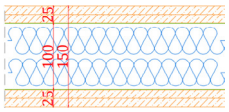
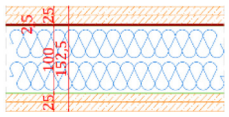
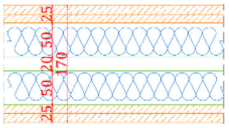
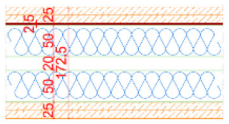
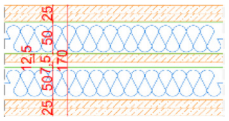
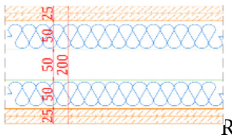
Ss: Surface area ($m^2$)

For the 10 wall sections with determined Rw values, three different hypothetical room sizes were created to determine which acoustic performance class was most useful according to the specified regulations. These sections were considered as partition walls for office meeting rooms. The hypothetical rooms were modeled in the KS-Schallschutzrechner 8.03 acoustic simulation program, which performs $D_{nT,A}$ value calculations in accordance with the TS EN ISO 12354-1 (2021e) standard. These values were then calculated for each wall section in three different hypothetical room configurations.

To input data into the KS-Schallschutzrechner 8.03 simulation program, it was assumed that side walls were constructed using 19.5 cm horizontally perforated bricks (800 $kg/m^3$) with 2 cm plaster on both surfaces (1600 $kg/m^3$). Additionally, the ceiling and floor slabs were modeled as 25 cm reinforced concrete slabs (2400 $kg/m^3$). The surface area of each gypsum board wall was constant at 15.75 $m^2$. These walls were evaluated for three different scenarios, where only the receiver room volume varied, and their corresponding DnT,A values were determined using the simulation program. Figure 6 presents the relevant plans of the hypothetical room configurations:

The 10 types of gypsum board partition walls measured under laboratory conditions were evaluated for three different receiver room volumes while keeping the partition

**Table 2.** Wall Section Specifications and Measurement Results (RW) of the Test Specimen

| Wall Code | Wall Sections | WALL TYPES | | | | | Laboratory Result Rw (C;Ctr) |
|---|---|---|---|---|---|---|---|
| | | Layering | | | Physical Properties | | |
| | | Material | Thickness (mm) | *Qty | Density (kg/m³) | Weight (kg/m²) | |
| D01 |  | Gypsum panel | 12,5 mm | 4 | 464 kg/m³ | 5,8 ±0,2 kg/m² | 49,50 (-4; -11) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 1,44 kg | |
| | | DC100 | 47/99/47 | 8 | - | - | |
| | | DU100 | 38/100/38 | 2 | - | - | |
| D02 |  | Gypsum panel | 12,5 mm | 2 | 1000 kg/m³ | 12,5 ±0,5 kg/m² | 51,30 (-2; -6) |
| | | Gypsum panel | 12,5 mm | 2 | 464 kg/m³ | 5,8 ±0,2 kg/m² | |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 2 kg/m² | |
| | | DC100 | 47/99/47 | 8 | - | - | |
| | | DU100 | 38/100/38 | 2 | - | - | |
| D03 |  | Gypsum panel | 12,5 mm | 4 | 1000 kg/m³ | 12,5 ±0,5 kg/m² | 59,00 (-3; -9) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 2 kg/m² | |
| | | DC100 | 47/99/47 | 8 | - | - | |
| | | DU100 | 38/100/38 | 2 | - | - | |
| D04 |  | Gypsum panel | 12,5 mm | 4 | 464 kg/m³ | 5,8 ±0,2 kg/m² | 47,60 (-1; -6) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 2 kg/m² | |
| | | Sound barrier | 2,5 mm | 1 | 50 kg/m³ | 5 kg/m² | |
| | | DC100 | 47/99/47 | 8 | - | - | |
| | | DU100 | 38/100/38 | 2 | - | - | |
| D05 |  | Gypsum panel | 12,5 mm | 4 | 464 kg/m³ | 5,8 ±0,2 kg/m² | 55,60 (-5; -12) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 1,44 kg | |
| | | DC50 | 47/49/47 | 16 | - | - | |
| | | DU50 | 38/50/38 | 4 | - | - | |
| | | Air gap | 20 | 1 | - | - | |
| D06 |  | Gypsum panel | 12.5 mm | 2 | 1000 kg/m³ | 12.5 ±0.5 kg/m² | 64,20 (-5; -12) |
| | | Gypsum panel | 12.5 mm | 2 | 464 kg/m³ | 5.8 ±0.2 kg/m² | |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 2 kg/m² | |
| | | DC50 | 47/49/47 | 16 | - | - | |
| | | DU50 | 38/50/38 | 4 | - | - | |
| | | Air gap | 20 | 1 | - | - | |
| D07 |  | Gypsum panel | 12.5 mm | 4 | 464 kg/m³ | 5.8 ±0.2 kg/m² | 58,60 (-4; -11) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 2 kg/m² | |
| | | Sound barrier | 2.5 mm | 1 | 2000 kg/m³ | 5 kg/m² | |
| | | DC50 | 47/49/47 | 16 | - | - | |
| | | DU50 | 38/50/38 | 4 | - | - | |
| | | Air gap | 20 | 1 | - | - | |
| D08 |  | Gypsum panel | 12.5 mm | 4 | 464 kg/m³ | 5.8 ±0.2 kg/m² | 53,50 (-6; -14) |
| | | Gypsum panel | 12,5 mm | 1 | 1000 kg/m³ | 12,5 ±0,5 kg/m² | |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 2 kg/m² | |
| | | DC50 | 47/49/47 | 16 | - | - | |
| | | DU50 | 38/50/38 | 4 | - | - | |
| | | Air gap | 7,5 | 1 | - | - | |
| D09 |  | Gypsum panel | 12,5 mm | 4 | 464 kg/m³ | 5,8 ±0,2 kg/m² | 57,30 (-5; -12) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 1,44 kg | |
| | | DC50 | 47/49/47 | 16 | - | - | |
| | | DU50 | 38/50/38 | 4 | - | - | |
| | | Air gap | 50 | 1 | - | - | |
| D10 |  | Gypsum panel | 12,5 mm | 4 | 464 kg/m³ | 5,8 ±0,2 kg/m² | 57,50 (-4; -11) |
| | | Rock wool | 40 mm | 2 | 50 kg/m³ | 1,44 kg | |
| | | DC50 | 47/49/47 | 16 | - | - | |
| | | DU50 | 38/50/38 | 4 | - | - | |
| | | Resilient Channel | - | 5 | - | - | |
| | | Air gap | 50 | 1 | - | - | |

*Qty: Quantity.

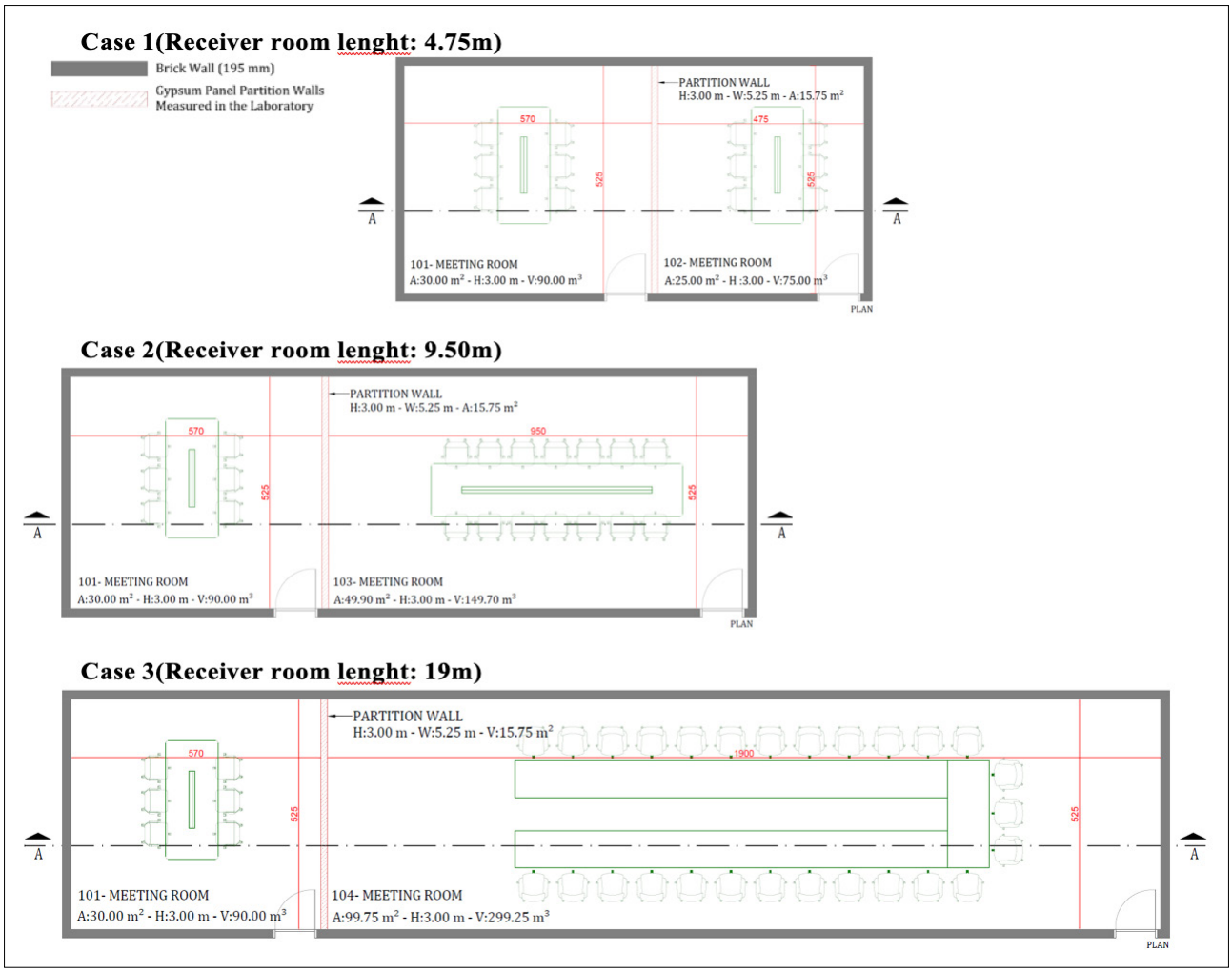



**Figure 6**. Plans of Hypothetical Room Configurations (Credit to authors).

wall section properties constant. The room specifications are provided in Table 3. In the first scenario, the longest dimension of the receiver room was set at 4.75 m. For the second scenario, the length was doubled to 9.50 m. In the third scenario, the length was doubled again to 19.00 m. Using the wall width as a reference, the $D_{nT,w}$+C values were calculated in the simulation program based on the following ratios: V/S = 75/15.75, V/S = 149.70/15.75, and V/S = 299.25/15.75.

Simulation results for all other walls across the three different hypothetical room configurations are provided in Table 4. As the V/S ratio increases, it is observed that the DnT,A value also increases. For instance, the Rw value of 49.5 (C-4; Ctr-11) obtained from the laboratory measurement for the first wall corresponds to a $D_{nT,w}$+C value of 46.9 dB while the V/S ratio is 4.76. Additionally, when the V/S ratio increases to 9.50 in the second scenario, the $D_{nT,w}$+C value rises to 49.9 dB. In the final scenario, the

**Table 3.** Room specifications of hypothetical rooms

| Case | Room Name | Length (m) | Width (m) | Heigth (m) | Area ($m^2$) | Volume ($m^3$) | Wall Area ($m^2$) |
|---|---|---|---|---|---|---|---|
| 1 | 101-Meeting Room (Source Room) | 5.70 | 5.25 | 3.00 | 30.00 | 90.00 | 15.75 |
| | 102- Meeting Room (Receiver Room) | 4.75 | 5.25 | 3.00 | 25.00 | 75.00 | |
| 2 | 101- Meeting Room (Source Room) | 5.70 | 5.25 | 3.00 | 30.00 | 90.00 | |
| | 103- Meeting Room (Receiver Room) | 9.50 | 5.25 | 3.00 | 49.90 | 149.70 | |
| 3 | 101- Meeting Room (Source Room) | 5.70 | 5.25 | 3.00 | 30.00 | 90.00 | |
| | 104- Meeting Room (Receiver Room) | 19.00 | 5.25 | 3.00 | 99.75 | 299.25 | |

**Table 4.** Simulation Results

| Wall Code | Sound insulation value, dB | | | |
|---|---|---|---|---|
| | Laboratory Results Rw (C;Ctr) | $D_{nT,w}$+C ($D_{nT,A}$) | | |
| | | Case 1 V/s = 75.00/15.75 | Case 2 V/s = 149.70/15.75 | Case 3 V/s = 299.25/15.75 |
| D01 | 49.50 (-4; -11) | 46.9 | 49.9 | 52.9 |
| D02 | 51.30 (-2; -6) | 50.1 | 53.1 | 56.1 |
| D03 | 59.00 (-3; -9) | 54.4 | 57.4 | 60.4 |
| D04 | 47.60 (-1; -6) | 47.8 | 50.8 | 53.8 |
| D05 | 55.60 (-5; -12) | 51.1 | 54.1 | 57.1 |
| D06 | 64.20 (-5; -12) | 55.6 | 58.6 | 61.6 |
| D07 | 58.60 (-4; -11) | 53.7 | 56.7 | 59.7 |
| D08 | 53.50 (-6; -14) | 48.6 | 51.6 | 54.6 |
| D09 | 57.30 (-5; -12) | 52.3 | 55.3 | 58.3 |
| D10 | 57.50 (-4; -11) | 53.1 | 56.1 | 59.1 |

room volume increases approximately fourfold compared to the first room and the V/S ratio reaches 19, the $D_{nT,w}$+C value is calculated as 52.9 dB while using the simulation program.

### Comparison of Simulation Calculation Results with the Regulation

Within the scope of the "Regulation on Protection of Buildings Against Noise," published in the Official Gazette on May 31, 2018, an A-F classification system was introduced to determine the acoustic performance classes of buildings. In this classification, A represents the highest acoustic performance, while F represents the lowest. According to the regulation, new buildings must achieve a minimum acoustic performance of Class C, whereas existing buildings are evaluated with a minimum requirement of Class D (Ministry of Environment, Urbanization and Climate Change, 2018).

Table 5 presents classifications based on noise levels and sensitivity grades for office and administrative building spaces, considering source and receiver room scenarios (Ministry of Environment, Urbanization and Climate Change, 2019). In the hypothetical setup examined in this study, the configuration involves two adjacent meeting rooms in an office building. When one room is considered the source, it is categorized as medium-noise (MG), while the other room, as the receiver, falls under the first sensitivity grade. This classification has been verified based on the regulation's criteria outlined in the following Table 5:

The minimum airborne sound insulation values to be

**Table 5.** Noise Sensitivity/Noise Levels for Various Building and Space Functions

| Building scale | | | Spatial scale | | |
|---|---|---|---|---|---|
| Building function | Source situation Noise rating | Receiver situation Sensitivity rating | Room | Source situation Noise rating | Receiver situation Sensitivity rating |
| Office and administration buildings | MG | III | Private rooms | MG | I |
| | | | Open-plan areas | MG | II |
| | | | Meeting rooms | MG | I |
| | | | Teleconferance rooms | MG | I |
| | | | Recreational areas | MG | II |
| | | | Circulation areas1 | MG | III |
| | | | Technical centers | HG | III |
| | | | Courtrooms | MG | II |

I: Building and uses that are very sensitive to noise; II: Building and uses that are sensitive to noise; III: Building and uses that are less sensitive to noise; HG: High level noise generation; MG: Moderate noise generation; LG: Low level noise generation.

achieved for the hypothetical rooms with defined noise levels and receiver sensitivity, based on the source and receiver room characteristics, are provided in Table 6 (Ministry of Environment, Urbanization and Climate Change, 2018).

The studies conducted across three different hypothetical scenarios are summarized in Table 7, alongside the regulatory values. The color coding in the table, taken from the original regulation, represents the acoustic performance classes. This table includes 10 different wall types and are identified by their respective wall codes. The laboratory results are presented as Rw(C;Ctr), while the simulation results for the three hypothetical scenarios are based on the three different receiver room volumes, as determined by the formula $D_{nTw}$+C ($D_{nT,A}$, dB).

According to these results, it can be observed in Table 7 that the $D_{nT,A}$ values, which result from three different design configurations, remain at or above the minimum D acoustic performance class. Through the evaluation of the acoustic performance class used for these three design spaces, under the assumption that they are existing structures, all the values presented in the table are within acceptable limits.

If these three rooms would be considered as newly constructed buildings, the D03/D06/D07/D09/D10 walls meet the minimum C acoustic performance class values under all three scenarios.

## RESULTS/DISCUSSION

As a part of this study, the Rw values obtained from the laboratory production of 10 different gypsum board partition wall types at the Turkish Standards Institution Tuzla Building Materials Fire and Acoustic Laboratory were applied to three different hypothetical room configurations. The $D_{nT,w}$+C values ($D_{nT,A}$) obtained from the KS-Schallschutzrechner 8.03 simulation program were compared with the target values specified in the current regulation for meeting rooms in office spaces.

The findings can be concisely presented as follows:

- The first four wall applications (D01-D02-D03-D04) were constructed using a single C100 profile. The

**Table 6.** Minimum Airborne Sound Insulation Values (DnT,A, dB) to be Achieved Based on Source and Receiver Room Characteristics

| Source room noise rating | Receiver room ensitivity | Acoustic performance class | | | | | |
|---|---|---|---|---|---|---|---|
| | | A | B | C | D | E | F |
| Moderate level noise (MG) | | | | | | | |
| 75≥ LAF,max >55 dB | I | 62 | 58 | 52 | 48 | 44 | 40 |

**Table 7.** TSE laboratory Rw and DnTw+C Values (DnT,A, dB) of Sections

| Wall Code | Sound insulation value, dB | | | |
|---|---|---|---|---|
| | Laboratory Results Rw (C;Ctr) | DnT,w+C(DnT,A) | | |
| | | Case 1<br>V/s = 75,00/15,75<br>K:5.70x5.25x3.00<br>A:4.75x5.25x3.00<br>(Length x width x height) | Case 2<br>V/s = 149,70/15,75<br>K:5.70x5.25x3.00<br>A:9.50x5.25x3.00<br>(Length x width x height) | Case 3<br>V/s = 299,25/15,75<br>K:5.70x5.25x3.00<br>A:19.00x5.25x3.00<br>(Length x width x height) |
| D01 | 49.50 (-4; -11) | 46.9 (D Class) | 49.9 (D Class) | 52.9 (C Class) |
| D02 | 51.30 (-2; -6) | 50.1 (D Class) | 53.1 (C Class) | 56.1 (C Class) |
| D03 | 59.00 (-3; -9) | 54.4 (C Class) | 57.4 (C Class) | 60.4 (B Class) |
| D04 | 47.60 (-1; -6) | 47.8 (D Class) | 50.8 (D Class) | 53.8 (C Class) |
| D05 | 55.60 (-5; -12) | 51.1 (D Class) | 54.1 (C Class) | 57.1 (C Class) |
| D06 | 64.20 (-5; -12) | 55.6 (C Class) | 58.6 (B Class) | 61.6 (B Class) |
| D07 | 58.60 (-4; -11) | 53.7 (C Class) | 56.7 (C Class) | 59.7 (B Class) |
| D08 | 53.50 (-6; -14) | 48.6 (D Class) | 51.6 (D Class) | 54.6 (C Class) |
| D09 | 57.30 (-5; -12) | 52.3 (C Class) | 55.3 (C Class) | 58.3 (B Class) |
| D10 | 57.50 (-4; -11) | 53.1 (C Class) | 56.1 (C Class) | 59.1 (B Class) |

densities of the panels used in the construction varied among these walls. In the D04 wall, a sound barrier weighing 5 kg/m² and measuring 2.5 mm in thickness was utilized, thus differing from the D01 wall and facilitating a comparison between the two. In D01, low-density panels (464 kg/m³) were applied in four layers, separated by 50 kg/m³ of fibrous material, while in D03, high-density panels (1000 kg/m³) were applied in four layers. Consequently, the higher density of the D03 wall resulted in higher Rw values.

- The Rw value of D04, which differed from D01 only in the inclusion of a sound barrier, was measured at a higher value when adjusted for correction factors (C; Ctr). When $D_{nT,A}$ calculations with correction factors were applied to the wall surfaces in the hypothetical rooms, D04 also demonstrated higher $D_{nT,A}$ values.
- In walls D05, D06, and D07, securely constructed using double C50 profiles with four panels, a 20 mm air gap, and 50 kg/m³ fibrous material. This construction technique was detected to be similar to single-frame applications with sound transmission loss values increasing as the panel density escalated.
- The difference between the D05 and D08 walls was the inclusion of a 12.5 mm thick, 464 kg/m³ density gypsum panel between the profiles in D08. This panel blocked the use of the beneficial air gap, resulting in lower Rw values for D08.
- In the production of double C50 construction walls coded D09, an increase in the air gap from 20 mm to 50 mm has shown positive effects. The findings indicate that the RW sound transmission loss value improves significantly with the increased air gap. Furthermore, these values are higher compared to the D05 wall, which shares the same specifications, aside from the air gap difference.
- In the production of plasterboard using C50 double construction, the D10 wall, which features a flexible connection profile, has demonstrated a positive increase in the Rw sound transmission loss value compared to the D09 wall. The D10 wall consists of 4 plates of the same density with a measurement of 20 cm air gap in between. This design choice highlights the benefits of incorporating flexible connections in wall assemblies, as it contributes to enhanced sound isolation performance.
- D10, which featured the same configuration as D09 aside from including a flexible connection profile, was observed to have a positive increase in the Rw value while demonstrating the effectiveness of the flexible connection in enhancing acoustic performance.
- The laboratory results for the 10 different wall types were constructed with materials of varying thickness and density, and revealed their distinct Rw values for each change. In the hypothetical room configurations prepared to evaluate these Rw values against regulation, it was observed that increasing the V/S ratio led to higher $D_{nT,A}$ values.

As demonstrated in this study, using Rw values determined through measurements in accredited acoustic laboratories, while also taking into consideration the receiver room volume, partition surface area, and lateral transmissions, and lastly verifying whether the required sound transmission loss is achieved, represents the most accurate approach. Therefore, following up with more similar studies will enable the selection of the most appropriate sections for compliance with regulations, particularly for noise control in buildings, and will pave the way for more effective solutions.

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**Article**

# Cognitive processes in parametric design: A systematic literature review of methods, models, and future directions

**İhsan Erdem ER*, Feride Pınar ARABACIOĞLU, Hasan TAŞTAN**

*Department of Architecture, Yıldız Technical University, Istanbul, Türkiye*

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## ABSTRACT

This study explores cognitive processes in parametric design environments (PDEs), synthesizing current research to identify key methodologies, theoretical models, and factors that influence design cognition. The review addresses challenges like cognitive overload, algorithmic dependence, and the learning gap between novice and expert designers. A systematic literature review (SLR), following PRISMA guidelines for transparency and reproducibility, was conducted to analyze studies on design cognition in PDEs, with a focus on empirical research examining cognitive processes, design behavior, and educational strategies. The review reveals that PDEs encourage creativity, iterative problem-solving, and dynamic design exploration but also pose cognitive challenges, particularly for inexperienced designers. Expert designers exhibit greater algorithmic fluency and adaptability, while novices often experience cognitive strain and reliance on black-box thinking, which limits their creative engagement. Educational gaps persist, highlighting the need for scaffolded learning models, hands-on workshops, and non-digital exercises to build algorithmic skills progressively. Additionally, the lack of standardized frameworks for evaluating algorithm quality and cognitive performance underscores the need for further research. This review provides insights for educators and researchers to bridge the gap between technical proficiency and creative innovation in parametric design.

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## INTRODUCTION

Design is an essential cognitive process, shaped by various internal and external factors. Several cognitive studies focus on the design process (Cross, 2001), with the origins of research in design cognition often attributed to Eastman (1969)'s foundational work. Dinar et al. (2015) defined design cognition as the analysis of the information designers use during the design process. Dinar et al. (2015) reviewed empirical studies on design cognition and revealed that most existing studies focus on the early, somewhat unclear stages of the design process, known as conceptual design. Despite the significant number of empirical studies, many researchers emphasize that the nature of the cognitive

***Corresponding author**
*E-mail adres: ihsanerdemer@gmail.com

processes involved in design remains unclear (Dorst & Cross, 2001; Jin & Benami, 2010; Kim & Ryu, 2014).

While design cognition has been studied extensively in general design contexts, the focus on cognitive processes within parametric design environments (PDE) has been relatively limited. Design cognition studies examine the influence of various factors such as design environments (Trump & Shealy, 2023), restorative experience (Ignacio & Shealy, 2023), situatedness (Gero & Milovanovic, 2023), and empathy (Aktaş Yanaş & Gül, 2025) on design processes. However, there are very few studies on parametric design cognition. Despite the growing popularity of parametric design in architecture, empirical evidence on designers' behaviors in PDE is limited (Yu & Gero, 2016). While much of the literature focuses on technological advancements in parametric design tools, our understanding of the cognitive processes underlying parametric design environments remains limited (Oxman & Gu, 2015).

Systematic literature reviews (SLR) can be beneficial in filling these knowledge gaps because they are commonly used to synthesize evidence and reduce bias. SLR systematically collects, synthesizes, and analyzes all relevant publications on a given topic using predetermined inclusion criteria, and it is held to the same standard as empirical research due to its transparency and repeatability. Conducting an SLR on cognitive processes in PDE can provide valuable insights into how designers think and study within these environments, highlighting common findings and differing perspectives. According to Marzano and Kendall (2006), cognitive tasks involve at least one of the following categories: decision-making, problem-solving, experimenting, and investigating. In the context of parametric design, all these categories are intensely utilized as integral components of the cognitive system in the design process.

Given the complexity and importance of these cognitive processes, it is crucial to synthesize existing research to better understand how they manifest in PDE. While there are several SLRs in related areas of design cognition, such as Dinar et al. (2015) on empirical studies of design cognition, Jiang and Yen (2009) on protocol analysis, and Hay et al. (2017) on cognition in conceptual design, none of these studies specifically focus on the cognitive dimensions of parametric design environments. This gap highlights the need for a comprehensive SLR to synthesize existing research and provide a clearer understanding of cognitive processes unique to PDE.

This study aims to systematically review studies that focus on design cognition in PDE and seeks to answer the following questions: (i) What is our current understanding of cognitive processes in PDE? (ii) What methods are applied in this field? (iii) What variables are typically examined in experimental studies? By addressing these questions, the study aims to bridge the knowledge gap in this area and offer a comprehensive synthesis of existing research on parametric design cognition. Unlike previous reviews that broadly address design cognition, this study focuses explicitly on the unique cognitive processes that differentiate PDE from traditional design environments. Furthermore, this review focuses on empirical studies within PDE, examining their methods and procedures to inform future research. It will also discuss the limitations of these methods and models, providing a deeper exploration of the impact of PDE on novice designers. Additionally, the review will address the challenges faced by educators, especially in countries with lower educational systems, and propose solutions to bridge these gaps.

**Design Cognition and Parametric Design**

Design is recognized as a complex cognitive activity, requiring designers to analyze, interpret, and solve problems through an array of structured and unstructured processes (Goldschmidt, 1991). Cognitive design studies often examine how designers engage in divergent and convergent thinking, with divergent thinking fostering the generation of multiple creative ideas and convergent thinking guiding the selection of the most feasible solution (Cross, 2001). This interplay between exploration and refinement is critical in design problem-solving, particularly in environments where dynamic changes and iterations are essential. Research on design cognition highlights the role of mental strategies such as abstraction, problem decomposition, and reflective thinking, all which support decision-making during the design process (Goldschmidt, 1991; Oxman, 2001). Protocol analysis is a widely used method to study these cognitive activities (Blandino et al., 2023), enabling the observation of designers' thought processes in real time. This method has evolved over the years, with recent studies incorporating multimodal protocols that use dual verbal protocols (Leem & Lee, 2024), eye-tracking (Härkki, 2023), video recordings (Gürel & Şenyapılı Ozcan, 2023), and even biometric analysis (Yu et al., 2023). These multimodal approaches offer a more comprehensive understanding of cognitive load, mental strategies, and problem-solving in design environments. These analyses reveal that designers engage in iterative processes, revisiting earlier design decisions as new information emerges (Oxman, 2001). Such insights could also provide a foundation for understanding cognitive processes in PDE, which differ significantly from traditional design settings.

PDEs introduce unique cognitive demands that challenge the traditional approaches used in design cognition (Oxman & Gu, 2015). Unlike traditional design, which often follows a linear process, PDEs require designers to engage with non-linear, iterative exploration through parametric logic. In PDEs, relationships between parameters must be defined before generating design outputs, necessitating a

higher level of abstraction and systematic thinking (Lee & Ostwald, 2019). Recent research emphasizes that this shift from manual design to parameter-driven logic requires cognitive adaptation, particularly for novice designers who are unfamiliar with computational logic (Dissaux & Jancart, 2022; Liang et al., 2019).

Understanding how changes in one parameter impact the entire design system is a significant cognitive challenge in PDEs. Unlike traditional design, where design elements are modified directly, PDEs require designers to define interdependent relationships between design elements. This relational thinking necessitates the use of computational frameworks that support parametric logic. Tools like Grasshopper and Dynamo enable designers to visualize these relationships through a node-based interface, where inputs, transformations, and outputs are visually represented as components in a flowchart (Caetano et al., 2020). These tools reduce the need for textual coding, but they introduce new tasks as abstraction, rule-based thinking, and spatial reasoning which can cause cognitive load.

Cognitive load is another significant factor in PDEs. The dual requirement to manage parameter logic while also focusing on design goals increases the cognitive load on designers (Lee & Ostwald, 2019). Novice designers, in particular, are susceptible to cognitive overload due to unfamiliarity with parametric workflows and the complexity of parameter-based relationships (Dissaux & Jancart, 2022). To address this, design educators have focused on developing step-by-step pedagogical approaches that gradually introduce students to parametric thinking. Visual programming tools play a key role in this process, as they allow designers to manipulate visual representations of parameters, thereby reducing the cognitive load associated with text-based coding (Caetano et al., 2020; Woodbury, 2010).

One of the most critical cognitive shifts in PDEs is the move from product-based thinking to process-based thinking (Lee et al., 2013). In traditional design, the designer focuses on achieving a final product, often working in a linear sequence. In contrast, PDEs emphasize the creation of a generative system that produces multiple design outputs. This shift changes how designers approach problem-solving, as they must think about processes, rules, and relationships rather than static objects (Caetano et al., 2020). This process-oriented thinking requires designers to conceptualize and manage the relationships between interdependent components, reflecting a higher level of cognitive complexity.

Another prominent issue in PDEs is the tendency toward "black-box thinking." When designers rely on pre-built algorithms or imported parametric scripts, they may lose sight of the logic and structure underlying the design process (Woodbury, 2010). This reliance on pre-built solutions can hinder creativity and limit the designer's ability to adapt to new design challenges. Vazquez (2024) suggest that educators should encourage students to build their own parametric rules and algorithms rather than relying on external libraries. By promoting computational literacy, designers can maintain greater control over the process, develop critical thinking skills, and avoid dependency on "black-box" systems.

Parametric design is used in various fields such as facade design (Dervishaj & Gudmundsson, 2024), structural optimization (Zhang et al., 2024), and urban planning (Tehrani et al., 2024). However, research on PDE education remains limited, primarily due to the high cognitive load for novices and black-box thinking. To address these challenges, it is essential to investigate the cognitive mechanisms of both novice and expert designers in PDEs. Therefore, this study systematically reviews existing research, examines methodologies and variables, and discusses the strengths and weaknesses of current approaches.

## RESEARCH METHOD

This section outlines the systematic methodology used to examine cognitive processes specifically within PDEs. The review follows the PRISMA guidelines, focusing on cognitive processes in parametric design, rather than general design. The subsections of this section include research design (3.1), which outlines the overall approach, the databases used for literature gathering (3.2), the inclusion and exclusion criteria for selecting relevant studies (3.3), the search strategy applied to ensure a broad and relevant collection of literature (3.4), and the selection process for narrowing down the studies (3.5). By focusing on parametric design, this section ensures that the cognitive processes analyzed are specific to the unique characteristics of PDEs, rather than general design environments.

### Research Design

This SLR was conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (Moher et al., 2009). The purpose of this review is to thoroughly analyze studies examining cognitive processes in parametric design environments.

### Databases

The studies included in this review were gathered from the SCOPUS and Web of Science (WoS) digital databases. To broaden the scope of the research, other databases such as IEEE Xplore, ACM Digital Library, ScienceDirect, JSTOR, EBSCO, and Taylor & Francis were also considered. However, SCOPUS and WoS were chosen as the primary databases because they provide comprehensive scientific research, including journal articles and conference papers (Zhu & Liu, 2020).

**Inclusion Criteria**

To be included in this SLR, studies had to meet the following criteria:

- The study must provide a theoretical or applied review of cognitive processes in parametric design environments.
- The study must present a model, technique, or method to evaluate one or more factors influencing cognitive thinking in PDE.
- The cognitive processes analyzed must involve a design problem.

The following exclusion criteria were also applied:

- The study is not in English,
- The study is not related to parametric design processes,
- The profiles of the participants or trainees involved in the study are not clearly defined,
- The studies are duplicate or repetitive across different databases,
- The full text of the article or paper is not accessible.

**Search Strategy**

The search strategy aimed to identify primary studies relevant to this literature review. Keywords were selected to cover two main concepts: parametric design and cognitive processes or education/training. To ensure that as many relevant research studies as possible were included, the search terms were derived from previous searches and are presented in Table 1.

**Selection Process**

The database search was conducted on December 1, 2024, and a total of 1,436 records were obtained (801 from SCOPUS, 863 from WoS). After removing duplicate entries, the selection process began with 874 records. This process consisted of two stages. In the first stage, the titles and abstracts of each study that met the inclusion and exclusion criteria were analyzed. In the second stage, the list was narrowed down to 30 studies (Figure 1).

Subsequently, the second review of the selection process, in which the full texts were analyzed, was conducted. As a result of this second review, 18 studies were deemed appropriate for inclusion, comprising 5 conference papers and 13 journal articles. To ensure the selection process was as inclusive as possible, no year restrictions were applied as a selection criterion. The distribution of the selected publications by year is shown in Figure 2. It can be observed that the selected studies span the years 2012 to 2024, with the highest number of studies conducted in 2012.

The selected studies were coded and analyzed using MaxQda and Microsoft Excel. The tables presented in the report were generated using MaxQda's code relation browser for the analysis. The themes or categories that emerged during the coding process were discussed in the findings section.

## FINDINGS

As a result of the SLR, a bibliometric analysis was first conducted to identify the leading journals and conferences in the field. Subsequently, the reviewed studies were classified based on the data collection methods they employed, and the most common protocol analysis methods were examined. Since the studies identified through the SLR are experimental, the experimental conditions vary. In the following sections, these variables are analyzed under three headings: participant groups, design tasks, and control group variables.

**Bibliometric Analysis**

The SLR included a bibliometric analysis of studies on cognitive processes in parametric design. The review revealed that studies in this area began to increase in 2012, with early publications being preliminary experimental studies presented at conferences. Over time, the results of these studies were published in journals.

The most frequently published journals in this field are the International Journal of Architectural Computing and the International Journal of Design Creativity and Innovation. Ju Hyun Lee (Lee et al., 2013; Lee et al., 2015, Lee et al., 2016; Lee & Ostwald, 2019; Lee & Ostwald, 2020) and Rongrong Yu (Yu et al., 2012b; Yu et al., 2012a; Yu et al., 2013; Yu et al., 2018; Yu & Gero, 2016) are the two researchers with the most publications in this field.

**Table 1.** Keywords of the study focus

| Database | Results | Keyword search and other applied filters |
|---|---|---|
| SCOPUS | 801 | TITLE-ABS-KEY ("parametric design" OR "parametric design environment") AND TITLE-ABS-KEY (cognit* OR "protocol analysis" OR "design thinking" OR "design education" OR educat* OR evaluation) AND (LIMIT-TO (LANGUAGE, "English") |
| WoS | 863 | Results for "parametric design" OR "parametric design environment" (Topic) AND cognit* OR "protocol analysis" OR "design thinking" OR "design education" OR educat* OR evaluation (Topic) AND English (Languages) and Article or Proceeding Paper (Document Types) and English (Languages) |

The * symbol has been used as a truncation operator to search for documents containing the root of the term followed by any number of characters.

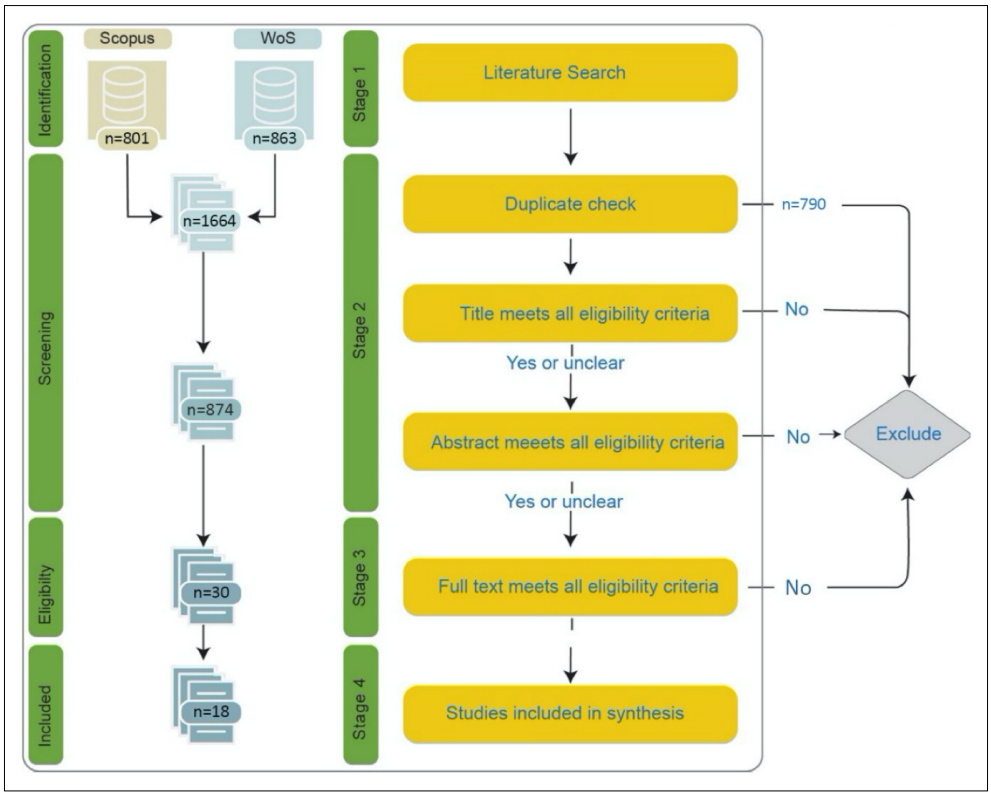


**Figure 1**. Study Flow Chart.

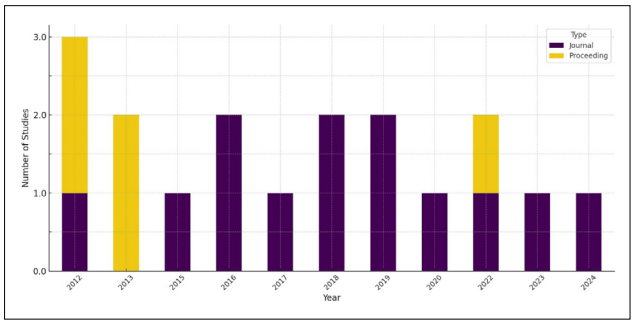


**Figure 2**. Distribution of the selected publications by year.

**Table 2.** Data collection methods used in the field of parametric design cognition

| Methods | Studies |
|---|---|
| Survey | (Alalouch, 2018; Namoun et al., 2019; Yang et al., 2022) |
| Interview | (Dissaux & Jancart, 2022; Lee & Ostwald, 2020; Namoun et al., 2019) |
| Personal Experience | (Aish & Hanna, 2017) |
| Protocol Analysis | Listed in Table 3 |

### Data Collection Methods

In studies on cognitive processes in PDE, various data collection methods are used to analyze users' design processes. These methods include surveys, interviews, personal experience, and protocol analysis. Table 2 presents the distribution of data collection methods used in studies on parametric design cognition.

In cognitive process studies, surveys are used to allow participants to describe their own cognitive processes through pre-structured questions. In Alalouch's, (2018) study, participants' cognitive processes were assessed using questions designed with a five-point likert scale. The survey employed in that study measured three factors: cognitive strategies, intellectual abilities, and attitudes of the participants. However, this method relies on self-assessment, which can lead to reliability issues. To address this problem, Namoun et al., (2019) combined the survey method with the think-aloud protocol used in protocol analysis.

The use of surveys in cognitive process studies requires self-evaluation, meaning the reliability of the data is contingent on the objectivity of the participants. Nevertheless, participants tend to evaluate the design environments or tools they use more objectively than their own cognitive processes. For this reason, the survey method can be used to measure usability, as in Namoun et al. (2019)'s, study, or to collect preliminary data, as in Yang et al. (2022)'s, study.

In the interview method, semi-structured questions are used to gather information about the participants' design processes, followed by quantitative evaluations. Like

surveys, interviews face reliability challenges, and as such, they should be validated through cross-referencing with other data, as demonstrated by Dissaux & Jancart, (2022); Lee & Ostwald, (2020).

Aish & Hanna, (2017) took a different approach, analyzing parametric design processes based on their own experiences. In their study, the authors evaluated the three most commonly used environments in PDE by discussing the challenges they encountered. However, this method is considered more of a preliminary trial and requires validation through comparisons with the experiences of other users.

The most frequently used method in this field is protocol analysis. In this approach, participants are asked to think aloud during the design process, and their processes are recorded. The recording can be audio, or video, as was the case in some studies. In PDE research, screen recordings are also commonly used. The consistency of the analysis improves as the volume of collected

data increases. The reliability of the analysis process must also be tested. In studies where the analysis is performed by a single researcher, the process is repeated at two different times and the results are compared. In studies involving multiple researchers, the consistency between their analyses is compared statistically. Additionally, since protocol analysis examines the design process, it is often supplemented by surveys or interviews with participants at the end of the process.

**Protocol Models**

Several theoretical models are used to analyze the data collected during protocol analyses. These models divide design processes into steps that are coded according to the selected model, then analyzed in terms of step sequences, repetitions, and durations. Table 3 shows the coding models used in the studies identified through the SLR, with FBS (Function-Behavior-Structure) and PPC (Physical-Perceptual-Conceptual) models being the most frequently used.

**Table 3.** Analysis models used in protocol analyses

| Models | Studies |
|---|---|
| Language-oriented coding | (Lee et al., 2016) |
| PSFIE | (Chien & Yeh, 2012) |
| PPC | (Lee et al., 2013, 2015, 2016; Lee & Ostwald, 2019; Öztürk Kösenciğ & Özbayraktar, 2024) |
| DMP | (Lee & Ostwald, 2020) |
| Knowledge retrieval | (Dissaux & Jancart, 2022) |
| FBS | (Gürel & Şenyapılı Ozcan, 2023; Yu et al., 2012b, 2013, 2018; Yu & Gero, 2016) |

The FBS (Function-Behavior-Structure) model developed by Gero, (1990) is one of the most widely used models in protocol studies on design. This model has been preferred in PDE studies due to its potential to cover the most meaningful cognitive aspects of the design process Yu et al., (2018). The FBS model's formulation is presented in Figure 3.

The FBS model defines the design process through six variables and eight transitions between them. These variables are:

- Requirements (R): This variable describes the things necessary to solve the design problem, independent of the designer.
- Function (F): It defines the purpose of the design and the designed object.
- Behavior (B): This includes the expected behavior (Be) and the behavior resulting from the structure (Bs) of the design object.
- Structure (S): This represents the components that make up the design object and the relationships between them.
- Document (D): It defines the representational outputs needed to communicate the design.

The transitions between these steps, as seen in Figure 3, include formulation, synthesis, analysis, evaluation, documentation, and reformulation I, II, and III.

The FBS model can be used directly, as in the studies by Yu et al., (2018); Yu and Gero, (2016), or it can be separated into subcategories of design and algorithms, as seen in Yu et al. (2013)'s study. Furthermore, in a study by Yu et al. (2012b), an extended version of the decomposed FBS model incorporates the concepts of external, interpretive, and expected worlds.

Another commonly used model is Suwa et al., (1998)'s. PPFC (Physical-Perceptual-Functional-Conceptual) model, adapted for PDE. The adapted version of the PPC model, shown in Table 4, consists of physical, perceptual, and conceptual variables.

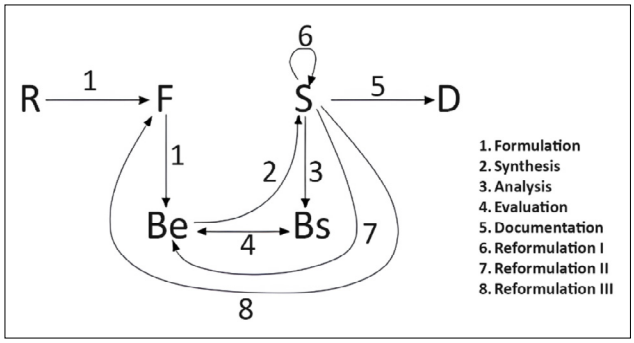


**Figure 3**. FBS model.

**Table 4.** PPC model (Lee et al. 2013)

| Level | Category | Subclasses | Description |
|---|---|---|---|
| Physical | Geometry | G-Geometry | Create geometries without an algorithm |
| | | G-Change | Change existing geometries |
| | Algorithm | A-Parameter | Create initial parameters |
| | | A-Change Parameter | Change existing parameters |
| | | A-Rule | Create initial rules |
| | | A-Change Rule | Change existing rules |
| | | A-Reference | Retrieve or get references |
| Perceptual | Geometry | P-Geometry | Attend to existing geometries |
| | Algorithm | P-Algorithm | Attend to existing algorithms |
| Conceptual | Problem-finding | F-Initial Goal | Introduce new ideas or goals based on given design brief |
| | | F-Geometry Sub Goal | Introduce new geometric ideas extended from a previous idea |
| | | F-Algorithm Sub Goal | Introduce new algorithmic ideas extended from a previous idea |
| | Solution-generating | G-Generation | Make generation or variation |
| | Solution-evaluating | E-Geometry | Evaluate primitives or existing geometries |
| | | E-Parameter | Evaluate existing parameters |
| | | E-Rule | Evaluate existing rules |
| | | E-Reference | Evaluate existing references |

The physical variable defines production actions and is divided into geometric and algorithmic categories. Modeling functions fall under the geometric category, while parametric rule sequences are classified under the algorithmic category. The perceptual variable refers to the mental visualization and consideration of the produced objects, and it is also divided into geometric and algorithmic categories. The conceptual variable, adapted from the study of Gero & Mc Neill (1998), consists of three classes: problem identification, solution generation, and evaluation. Like the FBS model, the PPC model can be used independently or in combination with other models. For example, in study by Lee et al., (2016), the PPC model was used in conjunction with a newly developed semantic model to investigate the relationship between cognitive processes and language.

**Data Evaluation Methods**

The data analysis methods used in the identified studies are listed in Table 5. The first method is statistical analysis, used in studies such as Chien & Yeh (2012)'s work for evaluating the design processes decoded through protocol analysis using standard deviation and percentage distribution. More advanced methods like the U-test and regression are used in studies (Alalouch, 2018; Yang et al., 2022) with control groups.

Descriptive analysis methods are primarily used to examine correlations, while the Linkography method is used to analyze transitions between codes. Linkography was employed by Lee & Ostwald, (2019) to analyze entropy between codes, allowing the visualization of relationships between steps in the design process, as shown in Figure 4.

**Table 5.** Data evaluation methods used

| Methods | Studies |
|---|---|
| Statistics and Descriptive | (Alalouch, 2018; Chien & Yeh, 2012; Gürel & Şenyapılı Ozcan, 2023; Lee et al., 2013, 2015, 2016; Lee & Ostwald, 2019, 2020; Namoun et al., 2019; Yang et al., 2022; Yu et al., 2013, 2018; Yu & Gero, 2016) |
| CAT (Creativty Assessment) | (Lee et al., 2013, 2015; Yang et al., 2022; Yu et al., 2018) |
| Learning Curve | (Aish & Hanna, 2017) |
| Linkography | (Lee et al., 2016; Lee & Ostwald, 2019; Öztürk Kösenciğ & Özbayraktar, 2024) |

The learning curve method was used by Aish & Hanna, (2017). In their study, problems encountered in the design environment were considered learning thresholds, and personal experiences were graphically represented and compared based on the issues faced during the process. MacLean et al., (1990) defined learning as the overcoming

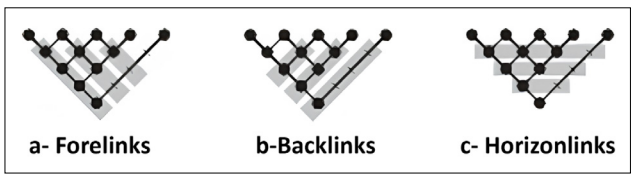


**Figure 4**. Linkography analysis samples (Lee & Ostwald, 2019).

of encountered problems. Myers (2002) suggested that effective learning can be represented by a smooth-sloped curve. Based on this, Aish & Hanna, (2017) concluded that Grasshopper is more conducive to learning in PDE.

The CAT (Creativity Assessment Tool) method is used in this field to evaluate design outcomes. These are rubric scales designed to measure creativity, allowing the relationships between processes and the final product to be examined. The rubric CAT scales used in studies identified through the SLR are based on the scale developed by Amabile, (1983). While these scales serve a similar function, there are slight variations between them. For example, the scales used in Lee et al., (2013); Lee et al., (2015) assess originality, usefulness, complexity, and aesthetics, whereas Yu et al., (2018) replaced complexity and aesthetics with the criterion of surprise. Yang et al., (2022), originality, usefulness, quality, and manufacturability were used as criteria. Upon reviewing the criteria used in CAT scales, originality and usefulness are consistently repeated. These scales can be used by the authors themselves or, as in Lee et al. (2013)'s study, to gather expert opinions.

**Participant Groups**

The distribution of participant groups in the studies included in this systematic review is presented in Table 6. Undergraduate students are defined as "students," while professionals with bachelor's degrees are categorized as "professional groups." A minimum of two years of experience with PDE is used to distinguish between experienced and inexperienced participants.

The most frequently studied group in PDE research consists of experienced architects, as PDE requires more prior knowledge than traditional design environments. Studies by Yu et al., (2018); Yu & Gero, (2016) analyzed the cognitive processes of experienced architects. However, there is limited research focusing on inexperienced users in PDE. Dissaux & Jancart, (2022) analyzed the thinking processes of inexperienced users during learning activities.

The second most common participant group consists of architects with mixed experience levels. In these studies, participants are separated based on their experience in PDE. Studies by Chien & Yeh, (2012); Lee et al., (2015) analyzed the cognitive processes of architects with mixed experience levels. In fields outside of architecture, the web design process was examined with twenty-four software developers by Namoun et al., (2019)'s, while the creative thinking process was analyzed with 110 participants by Yang et al., (2022).

**Table 6.** Participant groups according to the SLR

| Groups | Studies |
|---|---|
| Experienced professionals | (Gürel & Şenyapılı Ozcan, 2023; Lee et al., 2013, 2016; Lee & Ostwald, 2019, 2020; Öztürk Kösenciğ & Özbayraktar, 2024; Yu et al., 2012b, 2018; Yu & Gero, 2016) |
| Inexperienced professionals | (Yu et al., 2012a) |
| Mixed professionals | (Chien & Yeh, 2012; Lee et al., 2015; Yu et al., 2013) |
| Mixed designers | (Namoun et al., 2019; Yang et al., 2022) |
| Students | (Alalouch, 2018; Dissaux & Jancart, 2022) |

**Design Tasks**

The design tasks given to participants in the studies are listed in Table 7. The most frequently used design task is high-rise building design, consistent with the focus on form exploration in PDE. In these studies, the emphasis is on the building envelope rather than interior configurations. For example, Chien & Yeh, (2012); Lee et al., (2013) focused on high-rise building design. Other tasks used in the studies include pavilion, bridge, and public education center design.

While parametric design is commonly used in engineering, this review focused on architecture-related studies. However, a few examples from software engineering and industrial design were considered. For instance, Namoun et al. (2019) explored website design, while examined earphone design.

**Experimental Variables**

In the reviewed studies, it was observed that participant groups were generally small, as is typical for protocol analysis. In studies (Dissaux & Jancart, 2022; Lee et al., 2016; Yu et al., 2012a) where the participant group consisted of only two or three individuals, no variables were employed, and the cognitive processes of the designers were examined directly.

**Table 7.** Design tasks according to the SLR

| Design Task | Studies |
|---|---|
| Website | (Namoun et al., 2019) |
| Curve Control | (Aish & Hanna, 2017) |
| High-rise building | (Chien & Yeh, 2012; Dissaux & Jancart, 2022; Lee et al., 2013, 2016; Lee & Ostwald, 2019, 2020; Yu et al., 2012b) |
| Pavillion | (Chien & Yeh, 2012; Dissaux & Jancart, 2022; Öztürk Kösenciğ & Özbayraktar, 2024) |
| Pedestrian bridge | (Dissaux & Jancart, 2022) |
| Shopping mall | (Yu et al., 2013, 2018; Yu & Gero, 2016) |
| Community center | (Yu et al., 2013, 2018; Yu & Gero, 2016) |
| Vehicle stop | (Alalouch, 2018; Chien & Yeh, 2012) |
| Shelter | (Gürel & Şenyapılı Ozcan, 2023) |

**Table 8.** Variables examined in studies

| Variables | Studies |
|---|---|
| None | (Dissaux & Jancart, 2022; Lee et al., 2016; Yang et al., 2022; Yu et al., 2012a) |
| Environment | (Aish & Hanna, 2017; Chien & Yeh, 2012; Gürel & Şenyapılı Ozcan, 2023; Lee et al., 2013, 2015; Lee & Ostwald, 2019, 2020; Namoun et al., 2019; Öztürk Kösenciğ & Özbayraktar, 2024; Yu et al., 2013, 2018; Yu & Gero, 2016) |
| Experience | (Alalouch, 2018; Chien & Yeh, 2012; Lee et al., 2013, 2015; Lee & Ostwald, 2019, 2020; Namoun et al., 2019) |

In studies where cognitive processes are compared based on variables, two primary variables are identified: environment and experience (Table 8). In research examining the experience variable, participants are classified according to their experience in PDE. Alalouch (2018) categorized users based on their experience with different modeling software. Similarly, Lee et al., (2013); Lee & Ostwald, (2019) and Namoun et al., (2019) divided users into two groups: Experts and novices. This allowed for a comparison of the cognitive processes of participants working in the same environment on the same design problem, investigating the impact of experience on cognitive processes.

In studies where the environment is the variable, design processes are compared using different software and tools as design environments. Aish & Hanna, (2017) performed the same design task using different software, while Yu et al., (2018); Yu & Gero, (2016) compared design processes conducted in geometric modeling environments (GME) and PDE by using different design problems. Chien & Yeh, (2012) compared design processes across three environments: PDE, GME, and traditional pen-and-paper design. In Lee & Ostwald's, (2020), study involving six participants, participants were divided into experts and novices based on their experience. Additionally, one participant from each group worked in a code-based environment, while the others used a visual programming environment. This allowed for an investigation of the effects of both experience and environment on cognitive processes during design. The same method was also employed by Lee et al., (2015).

## DISCUSSION

The studies summarized in Table 9 highlight key factors influencing cognitive processes in PDEs, with a focus on experience and environment. Protocol analysis, used extensively across the reviewed studies, reveals how designers interact with parametric tools and adapt their cognitive strategies during design tasks. Frameworks such as FBS (Öztürk Kösenciğ & Özbayraktar, 2024; Yu et al., 2012a; Yu et al., 2012b) and PPC (Gürel & Şenyapılı Ozcan, 2023; Lee et al., 2013; Lee & Ostwald, 2019) are central to evaluating design behavior.

Experience consistently emerges as a significant variable, with expert designers demonstrating greater fluency and creativity, while novices frequently need on external assistance, such as tutorial videos or assistants, to navigate PDEs (Dissaux & Jancart, 2022; Namoun et al., 2019). Comparisons between PDEs and GMEs suggest that parametric tools can foster more design exploration, but may also lead to increased cognitive load, particularly for less experienced users (Gürel & Şenyapılı Ozcan, 2023; Yu et al., 2013; Yu & Gero, 2016). Lee et al. (2016) and Yu et al. (2013, 2018) find no significant difference in design behavior between PDEs and GMEs, suggesting that the influence of environment may depend heavily on individual experience.

Although PDEs show potential for enhancing creativity and expanding design possibilities, they introduce challenges such as steep learning curves (Aish & Hanna, 2017) and black box thinking (Dissaux & Jancart, 2022), limiting the designer's control over algorithms and decision-making processes. The tendency for novices to generate unexpected outcomes (Chien & Yeh, 2012) further underscores the need for educational models that balance exploration with structured learning.

The next sections delve into two critical aspects drawn from this synthesis: the challenges PDEs present for novice designers and the gaps in current educational approaches, followed by an examination of the methodological limitations in existing studies and recommendations for future research.

### Challenges of PDE on Novice Designers and Solutions for Educational Gaps

Parametric design is recognized as a fundamental component of current architectural practice, promoting innovation and expanding design alternatives. Despite its significance, parametric design is often introduced at later stages of architectural education, primarily within digital tools and computational design courses (Alalouch, 2018). This delay arises from the complexity of parametric modeling, which requires proficiency in software, scripting, and shape grammar. However, Gürel & Şenyapılı Ozcan (2023) demonstrate that PDEs can also be effectively integrated into the early concept design phase through collaboration with traditional hand-sketching methods. For instance, Alalouch (2018) introduces parametric principles with the "serial of planes" technique to foster early parametric thinking. While this technique effectively builds foundational understanding, it often results in simpler algorithms that lack the complexity needed for

**Table 9.** Summary of Reviewed Studies (in chronological order)

| Study | Test Variable | Collection Method | Evaluation Method | Participants | Design Task | Outcome |
|---|---|---|---|---|---|---|
| (Chien & Yeh, 2012) | Environment | Protocol (PSFIE) | Descriptive Analysis | 5 | High-rise, Pavilion | Novices produced more unexpected outcomes than experts. |
| (Yu et al., 2012a) | None (Explorative) | Protocol (FBS) | Descriptive Analysis | 2 | High-rise Building | Reformulation drives creativity. |
| (Yu et al., 2012b) | None (Explorative) | Protocol (FBS) | Descriptive Analysis | 2 | High-rise Building | Model captures most design activities. |
| (Yu et al., 2013) | Environment | Protocol (FBS) | Descriptive Analysis | 3 | Shopping Mall, Community Center | No significant behavioral difference. |
| (Lee et al., 2013) | Experience and Environment | Protocol (PPC) | Descriptive Analysis | 4 | High-rise Building | 'Generation' and 'Changing Parameter' linked to divergent thinking. |
| (Lee et al., 2015) | Experience and Environment | Protocol (PPC) | Descriptive Analysis | 4 | High-rise Building | Experts scored higher in creativity assessments. |
| (Yu & Gero, 2016) | Environment | Protocol | Markov Model | 8 | Shopping Mall, Community Center | More design patterns used in PDE than in GME. |
| (Lee et al., 2016) | Experience | Protocol (PPC) | Linkography | 4 | High-rise Building | No significant difference in cognition or spatial language. |
| (Aish & Hanna, 2017) | Environment | Personal Experience | Learning Curve | - | Curve Control | Different software shows varying learning paths. |
| (Alalouch, 2018) | Experience and Gender | Survey | Mann-Whitney U | 57 | Vehicle Stop | Gender has no effect; software knowledge enhances learning and imagination. |
| (Yu et al., 2018) | Environment | Protocol (FBS) | Descriptive Analysis | 8 | Shopping Mall, Community Center | PDE potentially enhances design creativity. |
| (Lee & Ostwald, 2019) | Experience and Environment | Protocol (PPC) | Linkography | 6 | High-rise Building | Entropy analysis measures cognitive complexity. |
| (Namoun et al., 2019) | Experience and Environment | Interview | T-test | 24 | Website | Novices preferred PDE; experts found tools limiting. |
| (Lee & Ostwald, 2020) | Experience | Protocol (DMP) | Descriptive Analysis | 6 | High-rise Building | DMP develops three creative loops in PDE, representing creative processes. |
| (Dissaux & Jancart, 2022) | None (Explorative) | Interview, Protocol | Descriptive Analysis | 18 | Pedestrian Bridge, Pavilion, High-rise | Participants relied on videos; assistants as last resort. |
| (Yang et al., 2022) | None (Explorative) | Survey | Regression Analysis | 110 | Music Playback Equipment | Model generates 3D sketches quickly. |
| (Gürel & Şenyapılı Ozcan, 2023) | Environment | Protocol (PPC) | Mann-Whitney U | 6 | Shelter | Increased cognitive actions in PDE vs. sketching. |
| (Öztürk Kösenciğ & Özbayraktar, 2024) | Environment | Protocol (FBS) | Linkography | 11 | Pavilion | Sketching enhances synthesis, PDE diminishes it. |

advanced design processes. Determining the optimal stage to introduce PDEs in architectural education remains an important area for further exploration.

Managing cognitive load is one of the most significant challenges in parametric design education, particularly when PDEs are introduced in the early stages of architectural training. This challenge arises from the steep learning curve (Aish & Hanna, 2017) associated with parametric modeling and the need to balance conceptual design exploration with technical skill-building. But integrating the technical knowledge required for PDEs into already intensive architectural programs is difficult. Workshops have been proposed as a practical solution for this problem (Öztürk Kösenciğ & Özbayraktar, 2024). By offering intensive, focused environments, workshops allow students to engage directly with parametric tools in a compressed timeframe. While workshops are effective in familiarizing students with PDEs, they may not always provide a long-term solution to managing cognitive overload or support the gradual development of expertise.

In recent years, integrating advanced technologies such as augmented and virtual reality (AR/VR) has been explored as a means to enhance parametric design education. For example, the pARam tool, which combines parametric design with AR, has shown promise in making artifact customization more intuitive and accessible for students (Stemasov et al., 2024). Similarly, AR/VR technologies have been found to improve spatial awareness and design communication, fostering a more immersive and engaging learning experience (Hafizi, 2024). These technological innovations can offer potential solutions for alleviating some of the challenges faced in parametric design education.

Another significant challenge in parametric design education is black-box thinking, often caused by reliance on online tutorials and pre-made scripts (Dissaux & Jancart, 2022). While these resources support self-regulated learning, they risk creating superficial understanding by obscuring the logic behind parametric systems. This reliance can hinder creativity and independent exploration. Educational models that incorporate the dissection and adaptation of tutorial content with expert guidance could foster deeper algorithmic understanding and reduce dependency on external resources. By making the underlying processes transparent, students can develop more flexible and adaptive problem-solving skills.

The creativity gap between novice and expert designers is another critical concern. Experts perform better in PDEs due to their accumulated knowledge and experience, enabling them to efficiently generate complex and innovative designs. In contrast, novices often encounter unexpected solutions (Chien & Yeh, 2012), which, while fostering creativity, may limit progress due to gaps in foundational knowledge. This highlights the importance of balancing technical skill-building with exercises that encourage divergent thinking. Scaffolded complexity and incomplete recipes (Vazquez, 2024), where students gradually progress from basic tasks to advanced challenges, could support this balance. Such strategies provide opportunities for both structured learning and open-ended exploration, accommodating the needs of learners at different skill levels.

In low-resource educational settings, these challenges are magnified by limited access to advanced software, hardware, and trained instructors (Atabek, 2019). To address these constraints, non-digital exercises such as manual shape grammar, physical parametric models, and algorithmic thinking through paper-based activities offer practical and accessible alternatives (Alalouch, 2018). These approaches simulate parametric processes effectively, enabling students to develop foundational skills without reliance on digital tools. For example, physical model-based workshops can introduce essential parametric concepts while fostering creativity and adaptability in resource-constrained environments. Additionally, Gürel & Şenyapılı Ozcan (2023) suggests developing AI-assisted scripting to simplify the coding process, further easing the transition into PDE for novice designers and highlighting this as a promising area for future research.

Addressing the multifaceted challenges of parametric design education requires innovative pedagogical strategies that balance accessibility, technical proficiency, and creative exploration. Workshops, scaffolded learning environments, and non-digital approaches each play a role in equipping students with the skills and mindset needed to navigate the complexities of PDEs. By fostering transparent learning processes and supporting learners at different stages, educators can prepare the next generation of architects to engage confidently and creatively with PDEs.

**Limitations of Current Methods and Future Works**

The methods employed to investigate cognitive processes in PDE vary widely, reflecting the complexity and layered nature of design cognition. Surveys (Alalouch, 2018; Yang et al., 2022) and interviews (Namoun et al., 2019) are commonly used, yet their reliance on self-assessment and introspection introduces inherent biases. Participants may misinterpret questions, provide socially desirable answers, or inaccurately recall their design processes, leading to results that may not fully capture actual behaviors. Similarly, protocol analysis, while a preferred method for real-time cognitive data, is subject to coding biases and inconsistencies among evaluators. These limitations highlight the need for combining surveys, interviews, and protocol analysis to enhance the validity and reliability of findings. However, few studies (Dissaux & Jancart, 2022; Lee et al., 2013) in this review effectively integrate multiple methods, underscoring a gap in broader research practices.

Protocol analysis remains the most widely adopted approach due to its ability to document design cognition directly through think-aloud protocols and audio-visual recordings. This method provides a granular view of the design process, capturing the sequence and flow of cognitive actions. Compared to self-reporting methods, protocol analysis offers a more objective perspective. However, the quality of the results depends heavily on coding accuracy and methodology. Additionally, (Shealy et al., 2023) have shown that the think-aloud method applied during protocol analysis creates additional mental load, thereby reducing the time allocated for design.

The absence of standardized coding schemes across studies introduces variability, making cross-comparisons difficult. Although not observed in the studies reviewed, the use of biometric data such as heart rate variability (Ignacio & Shealy, 2023) and EEG (Balters et al., 2023) in cognitive research presents an opportunity to improve the reliability of protocol analysis by providing physiological indicators. Future PDE studies could benefit from incorporating these tools to mitigate the risks of subjective interpretation.

A closer examination of protocol models reveals a strong reliance on frameworks like FBS and PPC. These models are instrumental in capturing design cognition, particularly in the iterative workflow characteristic of PDE. Despite their strengths, limitations persist. In Yu & Gero (2016)'s study, FBS protocol analysis indicated a higher frequency of function-to-structure (F→S) transitions in PDE compared to GME. However, the study could not determine whether the identified functions stemmed from pre-learned design patterns or novel rule sets developed during the design task. Similarly, Gürel, A., & Şenyapılı Ozcan, B. (2023) found increased perceptual actions in PDE relative to hand sketching, but the underlying cause whether driven by the design environment or individual cognitive styles remained ambiguous. Addressing such ambiguities requires post-experiment interviews and follow-up discussions, as demonstrated by Lee et al. (2013), to distinguish between emergent design strategies and prior knowledge.

The adaptability of cognitive models is evident when combined with supplementary methods such as semantic analysis (Lee et al., 2016) and entropy analysis (Lee & Ostwald, 2019). These hybrid approaches provide a more nuanced understanding of design complexity and variability. However, while Lee & Ostwald (2019) introduces a framework for quantifying cognitive complexity, the dynamic nature of cognitive styles which evolve with experience and task variation complicates the interpretation of data. The lack of established scales and benchmarks further restricts the generalizability of these findings, emphasizing the need for developing standardized measurement tools in future studies.

Several studies (Lee et al., 2013; Lee et al., 2015; Yang et al., 2022; Yu et al., 2018) investigate the relationship between design patterns and creativity in PDE, yet few address the performance of the resulting designs and none address the algorithm quality. The small sample sizes in most studies limit the scope for statistical analysis, resulting in a heavy reliance on descriptive methods. For instance, Yu et al. (2018) found no significant difference in creativity through mean-split analysis, with 30% variance set as the threshold, while Lee et al. (2016) similarly reported no meaningful variation in creativity scores. This suggests that design cognition alone may not directly correlate with enhanced creativity in PDEs. The absence of performance metrics raises questions about the practical implications of these cognitive models, indicating a need for studies that evaluate design output and performance alongside cognitive measures.

A broader issue is the inherent limitation of laboratory-based studies in capturing the macro-cognitive activities and unique creative strategies of designers. As Lee & Ostwald (2020) notes, controlled environments often exclude critical creative processes such as replication, integration, and analogical reasoning. Expanding experimental models to incorporate computational design principles such as combination, transformation, and emergence can help bridge this gap. However, achieving this necessitates new coding schemes and diverse experimental designs tailored specifically to the iterative and generative workflows in PDE.

While many studies compare PDE and GME, the scope of comparison remains narrow. As Lee and Ostwald (2019) highlights, extending these comparisons to include hand sketching (Gürel, A., & Şenyapılı Ozcan, B. (2023)) and digital fabrication (Öztürk Kösenciğ & Özbayraktar, 2024) could provide a more comprehensive understanding of how different environments shape design cognition. Emerging technologies like VR and BIM also present unexplored opportunities for expanding this research. Additionally, despite increasing attention to diversity in design, Gurel & Senyapılı Ozcan (2023) notes absence of studies addressing gender-based differences in PDE like Alalouch (2018). This represents an area that needs further exploration.

Expanding the scope of PDE research through interdisciplinary collaboration, incorporating insights from cognitive psychology, human-computer interaction, and artificial intelligence could lead to more holistic frameworks for PDE studies. This approach would not only deepen theoretical insights but also enhance the practical application of PDE in architecture, industrial design, and engineering. Addressing the limitations discussed here will be essential for advancing parametric design research and fostering more inclusive and adaptable educational models.

## CONCLUSION

This systematic literature review highlights the evolving landscape of cognitive research in PDE, identifying critical trends and methodological approaches across 18 studies. While parametric tools foster iterative and generative design processes, the findings reveal gaps in understanding how these environments influence cognitive load, creative performance, and design behavior across varying levels of experience.

The prevalence of protocol analysis as the primary data collection method reflects the demand for real-time cognitive insights in PDEs. However, the limitations associated with self-assessment biases and coding inconsistencies call for more diverse methodological frameworks. Integrating biometric tools and post-experiment interviews could address these challenges by providing objective data to complement subjective feedback.

A significant gap lies in the under-explored area of PDE education, particularly concerning how novice designers develop parametric skills and overcome black-box thinking. Although workshops and short-term learning models provide valuable introductory exposure, long-term strategies that balance technical complexity with conceptual exploration remain underdeveloped. Future studies should focus on scaffolded learning pathways that enable gradual mastery of PDEs while fostering independent problem-solving.

Additionally, research to date has largely centered on conceptual design phases, with limited examination of how PDEs operate during later design stages, such as analysis, fabrication, and evaluation. Expanding this scope could provide a more holistic view of parametric design's role throughout the entire architectural workflow.

Moving forward, there is a need to broaden participant diversity and consider cultural, demographic, and institutional differences in PDE adoption and learning. Exploring gender-based variations, low-resource educational settings, and alternative design environments, such as VR and digital fabrication, can further enrich the field.

Ultimately, advancing research in PDE cognition requires interdisciplinary collaboration that bridges the fields of architecture, cognitive science, AI, and human-computer interaction. By addressing the methodological and educational gaps identified in this review, future studies can drive more inclusive, innovative, and effective applications of parametric design across disciplines.

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**Article**

# Socio-spatial dynamics of class habitus: Reproduction of the middle class in Kozyatağı neighborhood

**Başak BÜLBÜL AKIN[1*], Asuman TÜRKÜN[2]**

[1]*Department of Political Science and Public Administration, Marmara University Faculty of Political Science, İstanbul, Türkiye*
[2]*Department of Urban and Regional Planning, Yıldız Technical University Faculty of Architecture, İstanbul, Türkiye*

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## ABSTRACT

This study examines the interaction between class and space, focusing on the mechanisms of "harmony and continuity" in the Kozyatağı neighborhood, where traditional and new middle classes coexist. The research aims to explore how class fractions and spatial practices contribute to the reproduction and transformation of urban space. Instead of focusing on large-scale, rapidly developing transformation areas, the study investigates the process of gradual, parcel-based urban transformation in a middle-class neighborhood, with a particular emphasis on socio-spatial continuity and change mechanisms, and the impact of urban transformation activities on these mechanisms. A qualitative research approach is adopted, utilizing semi-structured in-depth interviews with 45 participants, ethnographic observations, and data analysis with the MAXQDA software. The software supports a reflexive approach in discovering mechanisms and analyzing data, taking the researcher's position into account. The study is structured around three key scales: macro (broader socio-economic developments and urban transformation processes), district (common socio-cultural characteristics in Kadıköy), and local (neighborhood dynamics specific to Kozyatağı). Findings indicate that spatial continuity is sustained through common values, perception-taste-thought patterns, and social relations formed between class fractions at the district and local levels. The perceived class habitus of space significantly shapes residential location choices and mobility patterns. However, external conditions such as the economic crisis, the pandemic, and the earthquake have disrupted local dynamics, undermining class reproduction mechanisms and triggering intra-class conflicts. The study combines critical realism and Bourdieu's theoretical framework to contribute to the field of urban planning by addressing the coexistence practices of different class fractions and the external interventions affecting these practices.

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## INTRODUCTION

Urban space, beyond being a mere physical area, is conceived as a concrete reflection of social structures and class relations. In the 21st century, space is analyzed not only through economic dimensions but also in its social, cultural, and political aspects. In this context, space is discussed as an arena where class similarities, inequalities, power dynamics, and class struggles are formed. Within this context, the literature emphasizes the role of space in reproducing and transforming class relations, with a particular focus on the impacts of capitalism and neoliberal processes on spatial

***Corresponding author**
*E-mail adres: basak.bulbul@marmara.edu.tr

dynamics (Harvey, 1997; Giddens, 1999; Harvey, 2008; Harvey, 2012; Castells, 2014; Lefebvre, 2014; Harvey, 2016). The dialectical relationship between class and space reveals how space reproduces class, while class in turn shapes space. Examining this process of reproduction requires a deeper understanding of the conditions under which social classes sustain their existence, as well as the mechanisms, structures, and causalities through which they coexist, live together and maintain a sense of social order. Therefore, the internal relations that determine the harmony and continuity or crisis and transformation of space and class is crucial for urban studies.

This study examines the mechanisms that facilitate the reproduction of class space through Pierre Bourdieu's concepts of habitus, capital, and field, within the theoretical framework of critical realism. It discusses how the socio-spatial continuity and change of similarities and differences between intra-class fractions shape class space. Critical realism is used as the philosophical foundation of the study and to guide the methodology. Bourdieu's sociological approach and conceptual framework, which are considered closely related to this theory, help us understand the interactions between different class fractions through daily life practices, lifestyles, consumption habits, patterns of taste and perception, and preferences in residential areas. Thus, space emerges as a domain where social class habitus can coexist based on class similarities and differences, where different class fractions can create interwoven practices in a harmonious manner, yet also where conflicts between these classes can be observed.

This study aims to explore how the traditional and new middle classes collectively construct their residential areas, how mechanisms of intra-class cohesion operate, and how these mechanisms may transform into conflict through various externalities. In this context, the study focuses on the location and historical development process of Kozyatağı Neighborhood, emphasizing its role as a buffer zone between lower and upper-class settlements in a middle-class neighborhood. The impact of urban transformation activities that began after 2000 and their changing structure on the mechanisms of cohesion and continuity in the neighborhood are critically examined. The factors influencing these mechanisms are analyzed at three different scales: macro, district, and local. The dynamics at the district and local levels are specific to the place and contribute to the production of cohesion and continuity conditions. In this regard, class similarities, the transmission of habitus, and preferences in residential location affect the interactions, while the presence of traditional middle-class residents and local tradespeople reproduce the social relationships and networks that sustain the neighborhood's culture. However, in recent years, urban transformation processes shaped by macro-level developments such as the economic crisis, the pandemic, and earthquakes have altered the social pattern of the neighborhood, leading to social inequalities and socio-spatial segregation. The study investigates how the internal and external dynamics at different scales (macro, district, neighborhood) jointly shape class space. It seeks to answer questions regarding how class habitus is formed in space, how class is reproduced through interaction with space, how intra-class differentiations alter space, and how different class fractions establish relationships with one another through space. In this context, the study aims to establish a bridge between the theoretical approaches of social sciences and the field of urban planning by considering them together in class-based spatial analyses.

In the literature, middle-class settlements in Turkey are addressed in two main areas: the spatial configurations created with the rise of upper-class residential areas and luxury housing projects, and the emergence of the conservative middle class[1]. This study, however, focuses on the incremental transformation processes of middle-class habitus and space through parcel-based, piecemeal transformation activities in a middle-class neighborhood that includes different class fractions. It highlights the transformative role of space on class, examining how space gradually reshapes the middle class over time.

**Conceptual and Theoretical Framework: Critical Realism and Bourdieu**

In this study, critical realism is employed as both a philosophy and a research methodology, and used as a meta-theory, in order to ground Pierre Bourdieu's conceptual and theoretical approach, particularly as discussed in his work Distinction: A Social Critique of the Judgement of Taste (2015). This approach is explored in detail to highlight its practical implications in field studies. In this context, integrating critical realism with Bourdieu's framework is believed to strengthen both the theoretical and practical dimensions of the study. This combination allows for a more effective exploration of the subject, as it enables the two dimensions to complement each other throughout the research process.

Critical realism emerged in the 1930s as a critique of the dominant positivist approach to the philosophy of science in the social sciences (Danermark, et al., 2018). The philosophical foundation of critical realism is based on the works of Bhaskar (1998, 2008, 2011). Particularly in the field of human geography, studies have explored what critical realism might mean in practice. One of the key figures representing these approaches is Sayer (2019) (Erendil, 1998). Sayer engaged in a search for a methodology to reflect the ontological and epistemological framework of critical realism onto the practice of social sciences, emphasizing the importance of the relationship between methodology and theory, as well as conceptualization (Pratt, 1994).

Bhaskar is concerned with ontological and epistemological issues regarding the nature of reality and how we acquire knowledge about it. By emphasizing the relationship between scientific knowledge and existence, he argues that reality cannot be determined by knowledge and that it possesses a transcendental nature. He asserts that reality exists, but that understanding, perception, and conditions in cognitive processes lead to its variability. From this standpoint, Bhaskar contributes to critical realism through his approach to the "structure-agent" debate (Pratt, 1994). He argues that individuals often reproduce social structures unconsciously during their intentional activities, and sometimes even transform them[2]. Thus, while individuals' actions affect social structures, they are simultaneously shaped by these structures (Tekeli, 1994; Erendil, 1998; Bhaskar, 2011). Society exists independently of individuals and constitutes a prerequisite for individual action; however, the conditions for society's existence are also contingent upon individuals' reproduction of social structures and practices. In this way, as individuals reproduce the conditions of production, society becomes both the medium and the outcome of this activity (Sayer, 2019).

Critical realism approaches the relationship between individuals and society as a dynamic, mutually influential whole, while also seeking a practical and methodological framework to transcend dualities such as subject-object, thought-action, mental-material, knowledge-practice, theoretical-empirical, and qualitative-quantitative (Sayer, 2019). Similarly, Bourdieu, in his work, attempts to develop a framework of thought that addresses these dualities (Wacquant, 2007; Calhoun, 2007; Bourdieu, 2013). Sayer (2019) argues that the relationship between everyday life and practical knowledge is contingent upon historical, spatial, and social conditions, which are in a constant state of flux. Therefore, the reality he describes is not absolute but context-dependent. The validity and accuracy of knowledge are assessed in relation to its social context. For this reason, he proposes the use of the concept of "practical adequacy" rather than "truth" (Sayer, 1993; Sayer, 2019).

Critical realism's approach to "practice" views the individual as an agent who performs actions and generates meaning, while defining social structures as an internally connected set of objects and practices. Although transformations are difficult, objective conditions, mechanisms, and the meanings and practices that constitute them undergo changes over time (Sayer, 2019). Social practices are influenced by the differences in the meaning structures of the agents and interact with their practices. These differences are shaped by the conceptual tools used and social relationships. In social relations, agents interact based on mutually alterable shared understandings, which affect perception and learning processes, steering individuals to think through specific sets of concepts (Sayer, 2019). This approach of critical realism bears similarities to Bourdieu's concept of "habitus" and his action theory approach, used to explain the structure-agent relationship. Bourdieu argues that most actions are not based on a rational choice model but rather involve learned adaptation to familiar conditions. Through the concept of habitus, Bourdieu emphasizes that individuals possess patterns derived from their past experiences, capital, and social positions, which shape their perceptions, thinking, and ways of acting. Habitus is not genetically transmitted but acquired, forming the foundation of most practices. It materializes as lasting dispositions within the body, is reproduced within social positions, and varies depending on the type and volume of capital held in specific fields, shaping actions through the internalization of externalities. Through their habitus and game sensibilities, individuals both reproduce and are reproduced by social structures and classes (Bourdieu, 1986; Bourdieu, 1987; Bourdieu, 2006; Bourdieu, 2013; Bourdieu, 2014; Bourdieu, 2015). In this context, social space is an area defined by the quantity of capital embedded in distances within it. It describes relationships such as proximity, similarity, distance, and discord among groups, and determines the likelihood of groups genuinely coexisting (Bourdieu, 2013). Bourdieu's concept of social space becomes visible through spatial space, revealing the dynamics of similarity, difference, harmony, and conflict in class-based spaces. Moreover, Bourdieu does not passively position individuals; he argues that individuals also have the potential to transform these structures. Thus, he advocates for a "structural constructivism" that bridges the duality between the agent and structure through the externalization of the internal and the internalization of the external (Cresswell, 2002; Bourdieu, 2013; Bourdieu, 2016; Jourdain & Naulin, 2016).

The concept of "causality" in critical realism also bears significant parallels with Bourdieu's approach. Bhaskar addresses reality on three levels: the real (causal mechanisms), the actual (events), and the empirical (experiences). The empirical domain encompasses experiences and meanings, while the actual domain includes the events that occur in reality. The real domain, on the other hand, involves the structures and causal mechanisms that generate these events (Bhaskar, 1998; Bhaskar, 2008; Türkün Erendil, 2000; Bhaskar, 2011). This approach shifts the focus from events themselves to the structures and mechanisms that produce them. Causality, in this framework, refers not to abstract cause-and-effect relationships between events, but rather to the forces and mechanisms that generate objects or relationships. These forces are connected not only to objects and individuals but also to social structures. The relationship between objects and causal forces is necessary/intrinsic, while the relationship between objects and conditions is contingent/external (Danermark et al., 2018; Sayer, 2019). Bhaskar argues that structures and generative mechanisms should be analyzed as "tendencies". Agents

possess the tendencies of the class to which they belong, and thus distinguish what belongs to that class (Bhaskar, 2008). In this context, critical realism's understanding of causality aligns with Bourdieu's approach to social position, distinction, and tendencies.

Critical realism forms the philosophical foundation of this study, while Bourdieu's concepts concretize this philosophy. Although Bourdieu did not directly establish a relationship between class reproduction and space[3], within the framework of critical realism, the trio of "habitus-capital-field" provides a crucial tool for understanding the development and transformation of small-scale settlements. This approach serves as a guide for asking the right questions to uncover the implicit meanings and mechanisms within spatial studies. Moreover, the research designs and methodological approaches they offer are expected to facilitate the integration of philosophy, theory, and practice in fieldwork. The next section will discuss the adopted methodological approach, based on this conceptual framework.

## METHODOLOGY

In social sciences, theory, unlike in the natural sciences, cannot predict contingent relationships solely based on theoretical inferences. Instead, abstract theories and concrete research are considered together. Theoretical inferences about the internal relationships and causal forces at the abstract level are validated through exploratory empirical research at the concrete level (Sayer, 2019). In social sciences, generalization is often made through empirical induction; however, this approach provides a limited understanding of social structures. Critical realism, on the other hand, emphasizes the importance of "abduction" and "retroductive reasoning" processes for understanding the conditions of existence and causal mechanisms of social phenomena. Abduction involves moving from singular instances to general concepts and linking them to broader social structures. Retroductive reasoning, in turn, involves conceptualizing social structures and relations based on empirical observations. These processes reveal the conditions of action and thought of agents, as well as the underlying social structures and relationships (Pratt, 1994; Danermark et al., 2018).

The positivist approach in the social sciences associates causality with regularities between events, typically relying on quantitative methods. In contrast, critical realism emphasizes the causal powers behind these regularities, which are rooted in social relations and the objects that generate them and focuses on qualitative methods to understand social objects and relationships (Sayer, 2019). However, this does not mean that only qualitative methods should be used in social sciences. Both approaches offer distinct contributions depending on the research question and the internal or external relationships of the object being studied. According to Sayer (2019), in Harre's distinction between extensive and intensive research designs, extensive studies typically aim to examine the entire population, with common characteristics being identified through a representative sample. In this research design, descriptive and inferential statistics, surveys, and census techniques are commonly used, and potential causal relationships are often overlooked. In contrast, intensive research methods aim to explore the characteristics of typical members of a community, unveiling structural relationships and interactions. This research design primarily employs qualitative techniques such as participant observation, interviews, and structural-causal analysis. Rather than competing, extensive and intensive methods complement each other, and thus, their combined use is of significant importance (Pratt, 1994; Sayer, 2019).

In the context of this research, causality is sought within regularities; however, these regularities are not treated as universal and immutable laws. The aim of this study is to uncover the underlying mechanisms behind certain regularities and to examine how these mechanisms shape social reproduction under conditions of change. In other words, the relationship between continuity and change, shaped by internal mechanisms and external influences, is explored through the case of a small-scale urban settlement. In this context, taxonomic classes are defined, where individuals share similar causal forces (Sayer, 2019), and the combination of extensive and intensive research designs is adopted as the methodological approach in this study[4].

In this study, a qualitative research method was employed, adopting an exploratory, descriptive, and interpretative approach. Between January and June 2024, semi-structured in-depth interviews were conducted with 45 participants using open-ended questionnaires in the Kozyatağı Neighborhood. The interview sample was determined through convenience and snowball sampling methods, with the assistance of field observations and physical structure analysis[5]. The aim was to question perceptions of space and class in a broader context by interviewing a diverse range of actors, including residential users, business owners, real estate agents, construction companies, and the neighborhood headman. The data were analyzed using the MAXQDA Software. The program has been used as a tool to facilitate the identification of patterns within the data and the explanation of the underlying causes of these patterns. In particular, when analyzing large and complex qualitative data, it provides significant support to the researcher in discovering patterns of comparison, similarities and differences, internal dynamics, implicit meanings, causalities, and relationships thus exceeding the cognitive limits of the human mind. The process of categorizing qualitative data, constructing themes, interpreting and meaning-making these themes, and conducting in-depth analysis enables the researcher to examine and organize

the data systematically. In this way, it aids in uncovering the causal mechanisms and structures targeted by critical realism's intensive research design. While the program allows for both quantitative and qualitative analyses, it can also be used as a tool for the researcher to comprehensively address their data. Furthermore, such software is believed to enhance the explanatory power of the findings obtained through fieldwork, strengthening the relationship between theory and practice and helping them mutually inform one another[6] (Buracademy, 2024).

This program enables the researcher to analyze the data systematically while also allowing them to actively incorporate their intuitive approach and theoretical knowledge during the stages of coding and theme development, making it possible for the researcher to participate actively in the process. In this context, MAXQDA, unlike content analysis, allows the researcher to integrate the insights, observations, and perceptions gained during the fieldwork into the analysis process. The researcher can systematically record their thoughts and comments noted during and immediately after interviews, by revisiting the interviews and applying them to the coding and thematic stages. This information can then be integrated into the analysis through the program (Buracademy, 2024). In this way, the researcher's subjective experiences can contribute to the analysis. In this context, reflexive thematic analysis is considered as an integral part of the methodology[7].

At this point in the study, an ethnographic approach has been adopted, and semi-participant observation has been utilized to collect qualitative data[8]. The methodological structure of the study incorporates reflexivity[9], a process where the researcher continually questions their position and relationship with the object of study, as emphasized by Bourdieu. In this process, subjectivity is used as a research tool, with the researcher being aware of how their social position, knowledge, values, and biases influence the interpretation of data throughout the research process. Qualitative data were categorized and relationships were explored through codes and themes developed by the researcher, who combined both subjective insights and objectivity from the interviews, integrating theoretical and practical knowledge. In this context, the interviews were first transcribed, and potential codes and points of attention were recorded in a digital environment (on a Word document). All the data obtained were then transferred to the program. Subsequently, all the texts from the interviews were re-read through the program, and during this process, the initial coding work was carried out. After the coding was completed, all the codes were reviewed, and the interview excerpts under each code were re-examined. Meaningful patterns between the codes were identified, and specific codes were associated with each other. Thus, the codes that were related were grouped under specific clusters and listed under a common theme. After this stage, the visual analysis tools provided by the program (such as code clouds, code-theory models, etc.) were utilized, and causal relationships were explored in detail[10].

Critical realism, Bourdieu's approach, and reflexive thematic analysis together present a research design that integrates both theoretical and practical components, complementing each other. This approach brings together philosophy, theory, methodology, and practice, transforming the research into a holistic narrative. In the following section, the location and historical development of the study area, Kozyatağı Neighborhood, will be briefly presented.

## The Location and Historical Development of Kozyatağı Neighborhood

Kozyatağı Neighborhood is located in the Kadıköy District of İstanbul. To the north, it is bordered by the D-100 Highway and the İçerenköy Neighborhood of Ataşehir District, which is separated by this road. To the east lies the Bostancı Neighborhood, while to the south, it is bordered by Şemsettin Günaltay Street (Minibus Street) and the Suadiye Neighborhood, which is also separated by this road. To the west, Kozyatağı is bordered by the 19 Mayıs Neighborhood, with which it is commonly referred to as a single district (Figure 1).

The location of the neighborhood, when considered alongside the surrounding transportation corridors, serves as a significant indicator of class-based spatial dynamics. The boundaries of class-based spaces and, consequently, the gradations in housing prices, can be traced along three major transportation axes that divide the Kadıköy area along the east-west axis. The area between the coastal road and Bağdat Street, as well as the section between Bağdat Street and the railway, is characterized by upper-class residential areas. The region between the railway and the D-100 highway is home to middle and upper-middle-class settlements, while the area to the north of the D-100 highway predominantly features lower-middle and working-class residences (Kadıköy Municipality Academy, 2023). In other words, these axes segment the urban space into three distinct zones, each of which refers to different socio-economic residential areas. In this context, Kozyatağı Neighborhood is situated as a middle-class settlement between the other two zones, exhibiting characteristics of both, and serving as a transitional area that facilitates a gradual shift between the socio-spatial differences of the two adjacent regions.

When examining the historical development of the neighborhood, it is evident that until the 1970s, the area had a rural character, surrounded by agricultural land and walnut orchards. The region was named "Kozyatağı" due to the density of walnut trees. During this period, the area was characterized by low-density, garden-based, 1-2 storey wooden structures primarily used as summer residences. These buildings, typically unoccupied during the winter

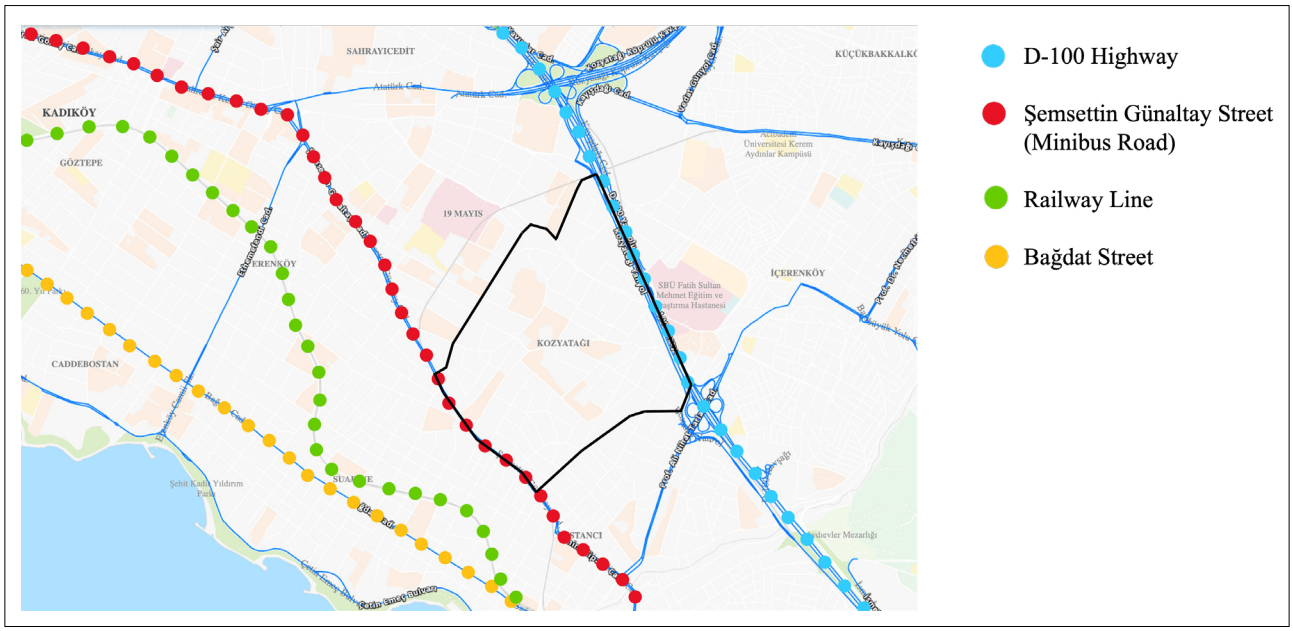


**Figure 1**. The Location of Kozyatağı Neighborhood and Key Transportation Corridors.

months, were used in the summer and the area was recognized as a holiday retreat. Additionally, between 1950 and 1970, the first examples of mass housing built through cooperatives were also observed (Femir, Akozan & Yapanar, 1952) (Figure 2).

In the early 1970s, the neighborhood retained its rural identity, characterized by a dominant fabric of mostly single-storey, detached houses with gardens. However, the Condominium Law in 1965 and the 1/5.000 scale Bostancı-Erenköy Area Development Plan in 1972 paved the way for the construction of apartment buildings, increasing the density of the area (İstanbul Metropolitan Municipality Department of City Planning, n.d.). Furthermore, with the opening of the Bosphorus Bridge and the surrounding ring road in 1973, Kadıköy began to emerge as an attractive residential area. With the zoning renovation that took place in Kadıköy in the same year, the construction conditions in the neighborhood were increased by up to 10 times (Gök & Çıtak, 2021).

In the late 1970s and 1980s, the neighborhood experienced a period of rapid construction with infrastructure improvements, cooperative development, and mass housing projects. With the amendments made to the Condominium Law with Law No. 2814 dated 1983, it was made possible to sell housing before the construction process was completed; with Law No. 2982 dated 1984, zoning regulations were made in the area, and new investments were encouraged through certain exemptions. However, as observed in the maps of the neighborhood's transformation in Figure 3 and noted in the

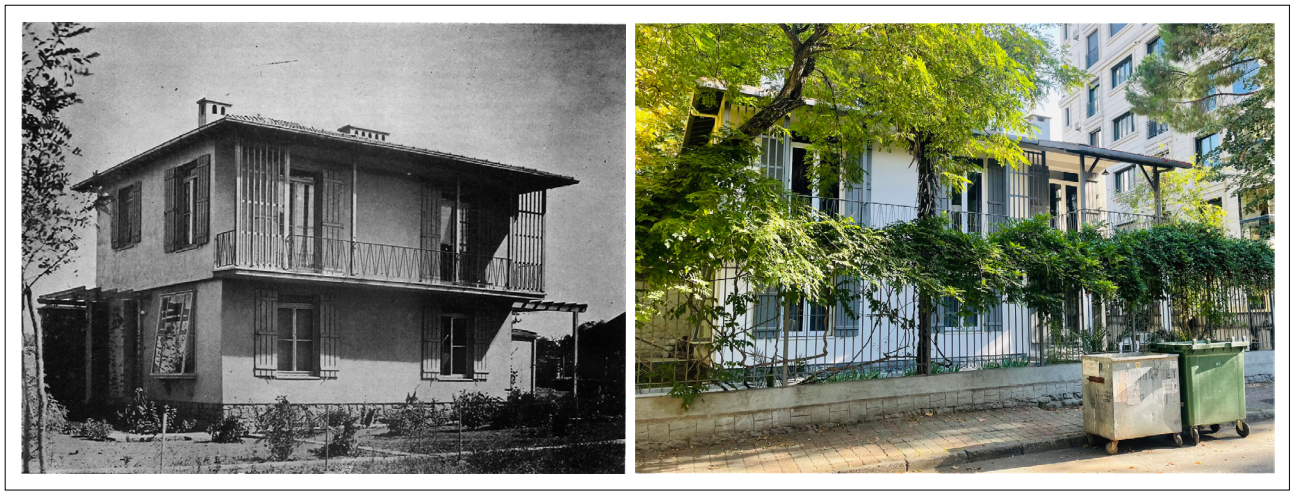

**Figure 2**. Şenesenevler Housing Cooperative Residential Example–1950s/2024 (Left image, Femir, Akozan & Yapanar, 1952; Right image, researcher's archive, 2024).

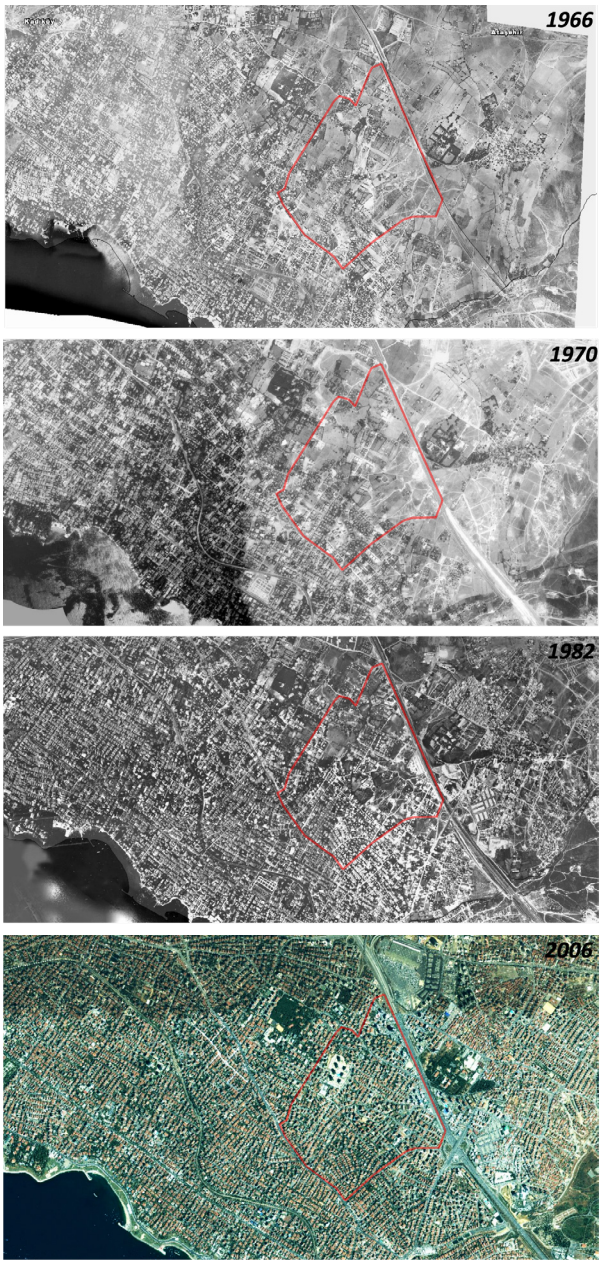


**Figure 3**. The Transformation of Kozyatağı Neighborhood from 1966 to 2006 (İstanbul Metropolitan Municipality, 2024).

interviews, agricultural land has rapidly been converted into residential areas. The neighborhood's historical mansions began to be demolished and replaced by high-rise apartment buildings. Additionally, mass housing projects carried out through cooperatives played a pivotal role in shaping the residential fabric of the area during the 1980s. However, in 1989, with the operationalization of the Kozyatağı junction and its connection to the highway, the region witnessed a concentration of office and commercial spaces due to the transportation advantages it provided (İstanbul Metropolitan Municipality, 2009).

Based on observations made as a neighborhood resident and interviews conducted, the 1990s marked a period of intensified mass housing projects in the neighborhood. During this time, high-rise, gated, and secure residential complexes were constructed, leading to an increase in the area's urbanization. In the interviews, it is noted that the most significant turning point in the transformation of the neighborhood fabric in Kozyatağı after the 1970s and 1980s was the urban transformation process following the 1999 Marmara Earthquake (Figure 3). The legal framework for urban transformation was first introduced in 2004, and the Urban Transformation and Development Law Draft was prepared in 2005 (Mimarizm, 2007). With the enactment of the Law No. 6306 on the Transformation of Areas under Disaster Risk in 2012, rapid identification of risky structures was carried out, leading to an increase in transformation activities (Kadıköy Municipality Academy, 2023).

Neighborhoods like Kozyatağı, which are representative of middle-class communities, function as "buffer zones" both spatially and socially, creating transitional spaces between the lower and upper classes. These neighborhoods accommodate the living practices and spatial demands of both traditional and new middle classes, while undergoing transformations through urban transformation processes. At the same time, new residents moving into the neighborhood become part of the emerging new middle class; the class similarities and spatial codes guide these two distinct class fractions towards developing certain practices of cohabitation. The next section will explore the "mechanisms of harmony and continuity" that emerge as the old and new middle classes share the same space.

## FINDINGS AND DISCUSSION

This section addresses the "mechanisms of harmony and continuity" that emerge as the traditional and new middle classes share the same space, and discusses the results of the interviews and observations conducted in the field. In this context, based on the data obtained, the similarities between class fractions are initially presented through the concepts of habitus and capital. To understand the similarities and differences in the economic, cultural, and social capitals of the traditional and new middle classes, findings related to demographic structures, lifestyles, consumption habits, spatial demands, daily life practices, and social relationships are interpreted. The perceived class habitus and shared values of Kadıköy District and Kozyatağı Neighborhood, which influence the location preferences of new middle-class residents introduced by urban transformation processes, are examined, along with the neighborhood-specific spatial characteristics and existing social structures at the neighborhood scale. While discussing the role of the neighborhood's former residents and local businesses in the reproduction of class,

the study also investigates the mechanisms that enable the harmonious coexistence and socio-spatial continuity of these former residents with the new settlers and businesses introduced by urban transformation. These mechanisms are explored in the context of how they are influenced by urban interventions shaped by national/international macro-level developments, and how they impact the class habitus and class space. In this context, under this heading, the focus is on the transmission of class habitus and the class similarities, the impact of class and spatial perception on the decision-making process of residential location, and the relationship between the continuity of commercial enterprises and neighborhood culture. The mechanisms of harmony and continuity presented by the relationship between class and space are questioned. During this inquiry, while examining how class similarities at the neighborhood and district levels contribute to the reproduction of these mechanisms, the negative impacts of macro-level developments are also discussed.

**Class Similarities and Transferred Habitus**

Demographic changes in Turkey, including the rise in the elderly population and the decline in fertility and mortality rates, are particularly evident in the Kadıköy district. Kozyatağı, a prominent neighborhood within Kadıköy, reflects these demographic trends, exhibiting a diverse age structure that includes not only a significant elderly population but also middle-aged (25-64 years), young adult (15-24 years), and child (under 14 years) groups (Kadıköy Municipality Academy, 2023). A clear relationship exists between the neighborhood's demographic composition and its spatial characteristics. For instance, areas with a high concentration of children are typically found near residential complexes, while the elderly and long-term shopkeepers are concentrated along Kaya Sultan Street and its surrounding areas, where the traditional urban pattern prevails[11] (Kadıköy Municipality Academy, 2023).

This demographic distribution is closely linked to ongoing urban transformation processes, with new residents exhibiting different demographic profiles compared to the former residents. A clear disparity is observed between the elderly, retired civil servants who constitute a majority of the former residents, and the younger, white-collar professionals who have recently moved into the neighborhood. Additionally, a relationship can be observed between property ownership and life cycle stages. New homeowners are predominantly individuals aged 50 and above, with established savings, whereas renters tend to be younger, either single or young married couples, with/without children.

The neighborhood's high proportion of children reflects the preferences of young families who have moved into newly constructed buildings as a result of urban transformation. This trend is consistent with the neighborhood's social amenities. Notably, all levels of education facilities are within accessible distances (Kadıköy Municipality Academy, 2023). Interviews conducted with residents indicate that compared to other districts, the quality of education in the area is highly regarded. Residents describe the neighborhood using terms such as "educated, cultured, refined, elite, polite, high-quality and conscious" (Figure 4). The cultural capital shaped within families, influenced by education and the living environment, plays a significant role in reproducing class habitus (Bourdieu, 2013; Bourdieu, 2015). In this context, the preference for sending children to schools in neighborhoods with similar social profiles represents a key element in maintaining class habitus and the continuity of class-based spaces.

The presence of migrant groups in the neighborhood serves as a significant indicator for understanding the demographic composition of both the old and new residents. Interviews indicated that the neighborhood hosts a limited number of migrant residents. Due to the high concentration of elderly and children, the presence of migrants from Turkic states, who provide daily or residential care services, was also noted. Additionally, families from Russia, Ukraine, and Iran have been reported to choose the neighborhood for homeownership. However, it was emphasized that these migrant groups share social, cultural, and economic characteristics similar to those of the neighborhood's residents, which has facilitated their integration into the area. In contrast, a small number of migrants from Syria and other Arab countries were unable to settle in the neighborhood and left within a short period. In other words, the class and spatial structure of the neighborhood attracts and accepts migrant groups with similar class backgrounds, while excluding those who do not fit, thereby maintaining its homogeneous structure. This pattern is also applicable to Turkish citizens. Interviews indicated that new residents tend to prefer living in areas with a "familiar or similar culture," and it was emphasized that lower-income groups or diverse ethnic groups are unlikely to live in the neighborhood. Moreover, it was pointed out that there is no concentration of residents from specific regions within Turkey, and that the neighborhood lacks strong regional affiliations or ties. Consequently, the continuity of the neighborhood's homogeneous class structure is shaped within the context of habitus and capital.

> "For example, the Syrians have filled the area. They're in every district. They couldn't settle here. They came, but they left just like they came. ... There are Russians. And they, I mean, they live well. Their socio-economic level is high, so they live comfortably. The living conditions are also the same as there. It's a quiet place. I mean, there's transportation here 24/7, it's very central. It's very close to the street, very close to the beach. Very close to the E-5, that's why. They're making great use of it." (Shopkeeper, Interview-23)

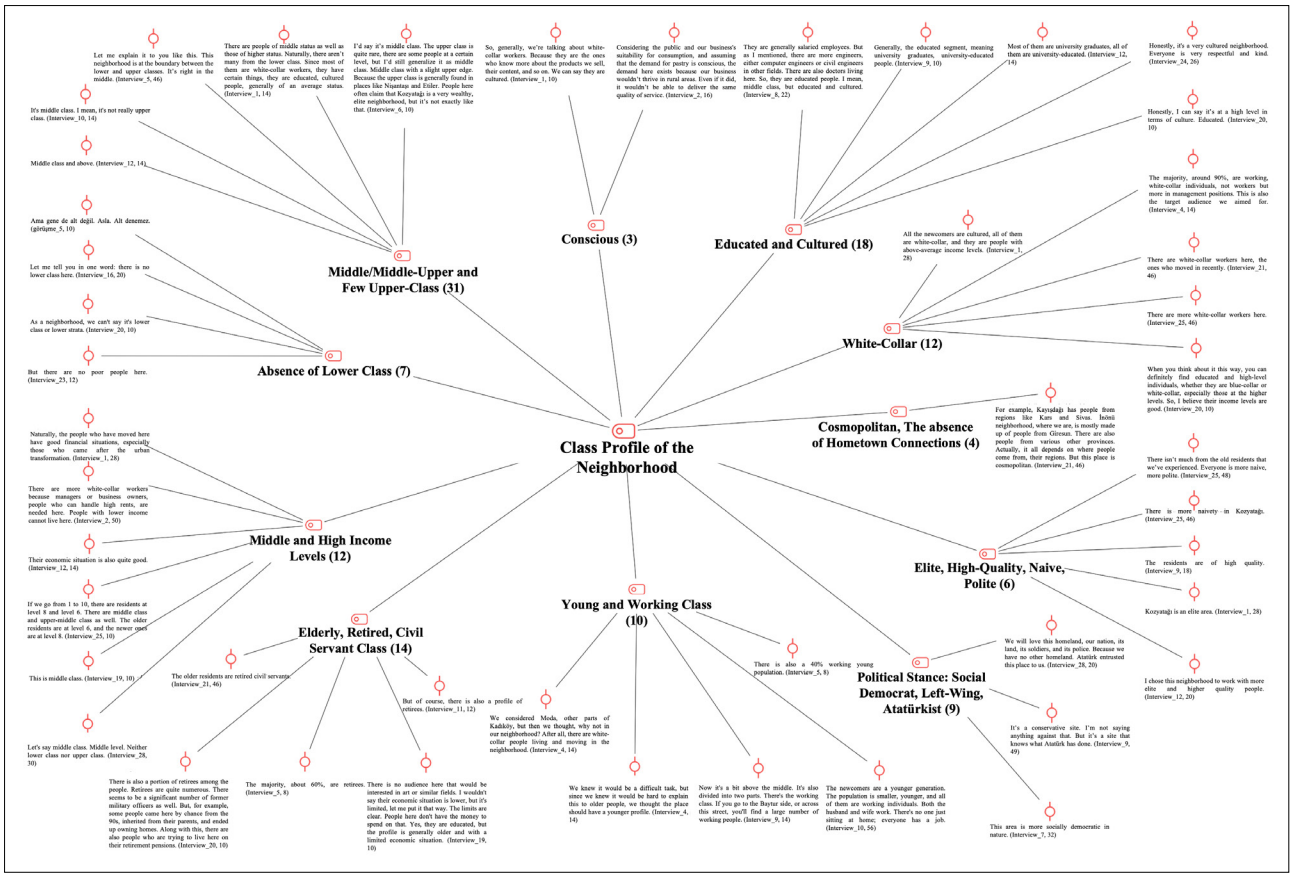


**Figure 4**. Class Profile in the Neighborhood (Code-Theory Model).

> "For example, Kayserians have always gone to Erenköy. We don't have that in our neighborhood. Look, in Bostancı, there are people from Malatya. We don't have that here. That's why we're uncomfortable. They come to us asking, 'Do you have associations?' We don't have an association like that. We don't have this hometown connection. For us, everyone's from the same place." (Neighborhood Headman, Interview-1)

> "I think like this, the shopkeepers or the people here aren't from the same origin or anything. For example, in some places, it's only people from the Black Sea, or only people from Sivas. Here, everyone is different. From different places. This is not a hometown neighborhood." (Resident, Interview-4)

The relationship between the demographic structure and space is understood through the economic, cultural, social, and symbolic capital possessed by residents, as well as the similarities and differences in the volumes of these capitals. According to the Kadıköy 2030 Current Status Report (2023), Kadıköy surpasses the İstanbul average in terms of education levels, with the highest number of graduates in higher education, undergraduate, graduate, and doctoral programs among İstanbul's districts. Kozyatağı, on the other hand, is defined as a neighborhood predominantly inhabited by middle-income groups (Kadıköy Municipality Academy, 2023). This study examines Kozyatağı as a middle-class neighborhood characterized by high education levels and middle to upper-middle income groups, hosting different class fractions, namely the traditional (old) and new middle classes.

Interviews revealed that the cohesion between old and new residents is largely facilitated by class similarities. The class profile of the neighborhood is commonly described using terms such as "educated," "middle to high-income," and "cultured." The concept of culture was addressed in three distinct ways: First, it was associated with education, with both groups being characterized as predominantly educated. Second, in the context of artistic and intellectual activities, it was noted that older residents refrained from participation due to economic reasons, while newer residents were disengaged due to a lack of interest. An interesting observation was made regarding the recent increase in ceramic workshops and art courses. The neighborhood head mentioned the opening of new ceramic workshops, but no particular emphasis was placed on this growth. Similarly, in other interviews, despite noting the increase in the number of ceramic workshops, these businesses were not generally recalled when asked about new enterprises in the area. Spatial observations further support this pattern,

although the number of ceramic workshops and art courses has increased, there is a noticeable lack of awareness and demand for this expansion. Interview with the owner of a ceramic workshop revealed that the participation of neighborhood residents in cultural activities is limited, with such events generally attracting participants from outside the neighborhood. Furthermore, it was observed that despite the high educational level of the younger generation, their cultural engagement has not developed sufficiently. This suggests that the cultural offerings, such as ceramic workshops, do not fully meet the expectations of the new middle class in practice.

On the other hand, the increasing number of gyms post-pandemic reflects the health-oriented physical activities pursued by white-collar young professionals, particularly those suffering from posture issues due to hybrid working conditions. Gym owners highlighted that participation in these activities is driven by health concerns and is not perceived as a cultural status symbol, especially when compared to similar neighborhoods like Suadiye. While the neighborhood residents are considered to have high cultural capital, taking into account their educational levels and social relationships, the area is still classified as a middle-class neighborhood in terms of economic capital. As a result, it was observed that there is a conscious preference for participation in physical activities, while interest in cultural events is limited, and the anticipated demand for cultural activities in the neighborhood has not materialized. In this context, the neighborhood's appeal to businesses offering such activities cannot be explained solely by cultural preferences; lower rental prices compared to neighboring areas also emerge as an important economic consideration.

Thirdly, it was observed that communication patterns in social life reflect cultural differences, with the older residents being more culturally endowed, while the newer residents, despite their higher educational levels, are culturally lacking. The older residents have strengthened their cultural and social capital, particularly through their education in village institutes and strong neighborhood ties. The neighborhood leader emphasized this cultural capital by stating, "My elderly residents grew up in the Village Institutes," highlighting the significant contribution of these educational institutions to the neighborhood's cultural capital. The cultural capital of the older residents is shaped not only by education but also by neighborhood relationships and the continuity of neighborhood culture. The traditional middle class transfers their cultural capital to the new middle class through everyday social interactions, thus producing a shared class habitus, despite the formation of different class fractions. This situation demonstrates the interaction between cultural and social capital. Although the habitus and capital of the old and new middle class differ, common factors such as education enable harmonious coexistence within the same neighborhood and facilitate the formation of a specific class habitus.

With the reproduction of class, the social, cultural, and ideological identity of space is also reshaped, thereby preserving the character of the neighborhood. Interviews highlighted the continuity of class space through the transmission of habitus. First, it was noted that individuals' actions are shaped not only by formal education but also by the social and cultural opportunities provided by their living environment, referred to as "environmental education." This form of education determines individuals' social behaviors and their adaptation to the environment. For example, it was observed that the respectful attitudes of building caretakers in social interactions were influenced by the residents of the neighborhood, which contributed to making class differences in the neighborhood livable. Second, the charitable and experience-sharing approaches of the older residents towards lower-class tradespeople were emphasized. This approach helps tradespeople establish a sense of belonging within the neighborhood, while also encouraging them to develop a similar habitus by sharing the thought patterns of the residents. Third, the transmission of neighborhood culture from older residents to newer ones through daily life and social interactions plays a significant role in maintaining a harmonious living environment. Despite challenges such as the pandemic and economic crises, it was observed that neighborhood ties have persisted, particularly when compared to other residential areas in İstanbul. Finally, it was noted that individuals who are perceived as "not belonging" to the neighborhood face difficulties in terms of social connections, communication opportunities, and access to services, which leads to their gradual exclusion from the space.

> "It's already known. I mean, the places to live in İstanbul are pretty much set. And here's the thing, if you don't belong here, you just end up leaving on your own. This place pushes you out. You want to leave. Because you can't find friends, you can't find a community, you can't find people to talk to. You can't find the products you want. What happens then? You leave. ... These neighborhoods don't change. Certain places don't change. You can't change Suadiye or Erenköy anyway. Because you don't have the power. I mean, there are rich people who go there, and those who became rich later. It doesn't change. You have no choice. Either you'll leave and choose a place that suits you, or you'll adapt to them. It's not like, these places don't change." (Shopkeeper, Interview-22)

> "...They're not the type to intervene and try to change things here, to make it the way they want. The ones who do, leave. After a while, they can't take it anymore. Either they're excluded from the building, or it's like a self-cleaning process for the neighborhood. Just like the sea

> cleans itself. I mean, after a certain point, you explode. Someone becomes a nuisance, they make noise, they're disruptive. They'll tell you, 'Don't do it,' 'don't do it three times,' 'don't do it four times.' If they're a tenant, they'll go to the landlord and say, 'Hey, either give your tenant a warning, or kick them out.' Or if they're the landlord, they'll deal with it in the building meeting. It starts with the building, and things get sorted out." (Shopkeeper, Interview-23)

Class habitus, within Bourdieu's conceptual framework, refers to the ways individuals think and act, shaped by their social position and living environment (Bourdieu, 2013; Bourdieu, 2015). In interviews, the forms of personal freedom and expressions of difference, which are integral parts of class habitus, were discussed in relation to the liberal atmosphere offered by Kadıköy and Kozyatağı Neighborhood. However, it was noted that this freedom is constrained by the neighborhood's cultural norms, and individuals may face exclusion if their actions conflict with the community's social values, or they may choose to leave the neighborhood voluntarily. This dynamic occurs through the neighborhood's internal social control mechanisms, which compel individuals to adapt to the neighborhood's culture.

Kadıköy is also characterized by ideological tendencies such as "Republican, Atatürkist, social democratic, and left-leaning" orientations, which are supported by local election results and observations of the area. In this context, the relatively harmonious relationship between old and new residents, as well as the lack of discomfort from the older residents regarding the newcomers, can be attributed to the agreement between these two factions under the umbrella of "secularism." Neighborhood residents, in this sense, create an invisible alliance and a shared language, with secularism forming a rational basis for their residential choices. Thus, political identity, which is part of the habitus, is also reproduced through the space itself (Figure 5).

> "For example, now, of course, due to the increasing pressures on certain aspects of life in our country, whether accepted or not, places like Kadıköy and Beşiktaş are preferred by the new generation because they believe they can express themselves more freely there. I think that's the case. In other words, when choosing a neighborhood, if possible, people take that into consideration. ... There is a specific profile of people here. It's a solidified profile. I think it doesn't change easily. ... Let me tell you something really funny. Now, my son went to Oxford for an MBA. He stayed there for about a year and a half. Students from all over the world. Then, a married couple, either Chinese or Japanese—I'm not sure—after returning here to İstanbul, they booked a hotel around Taksim. They were in touch with my son and wanted to meet. He happily agreed. He says, 'I'll show you the Asian Side, Bağdat Avenue.' As they were walking on Bağdat Avenue, they were looking around, and they said, 'There are so many tourists here.' They thought the people walking around were tourists. They asked, 'Aren't these tourists?' because of their more modern clothing and styles. My son said, 'No, they are Turkish.' They were surprised. Where we come from, it's not like that; it's more about wearing a headscarf. Even the women wearing headscarves on Bağdat Avenue offer a completely different visual experience. It's not like Eminönü." (Shopkeeper, Interview 11)
>
> "When my daughter was still in high school, ideologically, I enrolled her in the Atatürkist Thought Association in Kadıköy to expose her to some ideas and enrich her at that age. She was 14 years old. As she started attending the Atatürkist Thought Association, of course, some ideas began to form. ... I don't have friendships with people who have issues with the secular segment. That's my criterion for Atatürkism." (Resident, Interview 8)
>
> "I lean towards the left-wing view. My life experiences, my background... There's also an inclination that comes from my family. ... For the news, I watch Halk TV and follow Sözcü. I don't leave the house in the morning without reading the Sözcü newspaper." (Resident, Interview 2)

**The Influence of Class and Spatial Perception on Residential Location and Mobility**

The preservation of neighborhood culture and neighborly relationships, particularly among the older residents, emerges as a key dynamic that sustains the traditional pattern and authenticity of the neighborhood. The continuation of this tradition is viewed as a significant factor in the new middle class's decision to settle in the area. Moreover, perceptions of safety and tranquility in the neighborhood also serve as important motivations for residential choice. In interviews, the safety of the neighborhood is frequently emphasized, and this is addressed in three distinct ways. First, the neighborhood's class structure is linked to its sense of safety, with the respectful and cultured demeanor of its residents creating a secure environment. New businesses perceive the neighborhood as peaceful, welcoming, and culturally rich, and they are drawn to the area due to the relatively affordable rent compared to nearby Bağdat Street. Second, the ability of commercial establishments to leave goods outside without concerns for security is seen as an indicator of the neighborhood's resilience against external threats. Third, safety is also considered in the context of seismic risk and the neighborhood's geological conditions. The low-risk profile of the area and its preparedness for potential earthquakes are cited as factors that attract residents. Therefore, the perception of safety, tranquility, and authenticity in the neighborhood plays a pivotal role in attracting middle-class fractions that will further reproduce this class space.

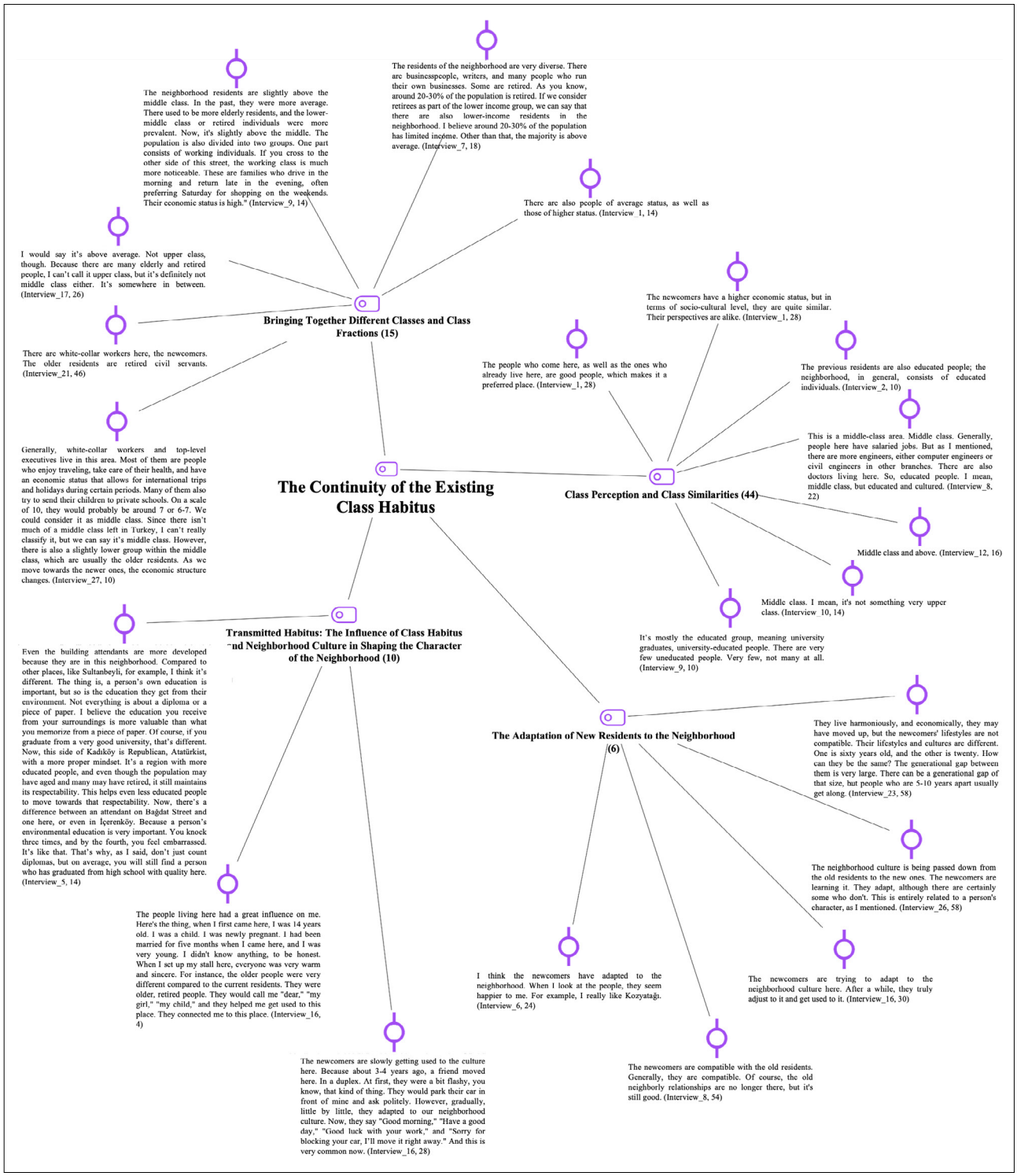


**Figure 5**. Codes and Interviews Referencing the Continuity and Harmony of the Existing Class Habitus (Code-Theory Model).

The class perception of the neighborhood significantly influences residential choice preferences. Kadıköy is often described as a "liberated zone," offering an attractive living space for individuals with similar class characteristics. The class habitus of Kadıköy, along with its social, cultural, and economic capital, lifestyle, and ideological stance, emerges as key determinants in residential selection. Compared to neighboring districts such as Suadiye, Erenköy, and Göztepe, Kadıköy is favored for its more affordable rental prices.

The older residents reflect a traditional middle class composed of educated, cultured retired civil servants and small-scale shopkeepers, while the newer residents are

generally higher-income white-collar workers. While the older residents are more vulnerable to the rising housing prices, the new residents are more adaptable, with rising demand driving up prices accordingly. This trend has accelerated spatial changes, particularly through urban transformation initiatives, and has led to the establishment of businesses catering to new lifestyles (e.g., cafes, organic product stores, supermarkets, restaurants, pet-related businesses, gyms, online grocery warehouses, etc.). The continuity and adaptation of the older residents in the neighborhood are shaped within the context of their economic capital[12] and the opportunities provided by the space. In Kozyatağı, the distribution of old and new businesses reflects the needs of different class fractions: older businesses are concentrated along Kaya Sultan Street, while newer businesses are located on Hilmi Paşa Street and Şakacı Street. The distinct separation of old/new axes, along with the recognized/perceived identities attributed to these locations by the neighborhood, enables residents to access the businesses, products, and social environments that meet their specific demands.

Moreover, the presence of local businesses that meet the daily needs of the older residents facilitates the continuation of local and closed-off ways of life. Commercial relationships within the neighborhood are intertwined with social connections, supported by flexible payment terms and credit systems, which in turn promote harmony and cultural continuity. Thus, the high accessibility and class similarities offered by the neighborhood make it possible for different fractions to coexist harmoniously, without conflict (Figure 6).

A key factor influencing residential choice is the neighborhood's location and accessibility. According to the Kadıköy 2030 Current Status Report (2023), industrial sectors are concentrated along the D-100 highway and Bağdat Avenue corridors. The metro stations within the neighborhood boundaries (M4 and M8) and their connections to public transportation systems direct the concentration of activity towards the D-100 highway, the Minibüs Road, and Bağdat Avenue, thereby channeling social life away from the neighborhood core. This spatial configuration contributes to the preservation of the neighborhood's social pattern by limiting the entry of sectoral activities into the residential area, thus mitigating the influx of external populations. While there are some ventures in the food and beverage sector, these businesses typically serve the local residents and do not attract customers from outside the neighborhood.

The high concentration of elderly residents and lower economic levels within the neighborhood also restrict demand for new businesses. While the accessibility of Kozyatağı, in terms of transport connections, remains a significant factor influencing both residential and commercial location choices, high rental prices and low demand have led to the failure and closure of new businesses. The high investment value and rental returns in the housing market, on the other hand, have accelerated the pace of transformation in the residential sector. As a result, changes in the business environment occur at a slower pace, whereas rapid transformation in the housing market is contributing to emerging housing issues.

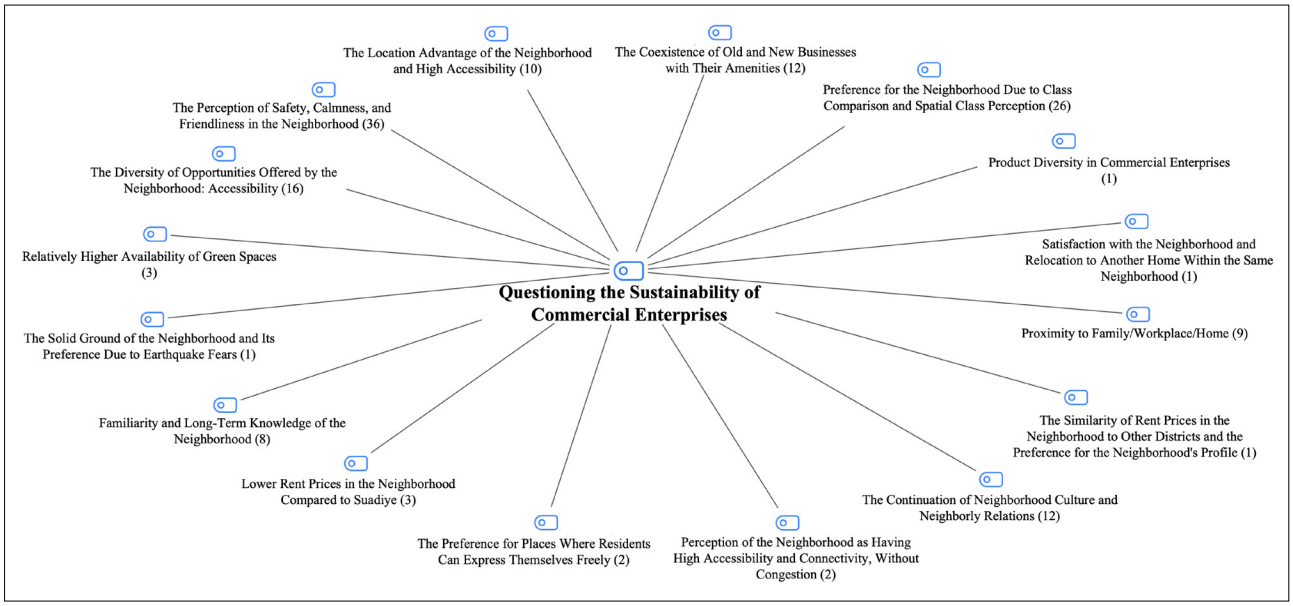


**Figure 6**. Factors Influencing Neighborhood Location and Satisfaction (Code-Theory Model).

**The Relationship Between the Continuity of Commercial Enterprises and Neighborhood Culture**

The actions of social classes are shaped in accordance with their habitus, and this process is reproduced through individuals' lifestyles, tastes, and preferences, which in turn manifest in everyday life practices (Jourdain & Naulin, 2016). In this study, it is observed that the mechanisms of the reproduction of the middle class are directly related to the everyday life practices and spatial uses within the neighborhood. The forms of social and cultural engagement by traditional middle-class residents demonstrate that local businesses play a significant role in maintaining social networks within the neighborhood. Interviews revealed that older residents regularly gather in affordable, long-established local businesses (e.g., bakeries and patisseries) and take advantage of the neighborhood's proximity to the coastline to organize walks and social gatherings along the shore. These gatherings typically take place in public spaces, minimizing financial burden. The end of the pandemic has further reinforced this outdoor meeting culture within the neighborhood. Additionally, retired men have been observed congregating in specific hours at older establishments to maintain their neighborhood ties. Older residents actively participate in the cultural transmission of the neighborhood by patronizing both old and new businesses, while excluding businesses that do not align with the local culture, thus preserving the neighborhood's social order. Not only elderly and retired individuals, but also their children and grandchildren benefit from these traditional establishments. This dynamic exemplifies the relationship between space and habitus. New generations, shaped by the social and cultural codes of the neighborhood from childhood, develop similar patterns of space usage. However, demographic changes, technological developments, and shifts in social relationships position the new generation between old and new lifestyles. In addition to the traditional businesses, meetings are also held in new-generation cafes, further strengthening social bonds within the community.

Interviews revealed that the strong neighborhood relationships among local shopkeepers are sustained not only through the bonds established over the years between the old businesses themselves, but also through the mentorship, support, and cultural transmission provided by these older establishments to the newer ones. Social connections and networks function as a key mechanism ensuring the continuity of businesses within the area. Furthermore, these relationships are also grounded in economic foundations. The use of social media by new businesses to attract customers increases the potential customer base for the neighborhood, thus fostering a sense of alignment and cooperation between businesses operating within the same space.

Interviews with commercial business owners highlighted that the owners of older shops have been particularly sensitive to rent increases in the neighborhood. During the pandemic, many shop owners, who were unable to operate, refrained from collecting rent and instead strengthened social relationships, developing local solutions to the challenges faced within the community.

> "Here's the thing, I think we are at an advantage. It's a bit related to mutual relationships. Our landlord supported us a lot. Even during the pandemic, he didn't take rent from us, even though he's only known us for a short time. With those incredibly inflated prices, thank God, we didn't get caught up in it." (Shopkeeper, Interview-25)

> "Old shop owners are more sensitive." (Shopkeeper, Interview-4)

> "...since the business owners are older, they know that it's not just about the shop rent, so they are a bit more sensitive." (Shopkeeper, Interview-1)

The strategy employed by the older shopkeepers to maintain rent increases at reasonable levels was also noted as a means to ensure regular rent payments and protect their economic income. This approach has helped regulate the relationship between property owners and tenants, securing the continuity of businesses and slowing down the pace of change. Moreover, the fact that many older property owners own multiple properties has enhanced their sense of economic security, enabling them to adopt a more critical approach during crises. This situation is directly related to the capacity of middle-class residents to devise strategies through property ownership.

Furthermore, three key factors contributing to the persistence of older businesses were identified. First, the predominance of families with children among the new residents, coupled with the high number of schools and daycare centers in the area, attracts middle and upper-middle-class families to the neighborhood. This dynamic helps ensure the continuity of traditional small businesses with lower competition, such as stationery store, ice cream parlour, haberdashery. Second, the higher income levels of new residents mean that they are less affected by price increases, allowing businesses like tailors and grocery stores to continue their operations. Third, older businesses are responding to the demands of new residents by diversifying their product offerings and adapting their sales strategies. For example, pharmacies are increasingly offering over-the-counter (OTC) and dermocosmetic products, while grocery stores are expanding their product range to function more like local markets.

In this context, while there are multiple reasons for the continued existence of old commercial enterprises in the neighborhood, it can be observed that their survival fundamentally depends on three conditions. The first

is that existing local networks, social relationships, and neighborhood culture serve as a protective shield for the old commercial enterprises; the old shopkeepers, especially those serving the traditional middle-class residents, are preferred and preserved. The second is that the higher economic capital of the new middle-class residents, compared to the previous ones, enables old shopkeepers to reflect the rising costs of products/services in their offerings. The third is that the old shopkeepers, who are more vulnerable to changing conditions and increasing rent prices, develop strategies such as increasing product diversity and reducing employment (Figure 7).

The ongoing urban transformation processes within the study area, shaped by macro-scale developments such as the economic crisis, the pandemic, and the earthquake, have begun to progress in a manner that dismantles the class-based similarities and mechanisms of harmony and continuity outlined thus far. Interviews indicate that the new middle-class residents moving into the neighborhood, with their higher economic capital, are able to afford market-oriented housing offerings, unlike the traditional middle-class residents. Due to high rents, former residents and shopkeepers are reported to have left the area, resulting in a shift in the class structure of the neighborhood. When this situation is analyzed in conjunction with Bourdieu's understanding of structural constructivism (Bourdieu, 2013; Bourdieu, 2016) and critical realism's internal and external causal forces (Sayer, 2019; Danermark et al., 2018), the internal mechanisms that reveal class habitus shape individuals' actions and produce collective values and practices of cohabitation. In this study, the actions and thoughts of the neighborhood residents, based on their habitus and social position derived from their capital, are made visible on the space, while reproducing the class structure at both the district and neighborhood levels. On the other hand, the external mechanisms discussed in this study as macro-scale developments, although not determining the actions of the agent, condition and limit these actions. In other words, the actions of the agent are shaped not only by internal mechanisms but also by the surrounding social structures (externalities).

## CONCLUSION AND EVALUATION

The uniqueness of Kozyatağı neighborhood is shaped by local dynamics that facilitate the harmonious coexistence of different class fractions, as well as mechanisms that ensure the continuity of the space. However, this uniqueness also manifests as a tangible reflection of the varying lifestyles, consumption habits, and class characteristics within the space. To understand the distinguishing features of Kozyatağı from other neighborhoods in Kadıköy, it is essential to examine three key mechanisms that govern continuity/change and harmony/conflict within the neighborhood: **the macro scale, the district level, and the local scale** (Figure 8).

**Macro Scale:** The first significant factor influencing the transformation of Kozyatağı neighborhood is the impact of broader economic, social, and environmental developments, particularly urban transformation processes, on the local space. Since the early 2000s, accelerated urban regeneration projects in İstanbul have directly affected Kozyatağı, leading to structural transformations within the neighborhood. However, in recent years, the risks associated with the February 6, 2023 earthquake, the

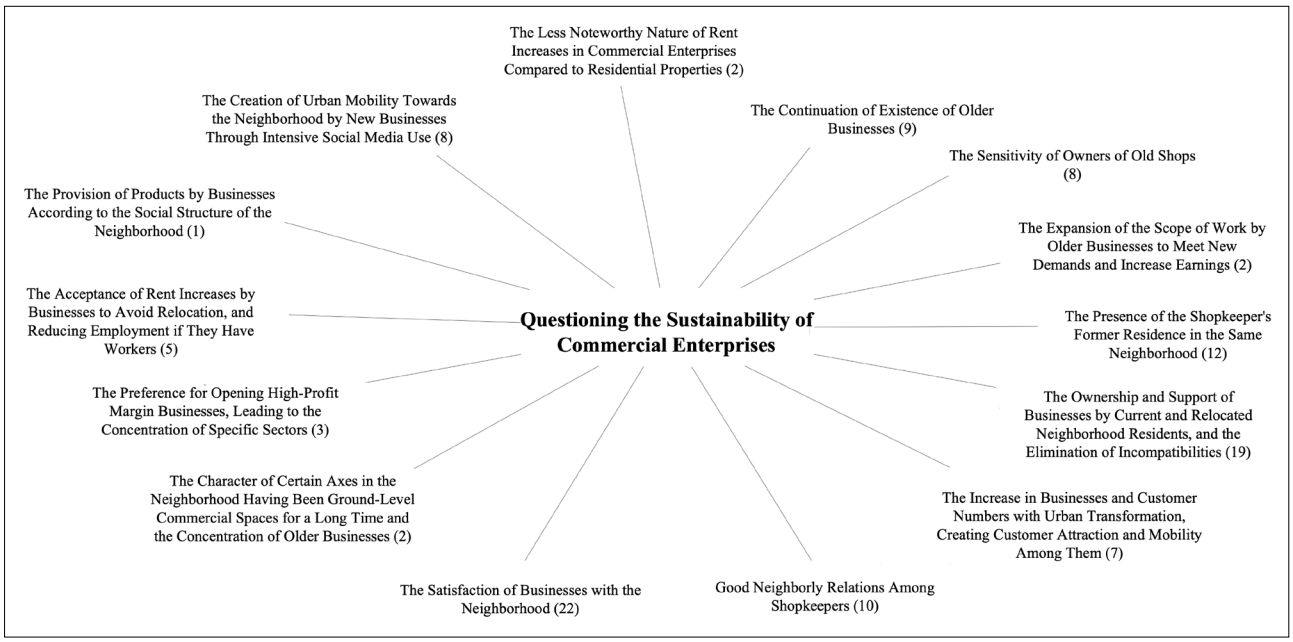


**Figure 7**. Examination of the Continuity of Commercial Enterprises (Coding and Frequencies).


**Figure 8**. A Word Cloud Generated Based on the Frequency of All Words Used in Interviews Revealing Mechanisms of Continuity/Change and Adaptation/Conflict.

ongoing economic crisis, and the pandemic have further reshaped the existing structure of the area. Transformation activities, justified by the earthquake risk, have influenced both the housing market and the social pattern, resulting in significant rent increases and class mobility.

**District Level:** Another significant factor distinguishing Kozyatağı from other neighborhoods in Kadıköy is the shared characteristics across the district, such as similar class profiles, lifestyles, the ability to live with a sense of freedom and security, and the creation of a common language under the umbrella of secularism. As a central district, Kadıköy hosts a diverse range of socio-economic classes, and the residents within the neighborhood are typically individuals who share similar social, cultural, and economic capital. This creates an atmosphere that supports the continuity of social relationships in the neighborhood, fostering a shared class habitus and lifestyle. Additionally, the local culture in Kadıköy has developed a common language and value system that ensures residents feel safe and free within their environment.

**Local Scale:** The unique structural characteristics of Kozyatağı Neighborhood reveal the core dynamics of social cohesion within the area. In this context, the neighborhood functions as a residential area with ground-floor commercial spaces, but it doesn't accommodate elements related to history, culture, or tourism. The neighborhood is characterized by a low seismic risk profile, responding to concerns about residents' safety, making it a low-risk zone. The changes occurring in the area take place gradually on a parcel-by-parcel basis rather than through an overarching transformation. New residents tend to prefer living with individuals who share similar social, cultural, and economic capital, which is similar to that of previous residents. They also perceive the area as more economically viable compared to other districts in Kadıköy. Additionally, the continuity of neighborhood culture and community relationships, which are thought to persist here relative to many other neighborhoods in İstanbul, fosters a sense of "authenticity" within the area. This perception is particularly reinforced by the neighborhood landscape observed in the streets and the presence of green spaces within the neighborhood. Kozyatağı offers a tranquil, calm, and secure atmosphere due to its central location, rich transport connectivity, and proximity to Kadıköy's center and the Suadiye-Bağdat Street, all within walking distance. Moreover, being near multiple transportation modes yet not open to an influx of external population, the neighborhood allows residents to meet their needs and access services without leaving the area. The coexistence of both old and new residents, as well as commercial establishments, enables the area to cater to two distinct class fractions.

In the neighborhood, the first of these three mechanisms defines the conditions for conflict, while the second reveals the dynamics of cohesion. At the local scale, the effects of the first and second mechanisms shape the class habitus and space in accordance with the neighborhood's unique structural characteristics. This triad of mechanisms creates the conditions under which both the class habitus and space are reproduced, establishing the structure that either enables or prevents the coexistence of old and new residents within the same space. In recent years, the slow process of

change observed in the 2000s has accelerated and become more fragile. The urban transformation process, justified by the risk of earthquakes, now presents an approach that questions the right to housing on behalf of the traditional middle class. The location-specific dynamics that facilitate the mutual reproduction of class and space are increasingly eroded, particularly under the influence of economic developments and market dominance.

## NOTES

[1]For detailed studies on the middle class in the relevant fields, see: Kurtuluş, 2003; Kurtuluş, 2005; Pérouse and Danış, 2005; Kurtuluş et al., 2012; Duman, 2015; Akçaoğlu, 2018; Özet, 2019.

[2]"The Transformational Model of Social Activity (TMSA)", see: (Bhaskar, 1998; Bhaskar, 2011).

[3]For studies that establish a relationship between Bourdieu's approach and space, see: (Arlı and Göker, 2014; Savage, 2014; Wacquant, 2018; Savage, 2020).

[4]In the thesis from which this study is derived, the extensive research design is also addressed. However, within the framework of this article, the findings obtained through extensive research are not presented. Instead, the focus has been directed toward the intensive research design, which is employed to explore the underlying mechanisms through the class structure identified in the extensive research. This methodological approach has been highlighted as a key focus, and its alignment with the theoretical framework has been noted accordingly.

[5]Based on field observations and the analysis of physical structures, the sample selection for interviews with commercial establishments was carried out. In this context, both old and new buildings, as well as the axes where commercial establishments are concentrated, were identified. New functions that have quantitatively increased in the area, in response to the different demands and needs of the traditional and new middle classes, were also detected, and transformations within the commercial establishments were examined. Accordingly, interviews were conducted with traditional and new businesses operating along the identified axes.

[6]The explanations regarding the use of the MAXQDA program encompass three different contexts. The first is that training on this program has been completed. In this context, a 10-session training set titled MAXQDA 2024 Summer School, available through the YouTube channel of Buracademy, a company founded by Burak Varol, a certified MAXQDA trainer, has been completed. The second context is that experience has been gained in analyzing data using the program during and after the training process. Therefore, the explanations are also based on the researcher's own applications of the program. The third context is that coding and categorizing into themes is not a new method for data analysis. Grounded theory in the analysis of qualitative data develops an abstract theory through the coding of data, linking them to each other, and categorizing them into basic categories (open coding, axial coding, selective coding). Therefore, grounded theory analysis, while not directly related to this program, is closely connected to the operational principles of the program. In this regard, the research methodology sources related to this abstraction process have also been guiding in the explanations. For further reference, see: Creswell, 2013; Neuman, 2014; Punch, 2016.

[7]For a detailed study of "reflexive thematic analysis", see: (Braun and Clarke, 2022).

[8]The fact that the author conducting the fieldwork is also a 32-year resident of the neighborhood has enhanced their observational capacity regarding the area. Throughout the fieldwork, the researcher has strived to strike a balance between being both an observer and a participant.

[9]For detailed reading on Bourdieu's approach to reflexivity and the position of the researcher, see: (Wacquant, 2007; Calhoun, 2007).

[10]The thesis from which this study is derived was written in Turkish, and therefore, the interviews, observation notes, and analyses related to the field study were conducted in this language. In this study, visual analyses of the program's outputs and contributions are presented for clarity, but the language of the article differs from the language used in the analyses. This discrepancy is considered one of the limitations of the study.

[11]These conclusions have been derived from the analysis of physical structures and data obtained through interviews, in conjunction with the analyses presented in the Kadıköy Current Status Report.

[12]This study does not address the processes of change and conflict; instead, it focuses on the mechanisms of continuity and harmony. As a result, the importance and outcomes of economic capital in the ongoing process of social and spatial change within the field are not discussed.

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**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.

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**Article**

# Integrated risk-oriented design method in architecture

**Semih Serkan USTAOĞLU[1,*], Sevgül LİMONCU[2]**

[1]*Department of Architecture, FSMVU Faculty of Arts, Design and Architecture, Istanbul, Türkiye*
[2]*Department of Architecture, YTÜ Faculty of Architecture, Istanbul, Türkiye*

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## ABSTRACT

Safe building design is a significant architectural design criterion in ensuring the health and safety of users. In Türkiye, recent buildings produced through constraints concentrated on resilience against disasters such as earthquakes, fires, floods, as well as those built with experiential traditional design approaches have proven inadequate for ensuring user safety and health. To prevent potential accidents involving users, a comprehensive approach is needed that, in addition to disaster-oriented design criteria, factors related to the building and its immediate surroundings, users, functions, and risks are considered. Consequently, an "Integrated Risk-Oriented Building Design" method is developed based on the traditional design approach in which risk factors and safety criteria are determined, necessary action steps sequences are organized precisely, user safety is ensured, and it is supported by decision-making and calculation methods whereby validating its applicability scientifically. Study stages include; literature review, developing a new method proposal by integrating existing decision-making and calculation systems with the traditional design method, and a case study testing the developed method. The proposed method aims to minimize built environment's risks within the structure and its surroundings per the identified criteria. It is believed that when the Integrated Risk-Oriented Building Design method is properly implemented by designers and experts, potential risks that users might encounter will be eliminated or mitigated, leading to the production of safe and healthy designs. Moreover, the proposed method is expected to serve as a guide for future studies that can be further developed through scientific research and respond accurately to evolving needs.

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## INTRODUCTION

The need for shelter arose from the necessity for humans to protect themselves from various challenging environmental conditions, maintain their lives in a safe and healthy environment that can withstand the adversities of nature, and their inability to feel safe in open spaces since the beginning of their existence. Buildings and shelters provide people with a safe environment, enabling them to live under suitable conditions. In this sense, buildings and their immediate surroundings are crucial for individuals to feel safe. However, over time, buildings have increasingly deviated from providing a safe environment due to factors

***Corresponding author**
*E-mail adres: sustaoglu@fsm.edu.tr

such as irregular urbanization, profit-driven concerns, rapid production, improperly used materials, faulty constructions, disasters, and departure from user- and environment-oriented design processes. Consequently, users are confronted with threats and dangers arising from these issues within the building and its immediate surroundings, which negatively impact their lives.

Many different approaches other than the traditional design approach have been developed in architectural design. However, the traditional design approach is widely used in the world. Through the traditional design approach, it is assumed that requirements will be met and hazards will be avoided when standards are applied by following appropriate sequences based on experience. However, the risk-oriented design method assumes that safety vulnerabilities will increase in traditional approach practices if the method is not adhered to, standards are violated, or there is a lack of experience (McDowell & Lemer, 1991). The traditional design approach, while inherently facilitating a faster and easier production process, is a system that increases the likelihood of safety risks. As it does not rely on quantitative data, it negatively impacts the awareness of both users and designers. The phases of the traditional design approach are presented in Figure 1.

Safety issues are of critical importance in architectural design, and defects not only represent damage to the design itself but also negatively impact the user's ability to live healthily within the building during when it is occupied (Isa et al., 2011). Buildings designed without consideration for user safety, incidents with dire results such as bodily injuries, internal organ damages, internal bleeding, fractures and dislocations in the skeletal system, burns, scalding, poisoning, and even death may be encountered (Güler & Çobanoğlu, 1994). In this context, it is necessary to identify built environment problems in and around the building through research and to investigate their root causes.

The primary cause of the issues mentioned within and around the building is the safety vulnerabilities created by the traditional design approach. As a result of these vulnerabilities, users are exposed to significant factors and accidents. When examining the role of accidents among causes of death, they rank third in Türkiye and fifth in Switzerland, Bulgaria, and the United States (Ural & Gün, 2008). In the United Kingdom, there are 2.7 million indoor

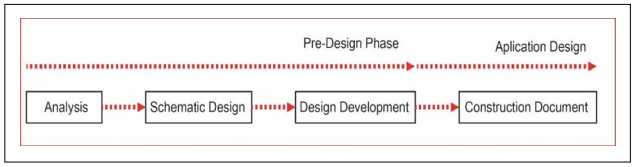


**Figure 1**. Traditional architectural design method phases (Dasgupta et al., 2019).

accidents annually, resulting in 5,000 deaths (The Royal Society for the Prevention of Accidents, 2019). Accidents caused by the built environment hold a significant place among overall accidents and should be considered a major threat to user health. Therefore, it is essential to analyze and elaborate on accidents occurring within the built environment. Studies conducted on built environment-related accidents at both international and national levels generally focus on indoor accidents experienced by users in residential settings. In a study conducted by Ural & Gün (2008) in Türkiye, it was found that residential accidents account for 28.3% of all accidents, and moreover it was observed that:

34.3% of residential accidents involve falls, of which 56.5% are falls from height and 43.5% are falls on flat surfaces.

Accidents involving burns in residences constitute 9.2% of the total, with 44.8% of these burns being attributed to building and building products (Ural & Gün, 2008).

In these studies, statistics related to disadvantaged user groups should also be defined when identifying user safety issues. In a study conducted by Bulgak et al. (2019), it was found that, as a disadvantaged group, 67.9% of elderly individuals encountered accidents within the built environment over the course of a year. In another study conducted with children, who represent another disadvantaged group, it was reported that 57.3% of children experienced domestic accidents (Gündüz & Aytekin, 2015). Studies on accidents experienced by users within buildings and their immediate surroundings have generally been conducted in the field of healthcare. However, efforts to solve these problems should not be limited to the healthcare domain; research should also be expanded and developed in the fields of user- architectural solutions. A literature review conducted on the Scopus database revealed the following findings:

- Out of 831 publications using the keyword "user safety," only 67 addressed architectural design and user safety.
- Out of 184 publications using the keyword "safe building," 108 focused on architectural design and user safety.

This analysis indicated that the publications predominantly dealt with topics such as fire safety, earthquake safety, disaster safety, and construction-work accidents. However, in addition to the risks mentioned, users frequently encounter everyday accidents within the built environment. The data analysis did not reveal any adequate or appropriate method proposals for preventing or reducing accidents through design management in this field. The primary cause of user accidents within the built environment is the mismatch between context, user, and design. To ensure that users are not exposed to the identified injuries, the buildings in which they spend a

significant portion of their lives must meet the necessary standards. For these conditions and requirements to be fulfilled, buildings must be designed safely. To achieve safe design, potential risks that users may encounter during the occupancy period should be identified and addressed before and during the design process. The traditional design approach, based on knowledge and experience, and considering economic and social benefits, is insufficient for achieving this. In response to this need, initial efforts to reduce potential risks during the design process began in the fields of engineering and production. These initial phases were taken under the framework of "Prevention through Design." The emergence of the "Prevention through Design" system dates back to 1980, when the National Occupational Health and Safety Commission (NOHSC) initiated courses for engineering students that highlighted the role of design in enhancing safety (Creaser, 2008). The integration of hazard analyses and risk assessments forms the core of the safety-through-design concept (Manuele, 2008). The method, initially developed in the field of engineering design, has subsequently been applied in the field of architecture as well. Fundamentally, the method focuses on the distribution of responsibilities and the management of this distribution. In the architectural field, this system operates through the following phases respectively: completion of the design process, establishing the relationship between safety risks and preliminary controls in the design, integrating information through analyses, and implementing these elements during the design process (Yuan et al., 2019).

The "Building Safety Index," developed from the Prevention through Design method, was created as part of a research project initiated by the Tokyo School of Architecture (Ho & Yau, 2004). The method primarily utilizes a system of establishing a fundamental framework through expert opinion to identify safety risks. In prioritizing identified safety issues, the Analytical Hierarchy Process (AHP), developed by Saaty, is employed (Ho & Yau, 2004). The method is integrated with the "Building Health Index" within the project to contribute to guiding both the design and usage processes, ensuring that users can live safely and healthily in the building. However, the system tends to overlook multiple risk probabilities due to the hierarchical nature of the framework.

In contrast to the traditional design approach, in design management conducted with risk analysis in architecture, safety vulnerabilities can be accurately predicted (McDowell & Lemer, 1991). Risk analysis in the lifespan of a building should commence during the planning phase, and risk management should remain active throughout this period, with regular inspections contributing to the risk analysis. In the design of safe buildings produced through risk analysis, effective communication with stakeholders and project participants is crucial. Additionally, this method is a systematic process of planning, identification, analysis, evaluation, and resolution, supported by the appropriate monitoring, review, and documentation of the identified risks (HK OCSH - Development Bureau, 2019; McDowell & Lemer, 1991). In the safe building design process supported by risk analysis, designers can assess the risks users may encounter throughout the building's lifespan and can prevent or mitigate issues that may arise during usage activities through design, detailing, and planning. In the literature, there are many studies developed with an inductive approach based on sub-risks such as fire, earthquake, etc. in a piecemeal manner. However, while these studies produce fragmented solutions, they are incomplete in terms of the interaction of risks. A holistic approach that addresses user safety risks is needed.

Despite the presence of significant insights and approaches in the reviewed scientific literature, it has been observed that, within the Prevention through Design method, safety risk analyses are conducted post-design, whereby in the Building Safety Index approach, safety issues in design are defined through a generalized framework. Moreover, the sub-phases utilized in this method prove inadequate in addressing multiple and interrelated risk probabilities. However, in a design process that prioritizes user safety, there is a need for a comprehensive methodology that:

- Identifies factors that adversely affect user safety,
- Analyzes, evaluates, and prioritizes issues impacting user safety in and around the building during the pre-design stages,
- Resolves these issues through a defined safety framework.

Such a methodology must focus on these elements as specified, establish the necessary action phases in a correct sequence, guide the process with appropriate strategies, and facilitate informed decision-making. In this study, the "Integrated Risk-Oriented Design Method in Architecture" has been proposed as a structured approach to address these requirements. This study aims to develop an 'Integrated Risk-Oriented Design Method in Architecture' proposal.

In the developed method, risks are determined as a result of analyses and evaluations of the building and its built environment, occupant, function and obligation. This method is based on the deductive approach to identify all risks, which is designed to minimize risks in buildings. It is assumed that this method, which is intended to address risks in a holistic manner, will provide the grading of risks affecting user safety and guide the study of sub-risks.

## MATERIAL AND METHODS

This method, which is deemed crucial for ensuring user safety in the built environment, has been developed using an inductive approach in the context of qualitative research. After an extensive literature review, factors negatively impacting users, potential risks they may encounter, and the adverse conditions these risks could create in the built environment were identified and classified. However, as the study aims to reduce user safety risks during the design phase, the risks addressed are limited to risks and risk derivatives specific to the design and pre- design stages. During the same process, potential approaches and phases that could be employed in the method's stages were identified, and the solution strategies for safe building design propositioned within the frameworks of Prevention through Design (PtD) and the Building Safety Index (BSI) were analyzed. Eventually, the method was formulated by grounding on these approaches. To assess the applicability of the formulated method, traditional design processes and architectural design circumstances were scrutinized. Data obtained from the literature review were integrated with the data of the conventional design practice and risk management insights. In the study, within the scope of risk management, a risk prioritization system was proposed which intends to resolve issues that risks may cause during the design phase, so that they are addressed before the users encounter them, and the Analytic Network Process (ANP), a comparative decision-making method developed by Saaty, was employed for this system. The core structure of ANP consists of a dynamic network configuration composed of clusters and interconnected nodes. Many decision problems cannot be structured in a purely hierarchical manner, as the interactions and dependencies between higher-level and lower-level elements must also be considered. The significance of criteria not only determines the priority of alternatives within the hierarchy but also influences the importance of criteria themselves. Feedback mechanisms facilitate the development of a roadmap to achieve the desired objectives, enabling the present to shape future outcomes (Saaty, 2006). The Analytic Network Process (ANP) analysis method, which is part of this approach, significantly contributes to the functionality of the system by addressing the interrelationships among criteria in the decision-making process and eliminating the need for a single-directional modeling approach in problem definition. Moreover, in this method resolved using the ANP system, the identification of multiple interrelated risk probabilities prevents the oversight of sub-group risks (Figure 2). Utilizing ANP during the decision-making process relieves modeling the problem as a network system, and during the modeling phase not only the relationships between the main criteria but also the internal impacts within them are taken into account (Ömürbek et al., 2013). Due to these features, ANP significantly contributes to determining the impact levels of risks in the prioritization of user safety issues that trigger one another within the built environment. In the study, the Super Decision software, specifically designed for such analyses, was utilized. The study primarily adopts an approach that integrates various existing techniques and further develops them into a practical and applicable form.

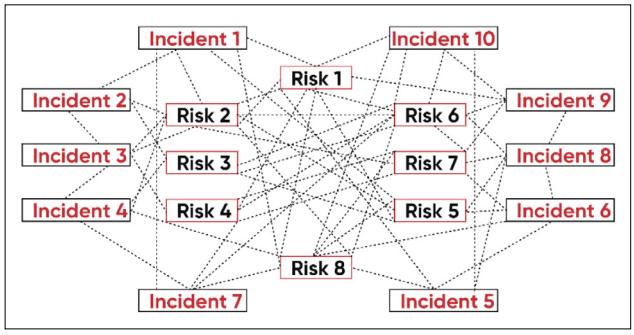


**Figure 2**. Risk and incident relation ANP flowchart (Saaty, 2006).

This study:

- Employs a qualitative research methodology in the stages of literature review and system development, and is non-manipulative,
- utilizes documentary and empirical methods as data collection techniques in the process of integrating documents, reports, and incidents;
- and, is an applied, Type 2 (method development) systematic research, as it aims to find a solution to an existing problem through design and development.

The flowchart of the research methodology is presented in Figure 3.

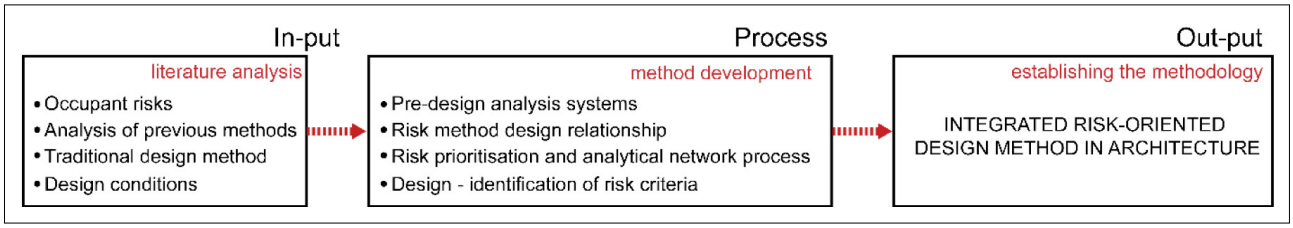


**Figure 3**. Research methodology flowchart.

## INTEGRATED RISK-ORIENTED DESIGN METHOD IN ARCHITECTURE

In safe building design, risk management system is proposed to be integrated with the overall design process, and accordingly potential risks that could negatively impact user safety, along with the issues they may cause are intended to be identified and addressed during the early stages of the design process through an integrated risk management system. For the design outcome to be safe, the risk management process must be actively maintained throughout the entire design period. (HK OSHC - Development Bureau, 2019). In this sense, defined risks that users may encounter should be analyzed and evaluated by designers. The analysis and evaluation process, which forms the foundation of decision-making, must be effectively utilized to identify risks specific to design conditions. The risk-analyzed design method should fundamentally incorporate a robust analysis and evaluation process, and the results obtained from these analyses should be used to prioritize risks and establish risk parameters. During the design process, risk parameters should be integrated with standard design parameters to achieve a safe design. In the final design phase, the developed design should be brought to an executable level without altering the established risk priorities. The risk management process should remain active from the risk identification phase to the completion of the design, and during risk control, the entire process and the final design product should be assessed for user safety. In this method developed, tools such as Risk Management, the Analytic Network Process (Saaty, 2008) and the injury classes and their safety relationship created by Ozanne-Smith et al. (2008) are utilized, and by quantifying the safety criteria in the design process that is generally carried out with qualitative values, facilitating the development of accurate solution options was intended. The flowchart of the risk-oriented safe building design method is presented in Figure 4.

The core and most crucial phase of the proposed method is the analysis and evaluation process. The entire system and approach are built upon these analysis and evaluation phases. In the analysis process, the building's immediate surroundings, users, functions, and requirements should be examined. The conditions specified in Figure 5 are evaluated in these phases. The analysis phase includes the following sub-criteria:

**Built Environment Analysis:** Urban risk analyses and maps, city and neighborhood context analyses, access and accessibility maps, emergency routes, safety and physical condition assessments, and sociological and psychological analyses of surrounding users.

**Occupant Analysis:** Sociological analysis of building users (relationships with others), physiological analysis (age, gender, anthropometric characteristics, health status, mobility, substance and alcohol use, etc.), and psychological analysis (mental state, psychological disorders, etc.).

**Function Analysis:** Evaluation of the primary and secondary functions of the building, user capacity, and the presence of hazardous functions (such as nuclear, fire, explosion risks).

**Obligation Analysis:** Review of design standards, regulations, and codes applicable to the specific site, region, and country.

The data obtained from the analysis phase are transferred to the evaluation phase. In the evaluation phase, preliminary studies related to risks are developed, and the information is incorporated into the risk management process.

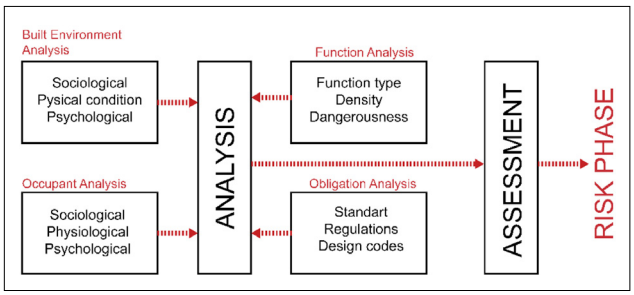


**Figure 5**. Analysis subsystems and evaluation.

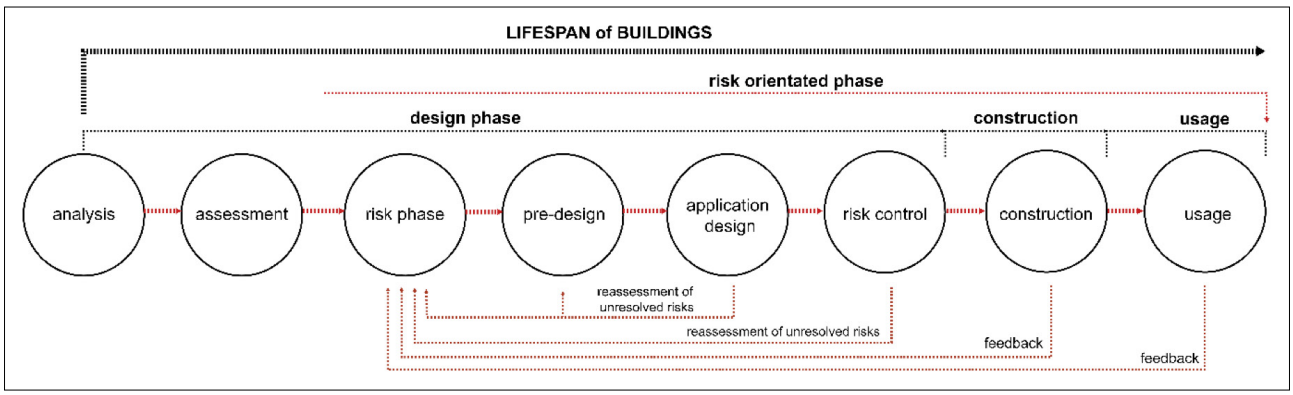


**Figure 4**. Risk – oriented design method in architecture flowchart.

Risk is measured in terms of the outcome or impact of the incident it may cause and the probability of its occurrence. Qualitatively, risk is evaluated in proportion to the expected losses if it causes an incident to occur and the likelihood of that incident occurring. Quantitatively, it is calculated by multiplying the probability of the incident by its potential outcomes (Misra, 2008). The risk analysis and evaluation process, which is part of the safe building design stages, is considered the most critical phase in ensuring safe building design (Ustaoğlu, 2020). In the process of managing safety, risk levels are rarely measured with absolute precision, and the levels of acceptability or thresholds that may pose safety concerns can only be determined through user consultations, expert consensus, scientific research, and public opinion surveys (McDowell & Lemer, 1991). This can be achieved by thoroughly identifying and analyzing potential risks in the pre-design phase and implementing measures to eliminate or mitigate them to low levels. The purpose of integrating the risk management process with the design process is to prevent the emergence of new risks and to minimize potential negative outcomes by avoiding existing risks.

To accurately assess risks with appropriate solutions, defined risks must be properly analyzed. For risks to be effectively analyzed, the risk factors must be correctly identified and integrated into a systematic framework. The risk process, which forms the foundation of the safe building design method, includes the identification of risks, analysis and evaluation of these risks, prioritization, and development of necessary solutions within the scope of risk management. For this analysis to be conducted accurately, it is essential to identify the factors influencing risk formation, the type and level of risk impact, and the design-specific risk acceptability level. This process involves recording potential future injuries identified in previous phases, defining risks that may pose safety issues, and conducting analysis and evaluation of these identified risks. In this phase, factors affecting risk identified in the previous process should be further developed and incorporated into the calculations. After determining the risk type and impact level, the potential outcomes and injury classes derived from these factors should be established and incorporated into the risk analysis phase.

The risk analysis phase involves identifying the injury class or classes of the risk, determining its probability, assigning a coefficient, assessing the impact level, and establishing a priority ranking. The risk analysis phase in safe building design should include the following principles (McDowell & Lemer, 1991):

It should employ a set of tools, methods, and procedures to characterize the threats posed by specific injuries.

In the absence of statistical data, expert, designer, and user opinions should be consulted to understand the likelihood of specific events occurring.

Criteria aimed at identifying the potential, injuries, and priorities of events that could lead to significant losses should generally be based on probability theory and statistical analysis principles.

Concepts such as health, safety, and property value should be taken into thoughtful consideration.

In buildings, users may encounter not only isolated injuries but also multiple or interconnected injuries that can be triggered during an incident. Additionally, when analyzed through specific examples, the same hazard may produce different impact probabilities for different user groups, such as severe harm (H2) for one group and serious harm (H3) for another. Therefore, each unique design should have its own specific risk management and risk analysis process. In this stage, where risk calculations are conducted, quantitative data are derived based on multiplying the probability of a hazardous incident by its potential outcomes. Hence, the possible damages and frequency of occurrence of incidents that may occur within the built environment must be identified. For this purpose, the table created by Ozanne-Smith et al. (2008) was utilized. The potential harm/impact classifications of injuries on users are outlined in Table 1.

The designer must evaluate the potential consequences and probabilities of harm classes that may impact users, in a design-specific manner, by considering the data derived from the analysis and evaluation phase along with the

**Table 1.** Harm classes and potential impacts (Ozanne-Smith et al., 2008)

| | Class 1 – Major (H1) | Class 2 – Severe (H2) | Class 3 – Serious (H3) | Class 4 – Moderate (H4) |
|---|---|---|---|---|
| Potential Harm/Impact | Death | Stroke | Loss of a finger | Occasional severe discomfort. |
| | Permanent paralyses below the neck | Loss of hand or foot | Fractured skull | Chronic skin irritation |
| | Permanent loss of consciousness | Serious fractures | Severe concussion | Broken finger |
| | 80% or more burn injuries | Serious burns | Serious puncture wound | Slight concussion |
| | | Loss of consciousness for several days | Severe burns to hands | Moderate cuts to the face or body |
| | | | | Severe bruising to body. |

potential risks of the building's surrounding environment and function which are identified during the risk analysis process. However, due to the lack of recorded and published scientific data and statistics on accidents and their outcomes in artificial environments encountered by users, it is not feasible for experts to determine the level of these harm classes without employing a decision-making method. Therefore, utilizing the Analytical Network Process (ANP) and the Super Decision software in resolving this network structure that arises during the decision-making process concerning the determination of harm classes will significantly contribute to simplifying the studies. After defining the harm classes that the identified risks may cause, a network system should be established between the risks and damage classes and among the interrelated risks using the Analytical Network Process (ANP) developed by Saaty. This network system allows experts to make value comparisons on the formation of risks and their impact on other risks during the decision-making process. The scale developed by Saaty is derived from fundamental principles that include obtaining a functional equation as a necessary condition by generalizing continuous comparisons and then solving this equation in real and complex domains (Saaty, 2008). In this comparison scale, the formation probabilities of harm classes relative to each other are determined by assigning values based on the significance of the relationships between the criteria being evaluated. Saaty defined the degrees of importance as follows: 1 - equal or same importance, where both activities contribute equally to the goal; 3 – moderately more important; 5 – obviously more important; 7 – strongly more important; and 9 – extremely more important (Saaty, 2008). As an important phase in the analysis of risks, the establishment of the analytic network process for determining the probabilities of harm classes is defined through a sample study in the Super Decision software, using a comparative analysis of risks and harm classes as illustrated in Figure 6.

In the calculation of risks' harm and weighting classes, one of the harm and weighting classes defined as 10, 100, 1000, or 10000 is determined based on the levels obtained from the limit matrices, resulting from the comparative analysis of risks, the impact of risks on other risks, and harm classes using expert opinions in the Super Decision software.

After determining the harm and weighting classes of the risks, it is necessary to establish their impact levels. In the process of determining the risk impact levels, the number of individuals affected by the harm and the frequency of harm occurrence are also significant inputs. The higher the number of individuals expected to be affected and the frequency of occurrence, the higher the risk coefficient, leading to an increase in the risk impact level. The calculation of the risk coefficient is performed using the coefficients given in Table 2 and the Risk Hazard Coefficient Matrix specified in Table 3.

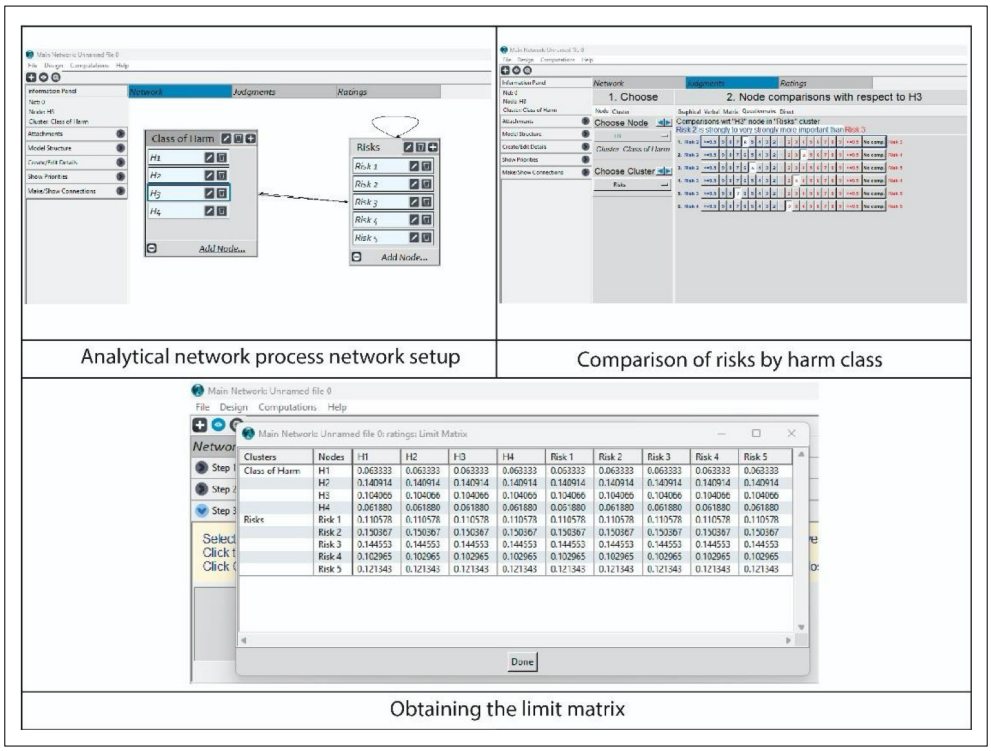


**Figure 6**. Obtaining comparative limit matrices of risks according to harm classes (adopted from Super Decision software).

**Table 2.** Table of coefficients for the number of individuals and the frequency of occurrence to be used in the risk coefficient calculation

| | Number of Individuals | Number of Individual Coefficient | | Incident Occurrence Frequency | Incident Occurrence Frequency Coefficient |
|---|---|---|---|---|---|
| Number of Individuals Impacted | 5000 and over | 6 | Incident Occurrence Frequency | Once per month or more | 6 |
| | 1000 - 4999 | 5 | | 0 – 1 years | 5 |
| | 500 - 999 | 4 | | 1 – 4 years | 4 |
| | 100 - 499 | 3 | | 5 – 9 years | 3 |
| | 50 - 99 | 2 | | 10-19 years | 2 |
| | 0 - 49 | 1 | | 20 years and more | 1 |

**Table 3.** Risk impact coefficient matrix (Slomka, 2005)

| | Incident Occurrence Frequency | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Level** | **1** | **2** | **3** | **4** | **5** | **6** |
| Number of Individuals Impacted | 1 | 1 | 2 | 3 | 4 | 5 | 6 |
| | 2 | 2 | 4 | 6 | 8 | 10 | 12 |
| | 3 | 3 | 6 | 9 | 12 | 15 | 18 |
| | 4 | 4 | 8 | 12 | 16 | 20 | 24 |
| | 5 | 5 | 10 | 15 | 20 | 25 | 30 |
| | 6 | 6 | 12 | 18 | 24 | 30 | 36 |

In the study conducted by Ozanne-Smith et al. (2008) to determine the risk impact level, the risk impact level is obtained by summing the results formed by multiplying the weighting class, risk hazard coefficients, and the probabilities of harm class occurrences. This calculation system is explained in Table 4.

By applying the calculation system developed by Ozanne-Smith et al. (2008) to all risk derivatives, the risk analysis results presented in Table 5 are obtained. Sorting these results from highest to lowest enables the identification of risks that need to be addressed, are acceptable, unacceptable, or need to be monitored.

Integrated risk analysis involves estimating the timeframes in which potential scenarios may occur after clearly identifying possible event chains that could lead to fatalities, injuries, and other losses, following the determination of risks, their dimensions, impact levels, and priorities (McDowell & Lemer, 1991). In the risk analysis phase, after determining the priority ranking of risks, the solutions to be developed in response to the dimensions of the risks and the processes that need to be improved must be identified and evaluated during the risk assessment process. In the risk assessment phase, a method of evaluation should be developed where there is a flow from high-impact risks to low-impact risks. Upon completion of the evaluation, the process moves to the creation of risk parameters. By establishing risk parameters, the general constraints of the design are defined, and the design process begins. The flowchart for analysis, evaluation, and risk process in safe building design is shown in Figure 7.

In the preliminary research phase of the design methodology in safe building design, analyses and evaluations are conducted to collect data for the risk process. The design process in safe building design is a convergence of the standard design management process and the risk process, where safety concerns and design criteria are integrated. In this process, data such as user characteristics, ergonomics, spatial and environmental features should be considered in conjunction with safety criteria. Based on the data obtained from the analysis and evaluation phases, the factors affecting the risk, the levels of exposure to the risk, and harm classes are identified, and risks are prioritized to develop necessary solution strategies. A roadmap is created to define the scope of the design and design decisions. Following these

**Table 4.** Risk impact score calculation table (Ozanne-Smith et al., 2008)

| **Risk Impact Score Calculation** | | | | | | |
|---|---|---|---|---|---|---|
| **Harm and Weighting Class** | | **1/ Risk Impact Coefficient** | | **Harm Class Likelihood** | | **Product** |
| 10000 | ÷ | 1/ Coefficient | x | % Class1 | = | P1 |
| 1000 | ÷ | 1/ Coefficient | x | % Class2 | = | P2 |
| 100 | ÷ | 1/ Coefficient | x | % Class3 | = | P3 |
| 10 | ÷ | 1/ Coefficient | x | % Class4 | = | P4 |

Hazard Score: P1+ P2+ P3+ P4.

**Table 5.** Integrated risk analysis

| Risks | Risk Origins | Possible Consequences | Harm Classes | Risk Impact Scores |
|---|---|---|---|---|
| R1 | RO1 | O1 | H1 – H2 – H3 – H4 | PA |
| R2 | RO2 | O2 | H1 – H2 – H3 | PB |
| R3 | RO3 | O3 | H2 – H3 – H4 | PC |
| R4 | RO4 | O4 | H3 – H4 | PD |
| R5 | RO5 | O5 | H4 | PE |

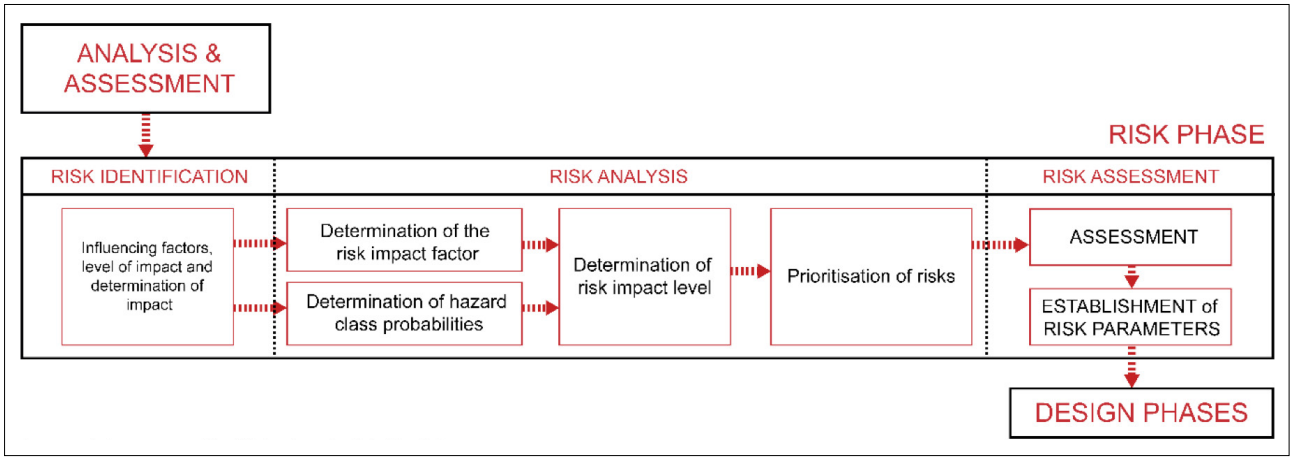


**Figure 7**. Analysis, assessment, risk and design phases in safe building design.

phases, it is important to share the process with the user, conduct post-design risk assessments, and address any identified issues in collaboration with the user. If no safety issues are found during the process, the design phase can be considered as completed (Figure 8).

The construction process of the building whose design is completed should also incorporate similar concerns. After the design phase of the risk-oriented building is finalized, its production should be carried out in accordance with the design specifications. Risk monitoring should remain active during the production phase as well. Design experts must continue their supervision to ensure that the production process is conducted under appropriate conditions. The method aims to provide the highest possible level of solutions to safety issues that users may encounter in and around the building throughout the occupancy period. Additionally, feedback should be collected from every design created with the contribution of the method during the occupancy phase, influencing the development of future designs. To facilitate this feedback, "Post-Occupancy Evaluation" and "Evidence-Based Design" methods should be utilized during the occupancy phase. During use, the safety evaluation of the designed building is conducted using the Post-Occupancy Evaluation method (Fay et al., 2016).

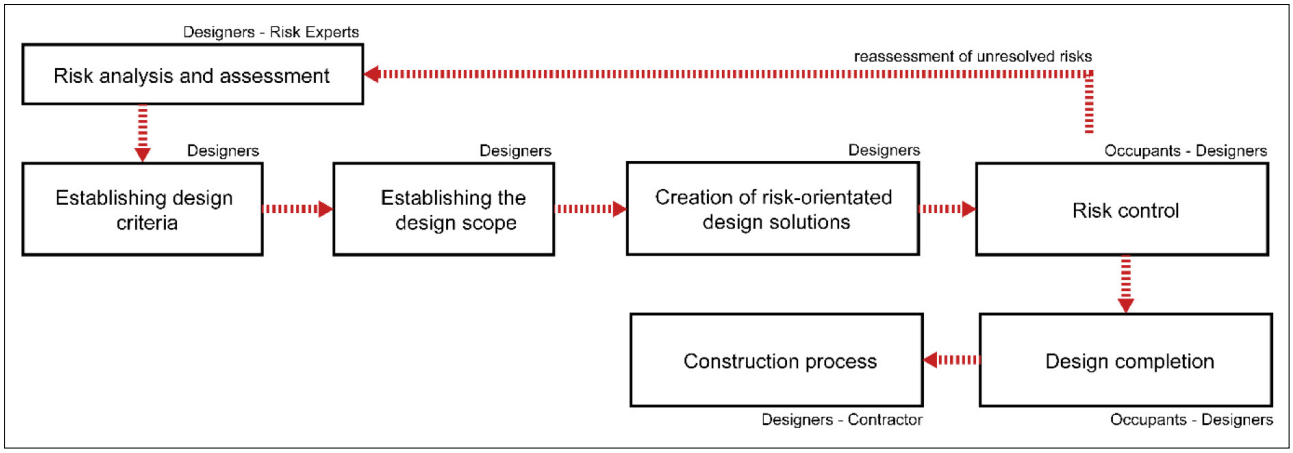


**Figure 8**. Design process in safe building design.

Evidence-based design incorporates a system that involves the user in the decision-making process, relying on the most accurate information obtained from reliable research and project evaluations. The method includes post-occupancy evaluation, and the information obtained from this process is used to enhance the design process. Evidence-based design is defined as a process that, by leveraging the most accurate experiences obtained throughout the process, reaches rational and practical solutions in collaboration with the user (Hamilton, 2003). The Safe Building Design Method is supported and developed through evaluations conducted using the Evidence-Based Design method (Fay et al., 2016) In risk- oriented building design, identified risks and risk solutions should be stored in a risk pool. The implemented solutions should be reviewed during the building occupancy phase using the Post-Occupancy Evaluation method and then transferred to the evidence-based design system. The data obtained from the evidence-based design system should be fed back into the risk pool to support future designs with system feedback. The flowchart of the integrated Risk-Oriented Building Design, Post-Occupancy Evaluation, Evidence-Based Design, and Risk Relation System is shown in Figure 9.

**Risk Prioritization with Integrated Risk-Based Design Method in a Primary School Case Study**

The region, area, or function of the case study of the research was not selected according to specific criteria. Within the scope of the study, the risk prioritization section of the proposed risk-oriented integrated method was examined. This examination was limited to 21 sample risks obtained from the analysis and evaluation phases related to the building's immediate surroundings, users, and function. The basis of this limitation is the validation of the risk prioritization working system. The harm classes of the defined risk types were determined. Factors such as the building's surroundings, number of users, user types, user behavior, and building function were analyzed for the risks with defined harm classes. In this context, a network system for risks and harm classes was defined in the Super Decision software, and comparative analyses were conducted. As a result of the calculations, numerical values of the risk impact levels were obtained. Based on these results, threshold values for risk impact levels that need to be addressed and controlled in design were determined (for this design, values of 2000 and above were defined as high risk, values between 1000 and 2000 as moderate risk, and values of 1000 and below as low risk)

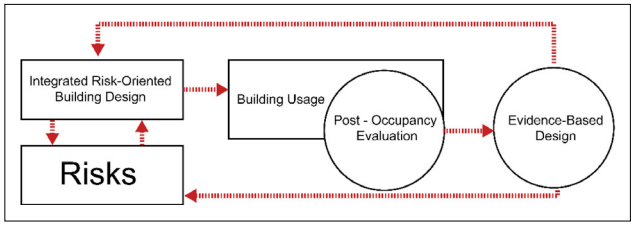


**Figure 9**. Integrated risk-oriented building design, post-occupancy evaluation, evidence-based design and risk relation.

The case study of the developed method was conducted on an educational building designed as a primary school for the residents of the Mimar Sinan Neighborhood in Sultanbeyli District, Istanbul. According to official regional statistics, the socio-economic status of Mimar Sinan Neighborhood is classified as C-D, with the majority of the population having completed primary or secondary education. The fear of crime is at a moderate level (Bilen et al., 2013), the average number of children per household is 3, and the majority of the population falls within the 0-44 age group. In the primary school building, 500 students, along with 30 teachers and administrative staff, are considered regular users, while 100 parents visiting the building daily are classified as transient users. Based on the data obtained from the analyses, potential risks arising from the building's immediate surroundings, users, and potential consequences of incidents related to the building's function and design have been addressed within the study's scope limitations before the design process. In this context, Table 6 outlines the risk origins, risks, and the harm classes that these risks may cause. After calculating the harm classes, the number of individuals affected, frequency of occurrence, and harm class probabilities of the identified risks according to the developed method, the risk impact levels were calculated, and the results are presented in Table 7.

As a result of the data obtained from the research, the following risks have been prioritized in terms of their importance: earthquakes, fire, incompatibility of the design with user behavior and number of users, risky active nature of the students due to their age, low safety and accident awareness among students, design and product decisions that disrupt the visual-cognitive process in spaces and building elements, and the selection of building products that are unsuitable for users. These issues are identified as safety concerns that need to be addressed in priority in the design process.

The following have been identified as moderate risks required to be resolved: low accident awareness among students, the presence of users from different age groups and with varying anthropometric characteristics, the active nature of children, low safety awareness in the surrounding social environment, lack of safety, accident, and harm awareness among students, flood risk in the region, moderate fear of crime in the community, mismatch between spaces/building elements and user anthropometry, and students' inclination towards exploration. Whereas the following have been identified as low-level risks: inadequate lighting forms that disrupt the

**Table 6.** Limited risks and harm classes in the educational building

| Risk No | Risk Origins | Risks | Harm Classes |
|---|---|---|---|
| R1 | RO1 | Located in a 1st-degree earthquake zone (İBB Deprem ve Zemin İnceleme Müdürlüğü, 2009) (Istanbul Metropolitan Municipality Directorate of Earthquake and Ground Research) | H1 – H2 – H3 – H4 |
| R2 | RO1 | It has moderate level flood risk (İBB Deprem ve Zemin İnceleme Müdürlüğü, 2009) (Istanbul Metropolitan Municipality Directorate of Earthquake and Ground Research) | H2 – H3 – H4 |
| R3 | RO1 | Marked as precautionary settlement areas (İBB Deprem ve Zemin İnceleme Müdürlüğü, 2009) (Istanbul Metropolitan Municipality Directorate of Earthquake and Ground Research) | H2 – H3 – H4 |
| R4 | RO1 | High crime rates in the area and the community's tendency towards harmful behavior (Bilen et al., 2013) | H3 – H4 |
| R5 | RO1 | A society with low safety awareness due to low educational level, consciousness, and awareness in the social environment (Endeksa, n.d) | H2 – H3 – H4 |
| R6 | RO1 | A society with a moderate fear of crime (Social environment prone to criminal behavior) (Bilen et al., 2013) | H2 – H3 – H4 |
| R7 | RO1 | Unplanned and disorganized built environment (Şatıroğlu, 2012) A society prone to exhibiting anomalous behavior | H2 – H3 – H4 |
| R8 | RO2 | A user profile with low safety perception and awareness due to inadequate family education and involvement (WHO, 2015) | H1 – H2 – H3 – H4 |
| R9 | RO2 | Inadequate accident and safety perception among users due to low socio-economic family background (Şahiner et al., 2011) | H1 – H2 – H3 – H4 |
| R10 | RO2 | Users from different age groups and with varying anthropometric characteristics | H2 – H3 – H4 |
| R10 | RO2 | Active nature of children (Kapısız & Karaca, 2018) | H2 – H3 – H4 |
| R11 | RO2 | Children's low perception of accidents | H2 – H3 – H4 |
| R12 | RO2 | Children's tendency to play with potentially harmful materials (Templer, 1992) | H1 – H2 – H3 – H4 |
| R13 | RO2 | Children's inclination towards exploration | H2 – H3 – H4 |
| R14 | RO2 | Lack of safety, accident, and injurious awareness in children | H2 – H3 – H4 |
| R15 | RO3 | Evacuation problems during emergencies due to the mismatch between the size and number of escape areas and the number of users | H1 – H2 – H3 – H4 |
| R16 | RO3 | Insufficient spatial area relative to the number of users | H2 – H3 – H4 |
| R17 | RO3 | Design implementation and product usage decisions in spaces and building elements that disrupt the visual-cognitive process | H1 – H2 – H3 – H4 |
| R18 | RO3 | Use of inadequate lighting forms in buildings that disrupt the visual-cognitive process | H2 – H3 – H4 |
| R19 | RO3 | Mismatch between spaces and building elements and user anthropometry | H2 – H3 – H4 |
| R20 | RO3 | Selecting unsuitable products in building (Maleque & Salit, 2013) | H2 – H3 – H4 |
| R21 | RO3 | Fire risk (Kılıç, 2003) | H1 – H2 – H3 – H4 |

Immediate Surrounding Originated: RO1 – User Originated: RO2 – Function Originated: RO3.

visual-cognitive process, an unplanned and disorganized built environment, being in a precautionary settlement area, high crime rates, and a social environment with a high tendency toward harmful behavior.

The case study highlights that the lack of standards and location-specific safety measures set by regulations and requirements leads to insufficient precautions and the inability to develop appropriate safety solutions for users. It is determined that safety risks should be examined in a location-specific and design-specific manner, and necessary solutions should go beyond existing regulations and requirements.

**Table 7.** Risks and risk impact score calculation results

| Risk No | Risk Origins | Harm Classes | Risk Impact Scores |
|---|---|---|---|
| R1 | RO1 | H1 – H2 – H3 – H4 | 14786.77 |
| R21 | RO3 | H1 – H2 – H3 – H4 | 12568.85 |
| R15 | RO3 | H1 – H2 – H3 – H4 | 10563.75 |
| R12 | RO2 | H1 – H2 – H3 – H4 | 9518.04 |
| R9 | RO2 | H1 – H2 – H3 – H4 | 9025.20 |
| R8 | RO2 | H1 – H2 – H3 – H4 | 6175.68 |
| R17 | RO3 | H1 – H2 – H3 – H4 | 5632.04 |
| R16 | RO3 | H2 – H3 – H4 | 3688.07 |
| R20 | RO3 | H2 – H3 – H4 | 2156.65 |
| R11 | RO2 | H2 – H3 – H4 | 1799.48 |
| R10 | RO2 | H1 – H2 – H3 – H4 | 1688.18 |
| R10 | RO2 | H2 – H3 – H4 | 1367.89 |
| R5 | RO1 | H2 – H3 – H4 | 1288.62 |
| R14 | RO2 | H2 – H3 – H4 | 1225.65 |
| R2 | RO1 | H2 – H3 – H4 | 1160.48 |
| R6 | RO1 | H2 – H3 – H4 | 1158.66 |
| R19 | RO3 | H2 – H3 – H4 | 1158.66 |
| R13 | RO2 | H2 – H3 – H4 | 1036.66 |
| R18 | RO3 | H2 – H3 – H4 | 876.22 |
| R7 | RO1 | H2 – H3 – H4 | 845.02 |
| R3 | RO1 | H2 – H3 – H4 | 656.75 |
| R4 | RO1 | H3 – H4 | 465.77 |

## CONCLUSION

Design is a system that encompasses parameters such as the analysis phase, suitability to location, occupant and function, ergonomics, accurate design and product decisions, and requires taking multi-criteria into consideration in decision-making. Safe building design aims to ensure occupant safety by integrating the design process and risk management system. The process is based on risk analysis and assessment steps. In this context, the built environment of the building, occupant, function and obligation are analyzed; risks are identified, evaluated and prioritized with the data obtained. Risk analysis involves calculating hazard results and probabilities by determining risk harm classes and probabilities of occurrence. In this process, decision making is supported by using tools such as Analytical Network Process (ANP) and Super Decision program. Risks are classified according to their impact levels and solutions are developed in order of priority. Possible harm classes include varying negative impacts and risk parameters are created with expert assessments. All these processes aim to control risks and ensure safety throughout the design process. The integration of analysis, assessment and risk processes in safe building design provides a design-oriented system that ensures occupant safety. Post-design risk auditing and building occupant feedback are supporting elements of the process. Testing the proposed method through case studies has confirmed that the data obtained supports the suggested method. Additionally, this system provides significant contributions and greatly enhances the process by evaluating design-specific processes in the context of location-specific designs. By developing solution proposals according to the priority order of risks and resolving problematic situations through the risk analysis system, it provides a roadmap for the designer and ensures that users can live more safely and healthily within the building.

It is believed that if the proposed method is correctly applied, location-specific solutions can be developed in building production worldwide. This method aims to identify and address safety issues that users may encounter during the design process through design-specific solutions, thereby eliminating or minimizing problems that negatively impact user health and result in loss of life and property. Functioning as an integrated system throughout the production and usage phases, this method, when combined with healthy building practices, will provide safe and healthy buildings that meet user needs. It is anticipated that supporting the method with statistics, scientific studies, and robust regulations will guide the development of safe building design methodologies.

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

**PEER-REVIEW:** Externally peer-reviewed.

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**Article**

# The influence of individual and organizational factors on the energy efficiency of office buildings: A consolidation

**Johannes WENINGER**[*1], **Sascha HAMMES**[2]

[1]*Department of Research and Development, Bartenbach Gmbh, Aldrans, Austria*
[2]*Department of Energy Efficient Building, University of Innsbruck, Innsbruck, Austria*

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## ABSTRACT

A significant portion of global energy demand is directly attributable to artificial lighting systems in buildings. Consequently, improving their energy efficiency is crucial for achieving current climate and environmental policy goals. However, the prevailing discrepancies between predicted and actual energy demand present a major challenge as a comprehensive understanding of the factors influencing energy consumption of artificial lighting systems is still lacking. Based on minute-by-minute long-term monitoring of an open-plan office in Austria several dedicated studies have been conducted in recent years to systematically and comprehensively quantify the impact of individual and organizational factors on energy consumption. In addition to quantifying workplace usage behaviour, the analyses also considered various control concepts and the influence of user combinations, both on an individual and probability-based level. The results emphasize the need for a greater integration of behavioural aspects into the strategic planning and operation of artificial lighting systems to optimize energy efficiency.

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## INTRODUCTION

Despite numerous efforts to enhance energy efficiency, the building sector remains responsible for approximately 30% of greenhouse gas emissions and about 40% of global energy demand, with artificial lighting being a major energy consumer (Dubois & Blomsterberg, 2011). In recent years, both building-related modelling techniques and energy-efficient technologies have achieved significant improvements. Despite these advancements, buildings often fail to meet the energy targets anticipated during planning and simulation phases. Current studies (Liang et al., 2019; Calì et al., 2016) show that actual energy consumption can exceed estimates made during the planning phase by up to threefold. Additionally, the efficiency of implemented control systems is rarely evaluated after they have been put into operation, leading to substantial challenges in meeting energy and environmental policy objectives. To improve the energy efficiency of lighting systems and reduce the risk of incorrect design estimates of energy demand, a

***Corresponding author**
*E-mail adres: johannes.weninger@bartenbach.com

deeper understanding of the causes of energy performance gaps (EPGs) (Cozza et al., 2021) and a comprehensive quantification of their magnitude is needed to both improve the accuracy of building performance design and simulation and ensure a positive contribution to societal challenges.

As a result, numerous studies on this topic have been conducted to date (Zou et al., 2019; De Wilde, 2014; Menezes et al., 2012). These studies reveal that the existing discrepancy between actual energy consumption and simulated forecasts, as described by the EPG, is closely linked to concepts of optimal energy usage. Therefore, they not only relate to the optimal functioning of a building, focusing on structural and design factors, but also to ensuring user-related requirements are met (Cozza et al., 2021). Estimating building energy consumption is therefore highly complex, and deviations during actual operation often result from the interaction of multiple factors (De Wilde, 2014).

Potential influences on deviations in operational energy consumption range from insufficient fine-tuning of control systems and suboptimal settings of technical components (Zou et al., 2019) to inaccuracies in measurement techniques and uncertainties in building modelling specifications (Calì et al., 2016). Unrealistic assumptions and forecasting errors in climate data (Erba et al., 2017) and occupancy models during the planning phase (De Wilde, 2014) further contribute to the manifestation of EPGs. System errors or improper use of systems by building occupants (Cozza et al., 2021; Menezes et al., 2012) can also have a significant impact. It is important to understand that it is almost impossible for building users to assess the energy impacts of system interventions, as they lack appropriate quantification mechanisms. As a result, decisions are primarily based on the satisfaction of immediate personal needs (Barthelmes et al., 2016), which may not necessarily align with long-term strategic and energy-saving control concepts. Consequently, it is currently assumed that uncertainty in user behaviour significantly influences the accuracy of energy demand performance forecasts made during the planning phase (Yoshino et al., 2017).

From a planning perspective, this critical role of user behaviour in contributing to the performance gap arises from a lack of detailed information about organizational and socio-cultural factors during the planning phase. The assumptions about occupancy behaviour used in planning and simulation are primarily based on empirically validated and standardized models, which are formulated as broadly as possible to ensure wide applicability (Wang et al., 2016). However, workplace occupancy dynamics are significantly influenced by individual factors such as job tasks, professional position within the organization, and social conditions, all of which can vary considerably between organizations and individuals. Consequently, the energy impacts of occupancy profiles are often stochastic (Zhou et al., 2015) and do not correspond to the static occupancy models used today. The issues arising from current model assumptions become evident in contexts with flexible social structures, such as flex-time regulations and remote work. Furthermore, workplace-specific dynamics, such as the proportion of meetings depending on the job position in an organisation (Panko & Kinney, 1995), present a practical challenge insufficiently addressed by current assumptions.

Currently, several approaches exist to address these problems in building energy simulations. For example, discrete Markov processes, based on predictors selected for statistical significance through forward and backward selection (Haldi et al., 2017), offer the advantage of capturing individual behaviour on a statistical basis. In recent years, machine learning techniques have also been increasingly used (Yılmaz et al., 2023; Weninger & Hammes, 2024). The development of improved methods for modelling user behaviour and their integration into simulation environments has been the subject of both past and current research efforts within the framework of the "Energy in Buildings and Communities" program of the International Energy Agency (IEA EBC; Yoshino et al., 2017). However, a comprehensive and suitable quantification of the multidimensional factors influencing energy demand and contributing to the performance gap is still lacking. Thus, the quantification of EPG and the development of appropriate counterstrategies remain key research topics to avoid inefficient building operation and ensure the achievement of energy targets.

**Scope of this Work**

In 2019, a Living Lab was established in the open-plan office of the R&D department of Bartenbach GmbH in Aldrans, Austria. Since then, high-resolution user and building-related data have been collected as part of a post-occupancy evaluation. In comparison with simulation models, these data have been used in multiple studies to evaluate the building's energy consumption. In addition to the goal of thoroughly breaking down and weighting the factors influencing energy consumption, targeted approaches were pursued to mitigate existing performance issues. Due to the significant impact of occupancy behaviour on the success or failure of predictions made during the planning phase regarding the building's energy efficiency, the analyses focused primarily on individual and organizational influences and their relationship to other relevant factors such as daylight availability, season, time of day, and building usage.

Using statistical methods, machine learning, and mathematical optimization techniques, the available data were analysed both using real datasets and synthetic datasets generated through sampling methods. In

addition to quantifying workplace usage behaviour, the analyses also considered various control concepts and the influence of user combinations, both on an individual and probability-based level. The findings underscore the need for increased integration of behavioural aspects into the strategic planning and operation of artificial lighting systems to optimize energy efficiency. Consolidated results from individual studies are presented, and future research perspectives are derived.

## DESCRIPTION OF THE STUDY OBJECT

The research and development building of Bartenbach GmbH in Aldrans, Austria, features a 160 m² open-plan office accommodating up to 28 workstations. To ensure optimal operation and comfort, the office is primarily used by 18 individuals, distributed across nine workstation zones. Four zones, each designed for two people, are located along the north side under a skylight, while five additional zones, also standard for two but expandable to four people, are situated along the south facade (Figure 1, left).

Both the daylight and artificial lighting systems in the office space have been optimized over several years. As a result, the lighting systems in the study object can be controlled separately for each workstation zone to accommodate individual lighting preferences (Boyce et al., 2000; Despenic et al., 2017; Veitch & Newsham, 2000), avoid associated conflicts (Chraibi et al., 2016), and significantly reduce the system's overall energy consumption (Hammes et al., 2020). The artificial lighting system provides two colour temperatures, ranging from 5,000 K in the morning to 2,200 K in the evening, to support the users' circadian rhythms. It is controlled by ceiling-mounted passive infrared sensors (PIR; Thermokon, RDI) that respond to occupancy. The implemented switch-off delays have been adjusted to an industry standard of 15 minutes (Nagy et al., 2016) to prevent incorrect system shutdowns. Additionally, the necessary artificial lighting is reduced by desk-mounted horizontal light sensors (Thermokon, LDF 1000A) based on the available amount of daylight. In this context, a normative standard of 500 lx according to EN 12464-1 is assumed as the target value.

The office is characterized by a large, glazed area on the south facade, ensuring high levels of daylight integration. On average, horizontal illuminance levels of over 500 lx are achieved at workstations between 9:00 AM and 4:00 PM, resulting in a daylight autonomy (DA) of 81.56% (Figure 2). To prevent glare and overheating, automatically controlled shading systems are installed on the exterior of the south facade and the interior of the northern skylights, along with an external static daylight system (Figure 1, right), adapted to the specific conditions and geographic location of the building. The automated control logic for both artificial and daylight can be overridden by users within each workstation zone via switches, ensuring high user acceptance (Despenic et al., 2017).

The occupancy structure in the building is highly dynamic. Core working hours are from Monday to Thursday, 9:00 AM to 12:00 PM and 2:00 PM to 5:00 PM, and Friday from 9:00 AM to 12:00 PM. Additionally, the organizational framework includes the option for remote work and flexible hours between 6:00 AM and 8:00 PM. To capture individual occupancy behaviour, PIR sensors (NodOn, PIR 2 1 01) are installed under each workstation, with detection areas limited to the specific desk. The building is centrally controlled by a programmable logic controller (PLC, BECKHOFF, CX5140-0141), which also logs all sensor data and actuator system states. With over 100 sensors in the R&D building, comprehensive monitoring of the indoor and outdoor climate, as well as the presence and absence of users at their workstations, is ensured in compliance with data protection regulations.

**Figure 1**. Interior (left) and exterior view (right) of the Bartenbach R&D building in Aldrans, Austria. In the right part of the interior area, the skylights of the north façade can be seen, the exterior view shows the static daylight system on the south façade.

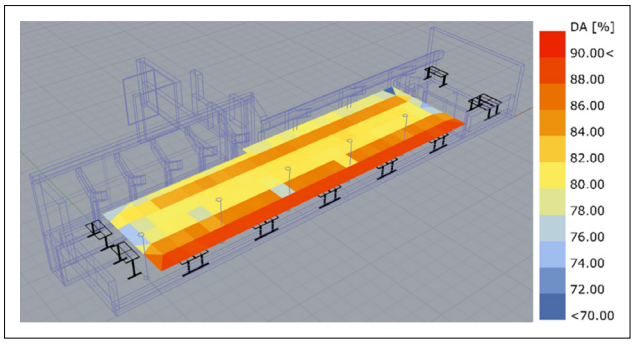


**Figure 2**. Daylight simulation of the study object, implemented with Radiance; simulation related to the normative minimum illuminance of 500 lx according to EN 12464-1; reference time: 8:00-18:00, daylight savings time not considered, calculated with glare protection.

Since 2019, all sensor data in the building have been collected in high resolution and stored in a machine-readable data format (.csv). Continuous data, such as those from lighting and environmental quality sensors, are recorded every minute. Status-based data, such as workstation occupancy or window opening states, are recorded on an individual level upon status changes. The collected data has been partially made available for research purposes (Hammes & Weninger, 2023).

## STUDY RESULTS

### Simulated and Real Energy Consumption

In general, energy consumption always results from a causal relationship, which arises from various influencing factors and their implementation in control systems. The extent to which this interdependence affects the results energy consumption simulations, especially in relation to the used occupancy model, was examined in a study conducted in 2021 (Hammes et al., 2021a). In this study, the building's energy consumption from September 2020 to October 2020 was simulated under several different control methods for the daylighting system, which included various assumptions about glare assessment and the corresponding limitation of available daylight indoors. Additionally, both static and dynamic occupancy models were simulated and compared to actual energy consumption data. To validate the accuracy of the simulations, a comparative energy consumption simulation was also conducted using actual measured workplace occupancy data.

The results showed a generally strong alignment with actual energy consumption, with an underestimation of approximately 14% due to hourly resolution of the weather data, in comparison to the real consumption of 121 kWh when using actual occupancy data in the simulation. Although this study found that both the assumed control method and the occupancy model had a significant impact on the simulated

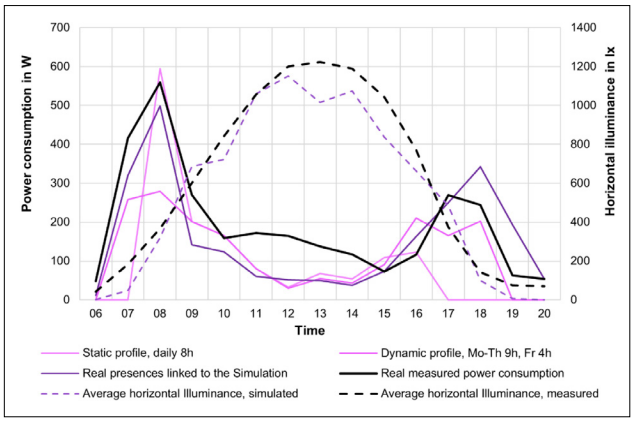


**Figure 3**. Average energy demand of different occupancy models, supplemented by the simulated and measured illuminance and the real energy demand (Hammes et al., 2021a).

energy consumption, the influence of the occupancy models was notably higher. Moreover, there was a considerable underestimation of the resulting energy consumption by approximately 50% on average. These discrepancies can largely be explained by the high availability of daylight, which, in many cases, shifts the primary use of artificial lighting to the early morning and late afternoon (Figure 3). In the building, due to the flexible working hours of employees, these times are characterized by high variability in occupancy, with considerable differences in the start and end times of the working day. Static occupancy models are inherently unable to capture these organizationally enabled variations, which manifest through individual behaviour. Adequately accounting for this variability in dynamic models also proves to be highly challenging. Although the dynamically assumed occupancy models in the study produced better simulation results, the deviations from actual energy consumption were still significantly underestimated.

Thus, assumptions regarding user behaviour in simulations must be considered primarily responsible for existing energy performance gaps. However, despite this insight, the study did not directly quantify the impact of user behaviour itself on the building's overall energy demand.

### Influence of User Behaviour

In the context of integral, sensor-coupled control approaches, the energy demand for artificial lighting is determined, on the one hand, by the currently available amount of daylight, which is supplemented by artificial lighting to reach the normative minimum illumination level at the workplace, and on the other hand, by the utilization of the workplace. In most cases, the presence and absence of individual users must be considered in conjunction, as general lighting typically illuminates multiple workstations simultaneously. As a result, the energy efficiency of the overall system is directly influenced by the alignment of individual presence patterns (Figure 4).

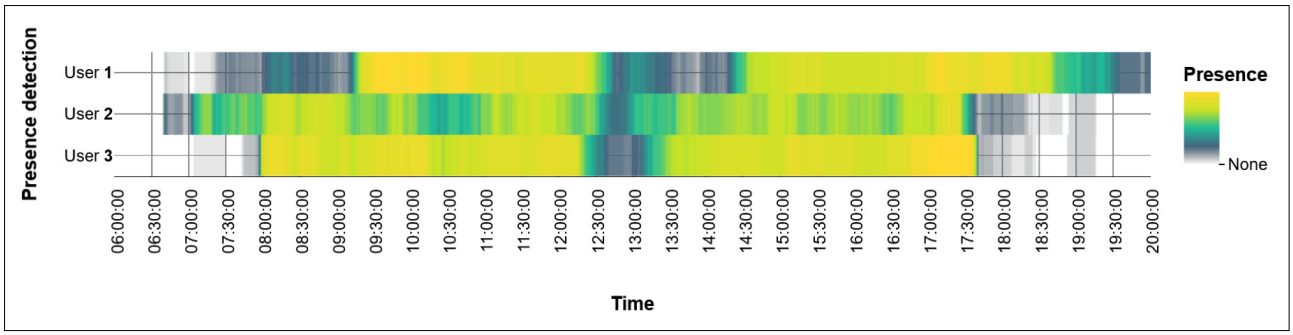


**Figure 4**. Exemplary representation of three real workplace occupancy profiles in the open-plan office, averaged daily in the period from September 2nd, 2020, to November 3rd, 2020 (yellow greenish: high occupancy, blue to grey: low occupancy, transparent: no occupancy).

In terms of fully quantifying the influence of individual user behaviour on the resulting energy consumption of a building, this circumstance presents a significant challenge, as substantial distortions can occur due to better or worse-suited user combinations, when only one specific room usage scenario is considered. Therefore, it is necessary to examine all possible combinations of users within a workplace zone and simultaneously account for their distribution across all available zones to obtain a comprehensive representation. However, even for smaller office spaces, such as the building studied with 18 users, this leads to more than 3 x 1029 possible spatial distributions of individuals. Consequently, this task cannot be solved within a finite amount of time. To nonetheless achieve a possible quantification of the influence of individual behaviour, a two-step optimization process using graph-theoretical algorithms was applied in a simulation-based study conducted in 2022 (Hammes et al., 2022). Real occupancy data for building users from July 2021 to November 2021 were paired for all combinations of two users, and the corresponding energy consumption was calculated using the zonally measured daylight availability. These data were then optimized for both user combinations and zonal assignment for best and worst-case scenarios.

The results show an increase in artificial lighting energy demand of approximately 83% from the best-case to the worst-case scenario (Table 1). For comparison, the actual energy consumption of the artificial lighting system during the nearly 100-day study period was around 83.8 kWh. Since the values were calculated using the same system configuration, the derived range only reflects user-related influences. The significant impact of individual behaviour on the overall energy demand of a building is not only confirmed by the present findings but also illustrates why current simulation assumptions, which would generally result in the same energy consumption for all scenarios due to the lack of individual variations, are insufficient for adequately estimating the performance indicators of real-world operations. To meet the requirements arising from this influence and to address the hidden potentials, the implementation of appropriate control strategies proves indispensable.

### Effects of Using User-Centred Information

Given the nature of individual influences, the effects of users or user combinations are spatially highly zonal. To effectively address these effects, the implementation of finely zoned lighting concepts is necessary. However, compared to comprehensive room-wide lighting controls, such concepts require an increased use of sensors. This heightened system complexity also necessitates the use of more powerful control components, which can in turn have adverse effects on energy consumption. A direct comparison of differently zoned control systems was conducted in 2020 (Hammes et al., 2020). In a simulation-based study, the energy consumption of room-wide, as well as north- and south-facing, and individually

**Table 1.** Overview of the influence of user combination and room positioning on the energy consumption of the artificial lighting system in the open-plan office for the period from July 1, 2021, to November 19, 2021 (Hammes et al., 2022)

| Occupancy Schemes | Adjustment of Room Position | |
|---|---|---|
| | Best-case scenario | Worst-case scenario |
| Adjustment of the user pairing | | |
| Best-case scenario | 58.4 kWh | 88.2 kWh |
| Worst-case scenario | 86.4 kWh | 96.7 kWh |

zoned control concepts was calculated. As additional benchmark value, energy consumption for a room-wide manual control scenario was considered in the study. The simulations were based on real data for occupancy and daylight availability from March 2021 to December 2021. The results clearly indicated the advantages of more fine-grained zoning, showing a reduction of approximately 55% in energy consumption compared to the sensor-based room-wide control approach (Table 2), highlighting the superior ability of smaller zones to respond to individual variations more effectively.

In addition, zoned lighting concepts offer further crucial advantages by allowing the integration of personalization methods through the connection of the lighting system to individual room areas. Beyond general comfort criteria, such as adjusting individually preferred lighting conditions, these systems can also contribute to energy optimization at a higher level. For example, a study conducted in 2021 (Hammes et al., 2021b) developed a method that adjusts the otherwise generalized switch-off times for PIR-based presence-controlled artificial lighting after leaving the workspace based on individual occupancy patterns. The method employed probabilistic approaches to individualize the switch-off times based on past information regarding the duration of absence from the workplace. The artificial lighting was turned off as soon as the probability of a longer absence exceeded the probability of a prompt return. This procedure was implemented within the control system of the open-plan office and evaluated under real usage conditions during the period from September 2020 to October 2020. Despite the relatively short periods of artificial lighting use in the open-plan office due to the high availability of daylight, the implemented method reduced overall artificial lighting energy consumption by 17%. A concurrent user survey also revealed that individual lighting control had no negative effects on user acceptance.

## DISCUSSION

The presented results clearly demonstrate that the expected energy consumption of buildings is significantly shaped by the individual behaviour of their occupants. This fact currently poses substantial challenges for the planning and simulation process, as the existing variability cannot be adequately accounted for in the related estimates due to generalized model assumptions. As a result, not only do significant deviations from the predicted energy consumption arise, but there is also a risk of incorrect system sizing, flawed specification of requirements, or ineffective definitions of control strategies.

Although it is currently very difficult to estimate the real impact of individual behaviour in planning processes, even low-threshold considerations of the potential variability of building users have proven to be highly beneficial. Zonal, sensor-controlled lighting designs are often effective approaches to significantly mitigate uncertainties in planning processes. Moreover, these concepts offer expanded possibilities, enabling the broader utilization of energy-saving potentials through personalized control strategies.

In theory, a targeted use of personalized lighting concepts can also be used to promote non-visual light effects. In typical general lighting setups, non-visual effects are usually achieved through continuous exposure to specific lighting settings, as individual factors are not adequately represented in the lighting concept. However, there is emerging evidence that intermittent light interventions may also produce acute light effects (Chang et al., 2012; Weninger et al., 2022; Canazei et al., 2023), by showing not only improved cognitive performance but also reduced heart rate variability. These interventions not only potentially possess a greater effectiveness compared to continuous interventions (Güler et al., 2008), but they could also have energy-saving effects in comparison to current health-promoting lighting solutions, as they are based on a significant reduction in the periods during which high vertical illuminance is required.

### Limitations

Even though the consolidated study results clearly indicate the significant influence of individual user behaviour on the building's energy consumption, they nevertheless constitute a case study. Personal influences on energy consumption are fundamentally tied to individual behaviour. Different building users, varying usage scenarios, or alternative organizational uses of the building may therefore lead to different outcomes. While the study results generally provide similar indicators, it must be assumed that further case studies with different usage patterns are required to make a universally valid statement.

**Table 2.** Simulation-based, normalized energy consumption of the artificial lighting system in the open-plan office according to differently zoned control concepts (Hammes et al., 2020)

| | Room-wide controls, manual | Room-wide controls, sensor | North/South zoning, sensor | 9 workplace zones, sensor |
|---|---|---|---|---|
| Normalized energy consumption | 117% | 100% | 88% | 45% |

Additionally, it should be noted that the evaluated building is characterized by above-average daylight availability. As a result, large parts of the day do not require the use of artificial light in terms of normative requirements, which leads to greater variability in energy consumption at the edges of the day. Given that there is typically a higher fluctuation in occupancy times during these periods, it is potentially possible that the influence of occupancy behaviour is overestimated in the presented results. However, whether this overestimation exists, and to what extent it manifests, would require comparative studies, which are currently unavailable.

## CONCLUSION AND FUTURE RESEARCH DIRECTIONS

Considering current climate and environmental policy discussions, improving the energy efficiency of buildings has become crucial for achieving increasingly important societal objectives. The lighting sector, as one of the largest electrical consumers in buildings, can make significant contributions. However, the realization of these potentials is currently hindered by inaccuracies in both the planning process and energy simulations as well as inefficient control strategies. User behaviour, which is influenced by both individual factors and organizational and social conditions, can therefore be considered as a central factor, as its impact on both the planning processes and the operation of controlled artificial lighting systems proves to be essential.

Both in relation to the improvement of user models and the design of user-centred lighting control systems, there are currently a variety of approaches (see, for example, Hammes et al., 2024). Specifically, advanced approaches utilizing data-intensive modelling techniques, such as machine learning algorithms, are becoming increasingly important in this field. However, the availability of relevant data remains significantly limited, as data collection is complex, and post-occupancy evaluations of building performance are still rarely conducted, despite their potential to address existing opportunities effectively. The primary reasons for this are often the cost and resource intensity associated with adapting control systems during operation.

In the context of personalized lighting control systems, this issue could be significantly mitigated. The adequate integration of user information generally aims not only to account for interindividual differences in the design of personal environments but also to recognize intrinsically or extrinsically motivated behavioural changes at an intraindividual level and to adjust control decisions accordingly. As a result, costly adjustments of implemented control logics would become a thing of the past in a fully personalized system, as these systems would operate within a framework of continuous re-evaluation of current decision-making and automatically perform necessary adaptations. In this context, reinforcement learning methods currently hold significant future potential.

However, from a planning perspective, such methods could exacerbate existing challenges. Current model assumptions about user behaviour, particularly in terms of hourly resolution in both planning and simulation, are unsuitable for effectively capturing individual differences. Should control systems significantly improve by adequately integrating individual behavioural patterns into decision-making processes, this would automatically widen the existing gap between predicted and actual energy consumption. Therefore, improving user behaviour modelling assumptions during the planning and simulation phase is of great importance to accurately estimate the processes of intelligent control systems and the resulting key energy performance indicators of buildings.

Improvements to currently applied methods and models are therefore necessary both for the design and operation of artificial lighting control systems. However, to develop and, more importantly, sufficiently validate current approaches on a generalized level, very large datasets are required, which are, from today's perspective, still far from being available in sufficient quantities. It is important to understand, that this challenge pertains not only to the impact of user behaviour on building performance but also to the understanding of user behaviour itself.

Today, it remains unclear to what extent user behaviour is truly driven by individual factors or whether cultural or organizational influences significantly limit individuality. If the latter is true, it could potentially lead to a substantial reduction in the complexity of user modelling, as only phenotypological considerations would be necessary. However, whether this simplification is feasible, and if so, whether and to what extent existing phenotypes can be transferred across different application areas, has not yet been adequately investigated.

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**Article**

# Variation of the room modes and impulse response according to surface absorption properties in a non-rectangular room

**Murat TIRAŞ*, Mehmet Nuri ILGÜREL**

*Department of Architecture, Yıldız Technical University, Istanbul, Türkiye*

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ANSYS modal acoustic; Finite element method (FEM); ISO 18233; ISO 3382; room impulse response.

## ABSTRACT

Determination of room mode frequencies and shapes in rectangular rooms can be done using calculation methods. Simple calculations cannot be made for non-rectangular rooms and the room must be simulated. In this study, the effects of 4 different acoustic designs on room modes and room responses were investigated using a fan-shaped room with a volume of 85 m³. The absorption coefficients of the acoustic materials used were calculated based on the reverberation time values obtained as a result of field measurements. T30, EDT, C80 and room response measurements made in the field in accordance with ISO 3382 and ISO 18233 standards and ANSYS modal Data was obtained as a result of comparing the room modes and shapes found with the Finite Element Method (FEM) using the acoustic module. It has been found that if the absorption coefficients of the acoustic devices to be used in the room are greater than 0.5, the room mode shapes and frequencies in the relevant frequency band change, and as a result, the room response becomes smoother. It has been observed that the peaks in the room response in a certain frequency band can only be smoothed out with sound-absorbing materials with an absorption coefficient greater than 0.5 in that frequency band. It has been evaluated that the absorbers, which will be effective in the frequency bands left by the room modes in the room response, will pull these bottom regions lower.

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## INTRODUCTION

The acoustic parameters to be determined in the arrangement of room acoustics are related to the room volume. Revealing the standing wave shapes of room resonances in small rooms determines at what frequency we can hear sounds depending on the location in the room. The paths of sound waves in the lower frequency region and the contribution of the room to the sounds at this frequency constitute a situation that needs to be examined. Analyzing sounds in the lower frequency region using the normal ray tracing method does not give accurate results (Bai, 1992). Because in these frequency areas where a diffuse sound field does not occur, sounds do not move smoothly and linearly (Beaton & Xiang, 2017). It is important to develop an acoustic design approach that aims to reach optimum

***Corresponding author**
*E-mail adres: [murattiras@gmail.com

values determined by taking into account the function of the room (Tıraş & Akdağ, 2024).

Low frequency room modes can act as a filter and can also cause the sound character of the music source to be perceived differently (Hikichi & Miyoshi, 2006; Kelle & Yılmaz Demirkale, 2022). When sound occurs in the frequency regions within the room mode frequency and bandwidth, room resonances take effect and create standing waves (Kleiner & Tichy, 2014). In small rooms, widely spaced modal frequencies in the lower frequency regions that are audible to the human ear, can color the sound in a noticeable, often undesirable way (Rossing & Fletcher, 2004). This coloration can create significant acoustic problems in listening rooms, recording rooms, and music study classes. Considerable effort has been devoted to developing design guidelines and approaches to mitigate these impacts (Boner, 1942; Gilford, 1959; Louden, 1971; Volkmann, 1942).

Small rooms with strong modal behavior will not have a diffuse sound field. In rooms with volumes between 30-200 $m^3$, the space and time distribution of sound energy will be irregular due to the lack of sound field diffuseness (Prato et al., 2016). In lower frequency regions where room modes occur at wide intervals, the decay curves of sound energy will also vary (Bistafa & Morrissey, 2003). This situation creates problems in determining room acoustic parameters. While determining the acoustic properties of rooms, equations and approaches have been developed considering that the sound inside the room creates a diffuse sound field (Qu et al., 2023).

In small volumes where a diffuse sound field does not occur, it may be useful to determine the available modes by using the room response curve (Das & Abel, 2022). Modal decay times of these modes can be calculated using quality factor and mode frequency data (Kleiner & Tichy, 2014). The room response curve refers to the sequence of sound signals that are emitted from the pulse sound source in the sound field and received at one point. In room response measurement, a sine sweep or MLS signal is usually used as the emitted signal and is generated by the source. (Lim et al., 2016; Wang et al., 2020).

Analytical solutions exist to predict modal frequencies in rooms with parallel walls based on solutions of the wave equation (Jian et al., 2022). The finite element method and the calculation method can be used to determine the room sound field, as well as it can be determined by field measurements (Čurović et al., 2024). Wave-based simulation methods, especially methods that can be formulated to work on unstructured networks such as the finite element method and the boundary element method, can use much more detailed geometric models and thus reduce the associated uncertainty (Bai, 1992; Ekmen et al., 2021). It seems that the finite element method (FEM) is a useful tool for the frequency region below 500 Hz in determining the room acoustic parameters. (Jiang et al., 2011).The use of the finite element method is preferred in the solution of complex geometries (Yoshida et al., 2021). Computer programs are used in the use of the finite element method (Mehra et al., 2012; Qu et al., 2023). With the ANSYS modal analysis module, the modal shapes and levels that will occur in the room can be determined on a frequency basis (Svensson, 2020).

Simulation programs are used in studies on room acoustics (Zhang et al., 2021; Zhu et al., 2022). While simulation programs using the ray tracing method find the volume acoustic parameters close to field measurements at 250 Hz and above, they deviate from these estimates in the 125 Hz and 63 Hz regions (Svensson, 2020). Ray tracing simulations use sound energy without taking the phase information of sound "rays" in consideration. While this provides good approximations, especially at high frequencies where the sound field is considered dispersed, it fails in predicting low frequency phenomena such as standing waves, phase cancellation and diffraction. Commercial FEM software such as Ansys is well suited for these calculations (Svensson, 2020).

It is seen that finite element method (FEM) and simulation programs are used to see the impact areas and quantities of room modes (Jiang et al., 2011; Yoshida et al., 2021). The two most important variables that affect room modes, are the character of the sound source and the absorption factor (Bistafa & Morrissey, 2003). The critical frequency concept introduced by Schroder shows us the limit value of the lower frequency region where room modes may cause problems (Jian et al., 2022). It is seen that sounds at frequencies below this limit value can be heard more strongly by being affected by room resonances. While the coefficient of 4000 was used in the formula published by Schroder in 1954, it was replaced with the coefficient of 2000 in 1964. It is stated mathematically that the use of the 4000 coefficient is more accurate for rooms with high absorbency (Dance & Van Buuren, 2013).

The aim of this study is to determine the areas of use in smoothing the room response by observing the changes in room mode frequencies according to the absorption characteristics of the type of the sound absorbing material used at the boundaries of the room. The main goal is to create an acoustic design guide to obtain an acceptable flat room response for the lower frequency region of the spectrum using the data obtained from the study.

In this study, the effect of absorbing materials on room modes and room response was investigated by using 4 different room versions, observing the change of room modes according to surface absorbance and the improvements in the room response curves that are resulting from this change. By determining the sound absorption coefficients

of sound-absorbing materials according to frequency, their impact areas on room response and room modes were determined according to the degree of absorption.

In this study, sound dispersive surfaces were not used. The theory of diffuse sound field is not valid at frequencies below the Schroder frequency (Vorlander, 2013). Since sound dispersive surfaces were not used and the scattering coefficients of the materials used were less than 0.1 below 500 Hz, the scattering coefficient was not taken into account.

## EXPERIMENTAL METHOD

In the experiments conducted in a fan-shaped room with an area of 30.78 $m^2$ and a volume of 86.8 $m^3$, 4 different room designs were used. As a result of the field measurements, T30, EDT, C80 and room response data were obtained.

In this room, which is planned to be used as a musical instrument study class, the data were evaluated comparatively as a result of the measurements taken from the position of the piano player in accordance with the piano position. Modal analysis was carried out using ANSYS 2023 R1 program for 4 different version room modal analysis. The areas of materials and the versions in which they are used are shown in Table 1.

**Table 1.** Use and area of absorbent materials

| | Area ($m^2$) | V1* | V2* | V3* | V4* |
|---|---|---|---|---|---|
| Curtain | 15.5 | | ✓ | | ✓ |
| 7 Panel | 9.1 | | | ✓ | ✓ |
| Carpet | 29.5 | ✓ | ✓ | ✓ | ✓ |
| Bulk curtain | 3.5 | ✓ | | ✓ | |

*V1(Curtain bulk), V2(Curtain), V3 (7 panels), V4 (7 panels + curtain).

The effect of absorber elements on room modes was investigated, and mode frequency and shape changes were observed. The modal effect created by the curtains, carpets and 7 different panels used in the room was evaluated and compared with the field measurement results and discussed. The methodological steps followed by the research are shown in Figure 1.

In the first stage, 4 different room designs were determined. For this fan-shaped room, room modes and shapes were found using the ANSYS modal acoustic module. Field measurements were carried out in the 4 room versions shown in Figure 2, and T30, EDT, C80 and room response results were obtained. By comparing reverberation time measurement results, absorption coefficients of the curtain and panels were calculated. At the same time, using the formula in the literature for the panels, the frequency with the most effective absorption was found. In the discussion section, the changes according to panel and curtain use on reverberation and room response were evaluated. In the conclusion section, the data obtained as a result of the discussion are presented.

### Field Measurements

Measurements were carried out in accordance with the ISO 3382-2 standard to determine the current acoustic conditions of the instrument working class. 2 source and 3 receiver points were selected (Figure 3), the source positions were positioned 150 cm above the ground, and the receiver points were positioned 120 cm above the ground (TS EN ISO 3382-2, 2008).

A studio speaker, Behringer ECM 8000 measurement microphone, microphone tripod, Arta software and microphone calibrator were used in the measurements. Among the ISO 3382 acoustic parameters, T30, EDT and C80, room response measurement was made for point

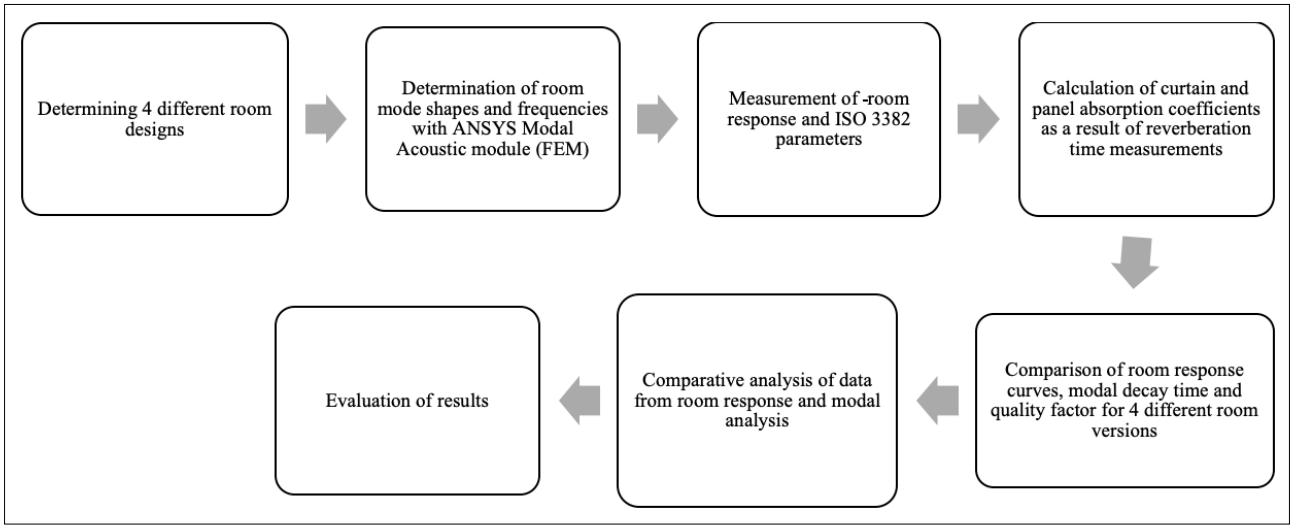


**Figure 1**. Method steps followed.


**Figure 2**. 4 different room designs and photos.

A1 in accordance with the TS EN ISO 18233-SS standard (TSE EN ISO 18233, 2010). The microphone positions and distance between the microphones were determined to be 1.2 meters using the formula for the closest distance between two microphones in ISO 3382. Sweep signal was used in room response measurements. Sweep signal has been shown to provide more accurate results in room response measurement.(Lim et al., 2016; Prato et al., 2016).

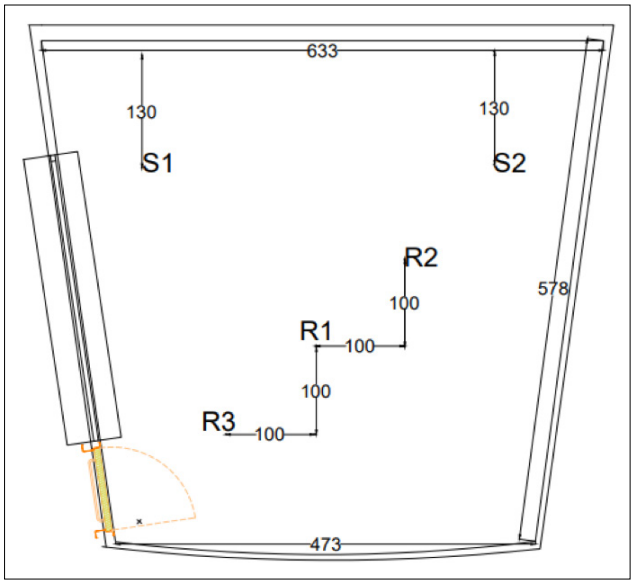


**Figure 3**. Measurement plan.

**ISO 3382 Acoustic Parameters (T30, EDT and C80)**

As a result of the measurement, reverberation time values were obtained. When we look at the T 30 values for the 4 different versions, we see that the reverberation time values decrease with the use of absorber elements. While there was no difference in the 4 versions in the 63 Hz region, it was determined that the biggest change was in the 250 Hz center octave frequency band (Figure 4, Table 2). A similar result is

**Table 2.** Reverberation time of V1, V2, V3, V4 versions

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|---|
| V1 T30 | 1.48 | 1.31 | 1.08 | 0.76 | 0.58 | 0.60 | 0.60 |
| V2 T30 | 1.52 | 1.19 | 0.83 | 0.57 | 0.45 | 0.43 | 0.37 |
| V3 T30 | 1.48 | 1.08 | 0.54 | 0.42 | 0.36 | 0.38 | 0.39 |
| V4 T30 | 1.52 | 0.99 | 0.52 | 0.35 | 0.29 | 0.31 | 0.35 |

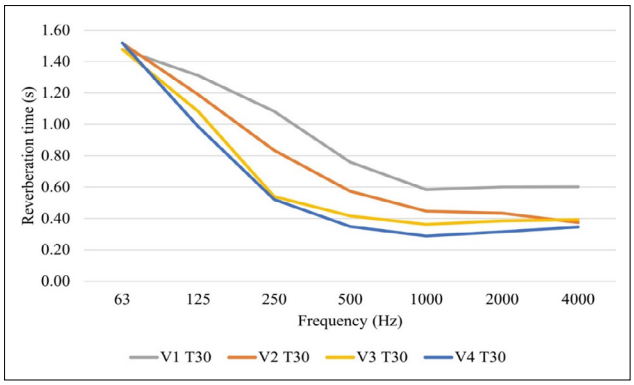


**Figure 4**. Reverberation time of V1, V2, V3, V4 versions.

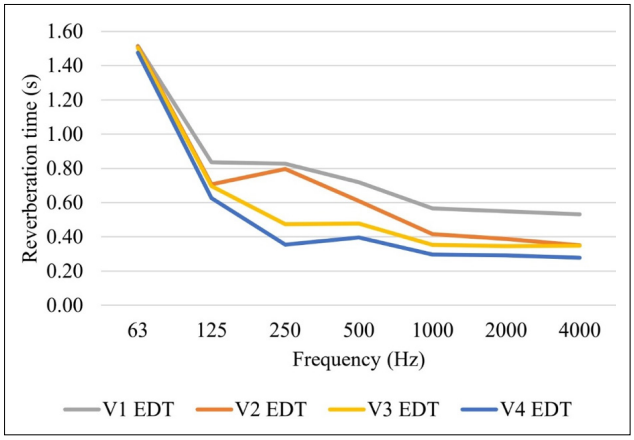


**Figure 5**. V1, V2, V3, V4 versions EDT.

seen in the EDT data. While there is no change in the 63 Hz central octave frequency, the rate of change is high in the 250 Hz region (Figure 5). The difference in EDT data compared to T 30 data is that the effect of using curtain between V1 and V2 is limited to the 250 Hz band. It was determined that the 0.25 second decrease seen in the T30 chart for 250 Hz was 0.03 seconds for the EDT parameter (Table 3).

When we look at the C80 data, it is seen that it generally increases according to frequency for each version. In the V1 version, it showed a decrease in the 125 Hz region after 63 Hz, and increased continuously at 250 Hz and above. A similar situation occurred in V2 and V3. In the V4 version, as the frequency increased, C 80 values also increased. It is seen that C 80 values increase as we move from V1 to V4 for every frequency region except 63 Hz (Figure 6). It was determined

**Table 3.** V1, V2, V3, V4 versions EDT

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|---|
| V1 EDT | 1.52 | 0.84 | 0.83 | 0.72 | 0.57 | 0.55 | 0.53 |
| V2 EDT | 1.51 | 0.71 | 0.80 | 0.61 | 0.42 | 0.39 | 0.35 |
| V3 EDT | 1.50 | 0.70 | 0.47 | 0.48 | 0.35 | 0.35 | 0.35 |
| V4 EDT | 1.48 | 0.63 | 0.35 | 0.40 | 0.30 | 0.29 | 0.28 |

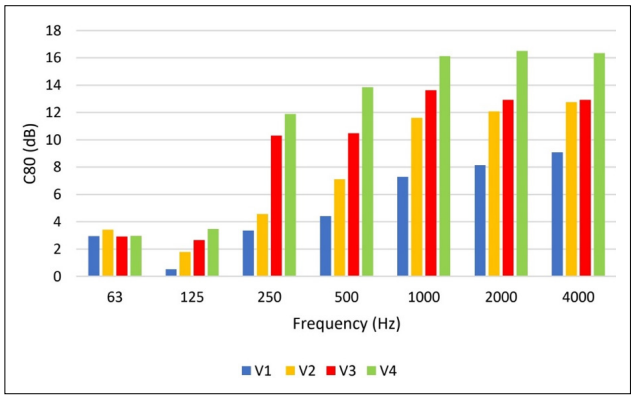


**Figure 6**. C80 measurement results.

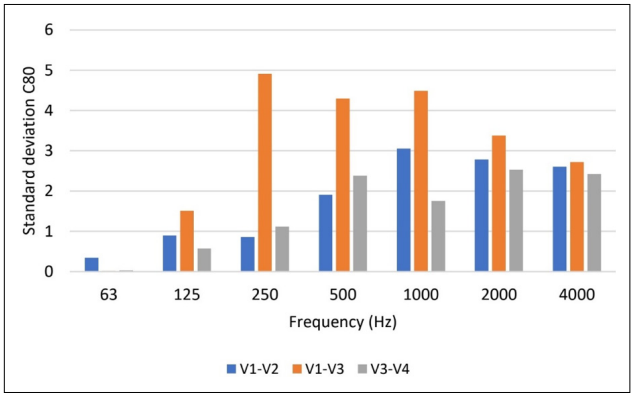


**Figure 7**. C80 standard deviation values.

that the increase in C 80 values was higher in the V3 and V4 versions where panel was used. It was calculated using equation 4 that the absorption coefficients of the panels would reach their highest value at 345 Hz. When we look at the change in C80 values, we see that the highest standard deviation value in the transition from V1 to V3 is at the 250 Hz frequency (Figure 7). It was determined that the effect of the panels on C80, still continued in the 500 and 1000 Hz regions, but decreased at 2000 and 4000 Hz. It was found that the effectiveness of the panels using wood with 23% perforation in front of the 10 cm sponge, was close to the calculations.

### Panel and Curtain Absorption

The absorption coefficients of the panels with perforated fronts and thick fabric curtains which are used in the scenarios created in the room, were determined using the reverberation time measurement results in accordance with the ISO 3382-2 standard. The difference between V1 and V2 room arrangements is the use of curtains. The absorption coefficients of the curtain were found from the difference in reverberation time between the two versions.

$$RT_1 = \frac{0{,}16.V}{A} \quad (1)$$

$$RT_2 = \frac{0{,}16.V}{A + a.S} \quad (2)$$

In Equation 1, the Sabin reverberation time formula is defined for V1. In Equation 2, the value of S is calculated by subtracting the total area of the curtain in bulk position from the total area of the curtain in open position. 15.5 $m^2$ curtain area is available in the V2 version. In the V1 version, the total area of the curtain is 3.5 $m^2$. In Equation 2, the area S is taken as 12 $m^2$. When the absorption coefficient was drawn from these two equations, the formula shown in Equation 3 was obtained. RT1 and RT2 values, obtained from field measurements were used in Equation 3 to find the absorption coefficients of the curtain according to frequencies.

$$a = \frac{RT_1.A}{RT_2.S} - \frac{A}{S} \quad (3)$$

Here

$RT_1$: V1 reverberation time

$RT_2$: V2 reverberation time

$A$: V1 sabin area

$S$: Curtain or panel area

$V$: Room volume

$a$: Absorption coefficient

Panel sound absorption coefficients were determined in the same way using Equation 3. The difference between V1 and V3 room arrangements is the use of 7 panels. The sound absorption coefficients of the panel were found by using the RT1 and RT3 field measurement results in Equation 3 (Figure 8).

It is seen that the panel sound absorption coefficients exceed 1 in the frequency regions of 250 Hz and above. It is thought that there is an edge effect in the formation of this situation.(Sauro et al., 2009)

**Panel Absorbency Calculation and Measurement**

The critical frequency value at which the absorption efficiency of a 10 cm thick sponge with a perforated panel in front begins to decrease, is found using Equation 4. (Egan, 2007),

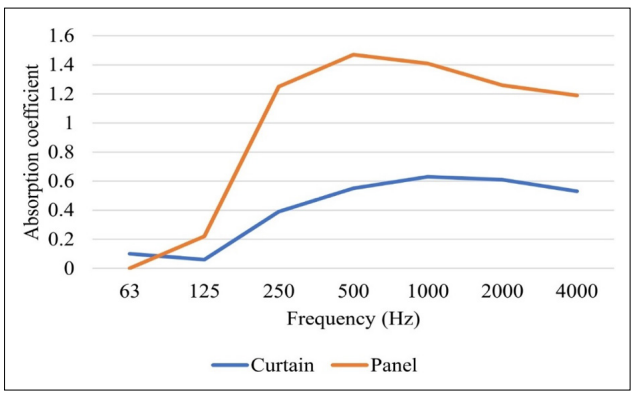


**Figure 8**. Curtain and panel sound absorption coefficients.

$$f_c = \frac{40P}{D} \quad (4)$$

where Fc is the critical frequency (Hz), P perforation percentage (%) and D hole diameter (inch). There are a total of 80 holes on the panels with a hole diameter of 7 cm. Panel dimensions are 103-126 cm (Figure 9). Total hole area is 3077 $cm^2$. Total panel area is 12978 $cm^2$. The perforation rate was found to be 23.7% and critical frequency was calculated as 345 Hz.

**Room Response and Modal Decay Time**

The room response is as shown in Figure 10 for 4 different versions. In all versions the floor is carpeted. In the V1 design, no sound-absorbing materials were used on the room walls and glass. In the V2 design, there is a thick curtain on the glass and door section. In the V3 design, there are a total of 7 panels on the walls. In the V4 design, 7 panels and curtains on the door and window section were used. It can be seen that a dip occurs at the frequency of 97.3 Hz in all four designs. At the frequency of 97.3 Hz, the sound level in V3 and V4 designs is 7 dB lower than in V1 and V2 designs. The use of 7 panels caused the dip region

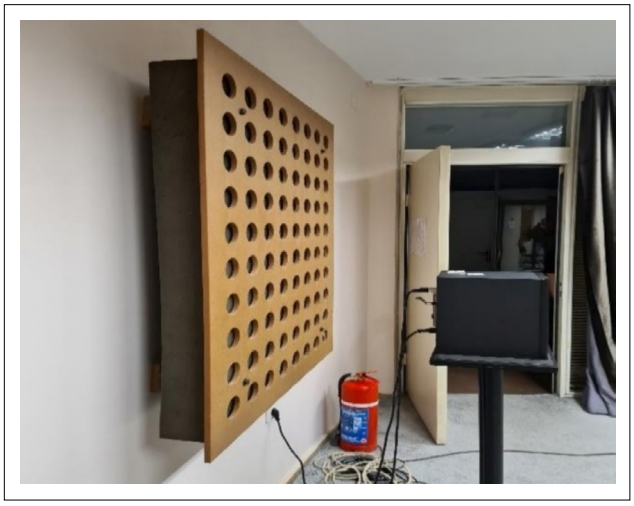

**Figure 9**. 10 cm sponge front wooden perforated panel.

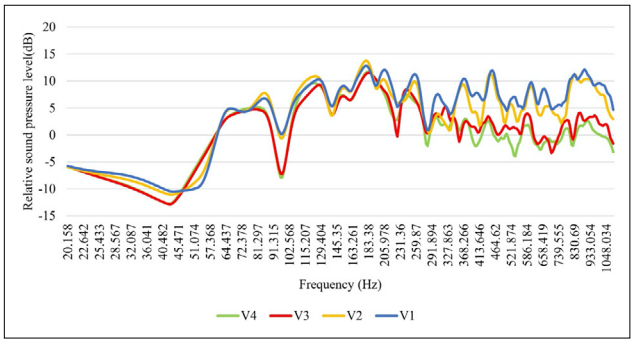


**Figure 10**. Room response.

at the frequency of 97.3 Hz to shift 7 dB lower. It has been observed that the use of curtains alone does not create a change in the room response up to 300 Hz. In the V1 and V2 versions, there is a change depending on the curtain usage situation.

Q values occurring at the frequency points where the room response curves peak are a criterion used to evaluate the perception of resonances. Q value was calculated using the formula given in Equation 5 (Everest, 2001), where Q is the quality factor, Δf is band width, F_c is mode frequency. It is obtained by dividing the peak frequency by the frequency range that is 3 dB below from the right and left. Q values calculated at the peak frequencies of the room response curves are given in Figure 10.

$$Q = \frac{F_c}{\Delta f} \tag{5}$$

For the V1 version, peak formations that could create a 3 dB difference on the right and left were detected for 8 frequencies. Peak occurrence was determined for 7 frequencies in V2 and 5 in V3 and V4. When V1 and V2 are compared, it is seen that the resonance frequencies are the same, but the peak at 455 Hz for V1 shifts to 445 Hz for V2. It was also observed that the peak at 205 Hz in the V1 version did not occur in V2. A peak occurred at 205 Hz only in the V1 version. The peak occurred at 85.7 Hz in V1 and V2 versions, and at 80 Hz in V3 and V4. Similar shifts occurred at frequencies of 179 Hz, 257 Hz and 454 Hz. It was observed that the 304 Hz and 368 Hz peaks that occurred in the V1 and V2 versions did not occur in V3 and V4. It is seen that the peaks disappear at these frequencies where panel absorbance is high.

At a frequency of 85.7 Hz, the Q value for V1 was 3.06, while it was 5.95 for V2. It has been observed that the use of curtains increases the Q value of the room mode at this frequency. The Q value of this peak, which occurred at 80 Hz between V3 and V4, increased from 2.94 to 3.5. It can be said that there is a similar effect, although less than the change between V1 and V2. Although there were minor changes in other peak frequencies between V1 and V2, no significant difference was observed. It is seen that in the V3 and V4 versions, the Q values decrease at the frequencies of 179 Hz, 241 Hz and 440 Hz compared to V1 and V2. It is seen that the peaks disappear at frequencies of 304 and 368 Hz. As a result of the calculations, it is predicted that the panel absorption coefficient will reach its maximum value at 345 Hz, and Q values also support this prediction. Both the shift and the decrease in the Q value at these frequencies compared to V1 and V2 occur as a result of the increase in panel absorbance. The absence of peaks at 304 and 368 Hz indicates that the panel is effective in the frequency region where its absorbance is highest (Figure 11).

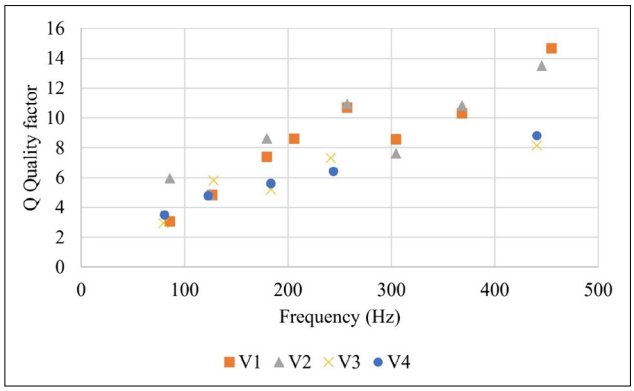


**Figure 11**. Q values of resonance frequencies.

Using Equation 6, the reverberation time value of the mode frequency is calculated. The reverberation time value of the mode frequency is found by multiplying the quality factor Q value by 2.2 and dividing the result by the peak frequency. In Figure 12, Tmodal values calculated using the Q values.

$$T_{modal} = \frac{2.2xQ}{f_c} \tag{6}$$

It can be seen in Figure 12 that, the reverberation time values of the mode frequencies seen in the room response, form a graph similar to the Q values. Tmodal is calculated using the Q value and as a result, it creates a functional graph depending on the Q value.

**ANSYS Simulation Results**

As a result of the simulations made with the ANSYS modal acoustic module, room modes in 4 different versions were examined. The degree to which room modes are affected by absorptive acoustic devices has been investigated. Despite its importance in structural dynamics and vibration, modal analysis is rarely performed in acoustics due to the high modal density of sound fields. Modal analysis results become important due to the low diffuse sound field in small volumes. There are differences in room mode shapes and frequencies when the surfaces are hard and reflective

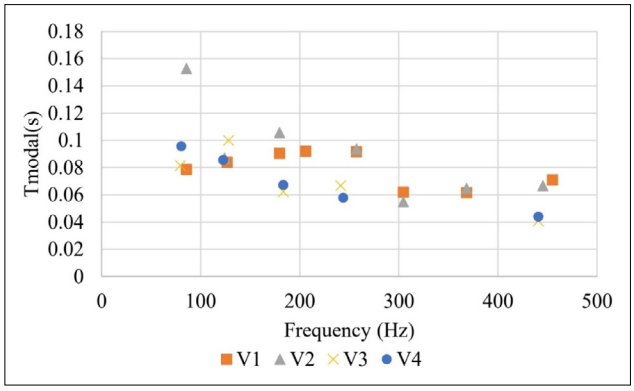


**Figure 12**. $T_{modal}$ values of resonance frequencies.

or when they are absorbing (Dowell et al., 1977; Meissner, 2008). As the absorption coefficient increases, the change in mode shapes also increases (Dowell et al., 1977). By changing the absorbance coefficient values of the curtain on the door and window and the carpet on the floor of the room where the study was carried out, it was observed how the modal frequencies and shapes changed. The changes in room mode shapes and frequencies were found by giving the absorbance coefficient values as 0, 0.2, 0.5 and 0.9, respectively. ANSYS Modal Acoustic module was used in simulation studies. Figure 13 shows the room modes in the first column, where there are hard walls and the absorption coefficient is 0. Column 2 shows the case where the absorbency of curtains and carpets is 0.2, column 3 shows the case where the absorbency is 0.5, and column 4 shows the case where the absorbency is 0.9. The first 3 axial modes of the x and y dimensions and the first axial mode of the z dimension are shown in Figure 13. When we look at the Figure 13, we see that there is no significant change between the situation where there is no absorbance and when it is at a value of 0.2. There was no deviation in the frequency values and the mode shapes did not change. It was found that when the 0.5 absorption coefficient in the 3rd column was used, the mode shapes did not change and the frequency values shifted less than 0.5 Hz. According to the data in the first 3 columns, it is seen that the room mode shapes do not change if the absorbance values of the surfaces are low. It can be said that when the absorption coefficient is 0.5, frequency deviations begin, but no change in mode shapes is observed.

In the last column, it was found that both mode shapes and frequency values changed when the absorption coefficient was 0.9. When the 4 columns are examined together, it is seen that the change capacity of the room modes increases as a result of the increase in the absorption coefficient. If the absorption coefficients of the absorber elements are high in the frequency band where the room modes are effective, it will be possible to change the frequency and shape of the room modes. It is seen that surfaces with low absorption coefficient do not affect room modes.

As a result of this simulation study, it is revealed that room modes can change as a result of high absorbance values. When 4 different room versions were examined, in cases V1 and V2, the situation in which the empty room was with or without curtains was examined. It is seen that in the case without curtains, only the absorbing areas originating from the carpet and the gathered curtains are formed, but their absorption coefficients are low for the frequency region below the Schroder frequency. For this reason, it can be seen in room response measurements that the effect of using curtains on room modes and room response occurs starting from 300 Hz. It is seen that the room response does not change in the V1 and V2 versions up to 300 Hz, but changes begin from 300 Hz onwards.

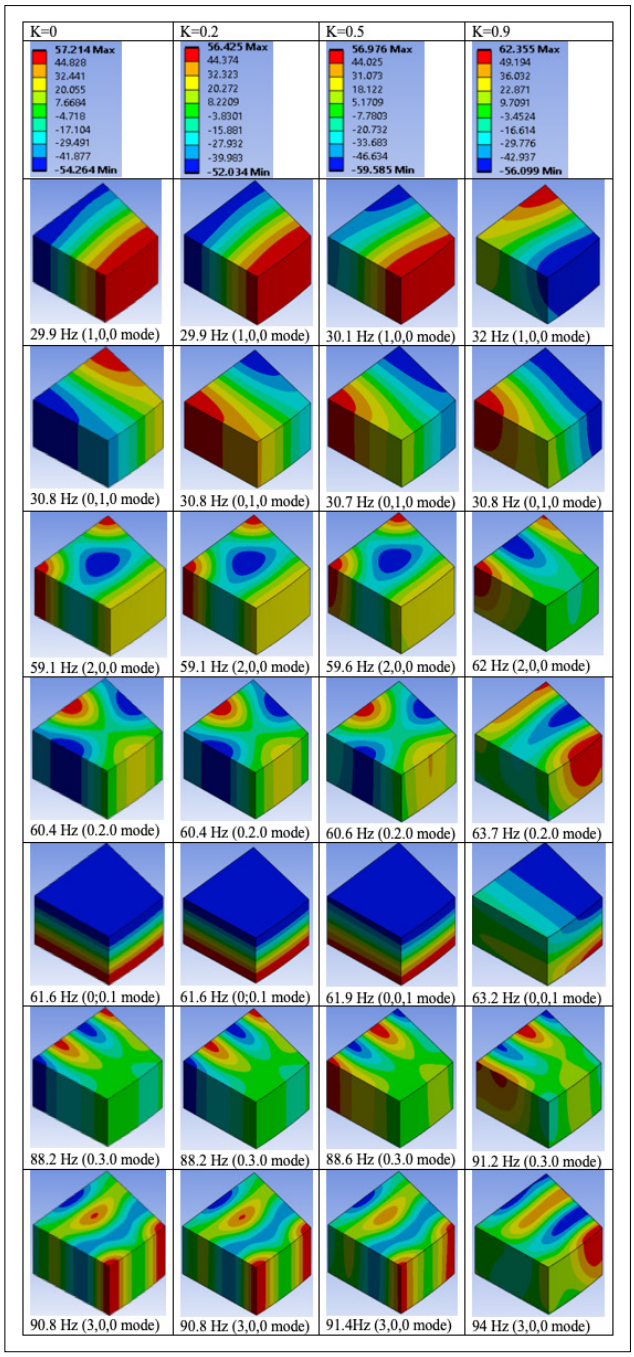


**Figure 13**. ANSYS modal analysis axial mode shapes and frequencies.

When the absorbance values found from area measurements where the panel and curtain were used for the region below the Schroder frequency, it was observed that there was no change in the simulation results compared to the solid wall. Since the absorptivity values are very low in this frequency band, there is no change in room mode shapes and frequencies for the region below the Schroder frequency. However, it is observed that there is a change in the room response and room mode shapes, especially since the panel absorption coefficients exceed 1 in the 250 Hz region.

## DISCUSSION

As a result of this study conducted on a non-rectangular room example, ISO 3382 parametric values, room response, room mode frequencies and shapes were found as a result of field measurement and simulation applications. These values for 4 different room versions were examined and compared. Changes resulting from the use of sound-absorbing materials have been observed (Table 4).

### Curtain Effect

In the V1 version, it was used as a curtain roller and a carpet absorber on the floor. In the V2 version, the curtain is drawn across the glass and door. When moving from V1 to V2, the expectation is that the reverberation time in the middle and upper frequency regions will shorten due to absorption. A 23% decrease was observed starting from the 250 Hz region. In the 4000 Hz region, the reverberation time decreased by 37.8% (Figure 14). As seen in the first row of Table 4, it has been observed that absorption is effective starting from the 250 Hz region. By comparing V1 and V2, absorption coefficient was found to be 0.39 in the 250 Hz region and 0.55 in the 500 Hz region. Figure 13 shows that there may be minor changes in room modes with this absorbance value. Absorptivity around 0.5 may cause minor changes in room mode shapes and frequencies. When we compare V1 and V2 in the room response curve, we see that there are decreases in sound level in some frequency regions starting from 280 Hz. It is seen that sound levels decrease and room response changes, depending on the use of curtains between 300-334 Hz, 392-426 Hz, 495-567 Hz, and 631-771 Hz. Absorption coefficient was found to be 0.55 in the 500 Hz center octave frequency region. In the room response, there was a downward change in sound level in 3 ranges in this frequency region.

The difference between V1 and V2 and V3 and V4 due to absorption begins to appear starting from 300 Hz. When we compare V3 and V4, there is a decrease in sound levels due to the use of curtains between 300-338 Hz, 388-422 Hz, 474-561 Hz and 770-1100 Hz. In addition, it was observed that in the V3 version, where only panels were used, a dip zone was formed in 3 different frequency regions compared to V4. V3 was found to be at a lower sound level than V4 between 221-231 Hz, 353-364 Hz and 680-724 Hz. While such a situation does not appear between V1 and V2, the reason why it occurs between V3 and V4 may be that there are changes in room modes due to the use of panels in this region and the use of curtains affects the room modes in these 3 frequency regions. It is thought that a thick velvet curtain reduces sound diffusion by increasing absorption on one side. It is seen that reverberation times decrease by 24% in the mid-frequency region between V1 and V2, and decrease by 23% in V4 and V3. It was found that the change between V1 and V2 was similar to the change between V3 and V4.

**Table 4.** Reverberation time changes according to versions

| Frequency (Hz) | 63 | 125 | 250 | 500 | 1000 | 2000 | 4000 |
|---|---|---|---|---|---|---|---|
| V1-V2/V1 | -2.63 | 9.26 | 22.99 | 24.49 | 23.56 | 27.73 | 37.82 |
| V3-V4/V3 | -2.81 | 8.85 | 3.37 | 16.16 | 20.34 | 18.05 | 12.14 |
| V1-V3/V1 | 0.02 | 17.46 | 50.18 | 45.22 | 37.93 | 36.03 | 34.72 |
| V2-V4/V2 | -0.15 | 17.09 | 37.49 | 39.18 | 35.31 | 27.46 | 7.75 |

### Panel Effect

Curtain bulk is added in V1 and V3 versions, and 7 panels are added in V3. As a result of examining the reverberation time, room response and room modes together, it was seen that the panels reduced the reverberation time in the mid-frequency region by 42% (Figure 15). In Section 2.3, the frequency range in which the panels are effective was calculated and the frequency with the highest absorbency was found to be 345 Hz. When we look at the reverberation time changes, it was found that the highest changes were in the 250 Hz and 500 Hz regions. It was observed that the panel absorbance calculated based on the reverberation

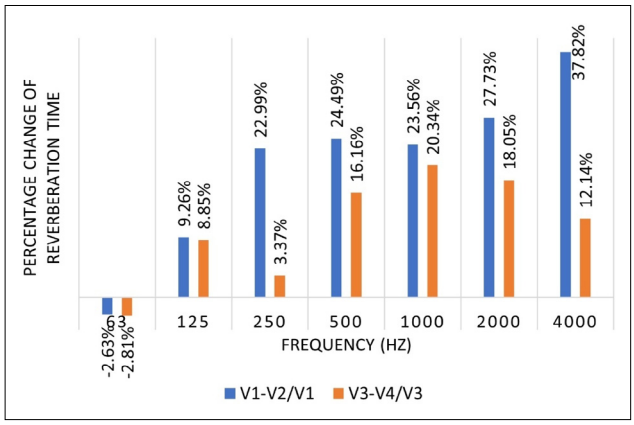


**Figure 14**. Reverberation time change percentage with curtain effect.

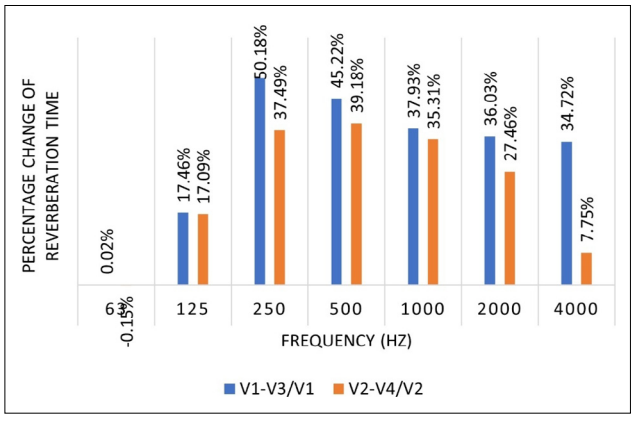


**Figure 15**. Percentage change of reverberation time with panel effect.

times had the highest absorption coefficient among the frequency regions with a value of 1.47 in the 500 Hz region.

Panel use lowered the dip point at 97.3 Hz in the room response curve by 7 dB. The same situation occurred for V3 and V4 at 97.3 Hz. As seen in Table 5, after the 95 Hz oblique mode and the 95.1 Hz tangential mode, 102.6 Hz tangential mode comes. It has been observed that the 7.6 Hz gap in between causes the room response to bottom out at 97.2 Hz. It was found that the sound level was 7 dB lower at the frequency of 97.2 Hz in V3 and V4 compared to V1 and V2. It is thought that the reason for this may be that the perforated wooden plate on the front faces of the 7 panels used, has a vibrating plate feature resulting from its own vibration frequency and increases the sound absorption of this frequency. It can be seen in the room response curve that similar situations occur at frequencies of 226 Hz and 356 Hz in panel use.

When we look at the change in the frequencies and shapes of the room modes with the absorption coefficients presented in Section 2.5, it is seen that the mode shapes and frequencies change when the sound absorption coefficients are greater than 0.5. Since the panel absorption coefficients found from both calculation and reverberation time measurement results in Section 2.3 took larger values in the 250 Hz and 500 Hz regions, the peaks in the room response that appeared at 304 Hz and 368 Hz frequencies compared to the case without a panel disappeared. The simulation results for modal analysis and the changes in the room response confirm each other. In the frequency regions where the sound absorption coefficient increased, the peaks formed by the influence of room modes disappeared at 304 Hz and 368 Hz, and the Q values of the peaks at 179 Hz, 241 Hz and 440 Hz also decreased. We can see the panel absorbance effect in the reverberation time, C80, room response measurement results, Q value and Tmodal calculations for the relevant frequency regions.

**Table 5.** Room mode frequencies and mode ranges

| Mode Frequency (Hz) | (x,y,z) mode | Difference (Hz) |
|---|---|---|
| 29.9 | 1,0,0 | |
| 30.8 | 0,1,0 | 0.9 |
| 44.3 | 1,1,0 | 13.5 |
| 59.1 | 2,0,0 | 14.8 |
| 60.4 | 0,2,0 | 1.3 |
| 61.6 | 0,0,1 | 1,2 |
| 67.8 | 2,1,0 | 6.2 |
| 68.5 | 1,0,1 | 0.7 |
| 68.9 | 0,1,1 | 0.4 |
| 72.3 | 1,2,0 | 3,4 |
| 75.9 | 1,1,1 | 3.6 |
| 85.3 | 2,0,1 | 9.6 |
| 86.2 | 2,2,0 | 0.9 |
| 86.3 | 2,0,1 | 0.1 |
| 88.2 | 0,3,0 | 1.9 |
| 90.8 | 3,0,0 | 2.6 |
| 91.6 | 2,1,1 | 0.8 |
| 95 | 1,2,1 | 3,4 |
| 95.1 | 3,1,0 | 0.1 |
| 102.6 | 1,3,0 | 7.5 |
| 106 | 2,2,1 | 3,4 |
| 107.6 | 0,3,1 | 1.6 |
| 109.1 | 3,2,0 | 1.5 |

## CONCLUSION

In this study, which aims at the modal analysis of non-rectangular rooms, reverberation time, clarity and room response measurements were made and compared with the modal acoustic simulation data of the room. Room response is used to determine room modes through measurement. By looking at the room response, the effect of room modes at the measurement point can be observed. One of the features that can affect room response is the sound absorption properties of the surfaces. Although it is known that room modes change with surface absorbance, studies on how the change will occur according to the absorption coefficient remain limited. As a result of the simulations carried out in this study, it was observed that as the sound absorption coefficients of the materials to be used on the surfaces increase, they can change the shapes and frequencies of the room modes in the frequency bands in which they are effective. It has been determined that this change begins when the absorption coefficient is greater than 0.5.

It was evaluated how accurately the empirical formulas produced to calculate the absorption effects of the acoustic devices to be used in the room according to frequency determined the impact area. It has been observed that the measurements and calculations confirmed each other. This experimental study, using variable absorbers, was designed for 4 different versions of the room. In the experiment designed with curtains in use in V1, curtains open in V2, 7 panels in use and curtains not in use in V3, and curtains and 7 panels in use in V4; the reverberation time of the curtains and panels, C80, room response and Q of the peaks were determined. Its impact on the values was investigated. According to the hypotheses generated at the beginning of the study, the panels will have the highest absorbance value at the 345 Hz frequency, and the absorbance values will decrease to the right and left of this frequency. It was hypothesized that the effect of curtain absorbance would also occur in the medium and high frequency regions. It is thought that as the absorbance values increase, the change

of room modes will increase and the room response will become smoother and the peaks will decrease.

As a result of field measurements, simulations and calculations, it was observed that the room modes changed with the absorbance and the room response became smoother. It has been determined that these changes occur in frequency bands where absorbing materials are more effective, and that the room response does not change in frequency bands where sound absorption coefficients are less than 0.5. It was found that the panels used in the V3 and V4 versions maximized their effectiveness around 345 Hz, as calculated, and as a result, they created changes in both room response and reverberation time and clarity parameters in the 250 Hz and 500 Hz regions. These panels contributed to the smoothing of the room response by eliminating the 304 and 368 Hz peak regions in the room response and reducing the Q values of the peaks at 179 Hz, 241 Hz and 440 Hz frequencies.

As a result of this study, it was found that the desired changes in room response and room acoustic parameters can occur as a result of the use of acoustic materials with correctly calculated absorbance depending on frequency. As a method, below steps in order were determined:

1. determining the room modes by simulation
2. obtaining reverberation time, clarity and room response curves by making field measurements
3. determining the absorption coefficients, layout and design of the acoustic absorption materials
4. manufacturing and assembling the acoustic absorption materials
5. making the measurements after the application of the absorbers and analyzing them comparatively with the first measurements.

Among the limitations of the research the fact should be expressed that the absorption properties of sound absorbing materials may vary depending on the usage patterns, room characteristics and design goals. Generalizations can be made in room acoustic design by taking into account the differences in these variables.

Based on this research, it is recommended for future research to discover materials with higher absorption capacities and test them in different room sizes and shapes.

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**Article**

# Evaluation of the origins of Sedad Hakki Eldem's Anitkabir competition project proposal through his sketches during his student years

**Kerim KÜRKÇÜ*, Nur URFALIOĞLU**

*Department of Architecture, Yıldız Technical University Faulty of Science and Engineering, İstanbul, Türkiye*

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## ABSTRACT

Sedad Hakkı Eldem, a prominent figure in modern Turkish architecture, was deeply influenced by his elite Ottoman family background and his early exposure to European culture. His education at Istanbul's Sanâyi-i Nefîse Mektebi and his interest in Anatolian heritage shaped his architectural philosophy. Eldem's 1924–1925 sketchbooks, containing 120 sketches and newspaper clippings, reveal his fascination with Turkish architectural styles, from Anatolian Seljuk to Ottoman designs, as well as European modernist influences.

The sketches cover a variety of subjects, including building designs, urban settings, and architectural details, reflecting his academic training and personal interests. The clippings focus primarily on Anatolian cities and Turkish architectural heritage, and were collected before Eldem's firsthand exposure to these places. Eldem's 1942 proposal for the Anıtkabir competition embodies this synthesis, drawing on the inspirations of his student years, particularly Seljuk and Ottoman architectural forms.

Although he did not win the competition, Eldem's design was recognized for its incorporation of traditional Turkish elements, exemplifying his vision of "Turkifying" the architectural heritage. His broader contribution to architecture is characterized by an integration of modernity with historical continuity, as seen in his teaching and professional work. Eldem's dedication to documenting and abstracting Turkish architectural traditions, evident in his early sketches, defined his lifelong architectural ethos.

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## INTRODUCTION

One of the leading architects and academics of modern Türkiye, Sedad Hakkı Eldem was born into an Ottoman elite family that played significant roles in the realms of culture, art, and bureaucracy during the late Ottoman Empire. His upbringing in a well-established family and subsequent exposure to European cities and culture until the age of 16 shaped his architectural education at Sanâyi-i Nefîse Mektebi, which enabled him to become a leading figure in the architectural development of modern Türkiye. His education in Europe, the cultural background of his father,

***Corresponding author**
*E-mail adres: kerimkurkcu@gmail.com

a bureaucrat, and his mother's side, which was based on Ibrahim Edhem Pasha and Osman Hamdi, fostered in him a multicultural understanding and a national consciousness. After he started his architectural education in Istanbul, his interest in local culture and national consciousness became more prominent in his sketches dated 1924 and 1925. The influence of this newly developing interest can be observed in his future works where he was researching and documenting the architectural heritage in a continuity, without ignoring its historical development. This approach to the question of heritage can also be observed in these lectures at the academy where he taught these studies to his students. In consequence of the aforementioned factors, in addition to his identity as an architect, he is also one of the most significant designers, practitioners, and educators of his period. This article aims to examine the connections between Sedad Hakkı's sketchbooks that are dated in 1924 and 1925 and his design proposal for the Anıtkabir Architectural Project Competition. In these sketchbooks, in addition to his sketches of various real or imagined buildings, we can also find newspaper clippings with the photographs of the new or historical buildings. This is being done in an ongoing doctoral thesis titled "Evaluation of Sedad Hakkı Eldem's Architecture through Sedad Hakkı Eldem's Unpublished Sketches"

This study employs five sketchbooks, as primary sources, consisting of 120 sketches that Sedad Hakkı drew during his first year as an architecture student in addition to the numerous newspaper clippings on urban settings or buildings[1]. Upon examination of the subjects depicted in the sketches and the notes written on them, it becomes evident that these drawings were created with three distinct purposes: firstly, as a part of his training at the academy, secondly, the excursions that accompanied his training and thirdly for his personal interests such as automobiles, fashion design, graphic design etc (Bozdoğan et al., 2005). The sketches encompass a diverse range of subjects, including graphic design, detail drawings, fashion design, façade and plan studies, furniture design, building design, urban design, interior design, transportation vehicles, and also functions such as accommodation, transportation, housing, and work. Moreover, the sketches are influenced by various styles and historical periods, including the First National Architecture Movement in Türkiye, Neoclassical, Chicago School, Transatlantic/Streamline Aesthetics, Ottoman, Anatolian Seljuk, and Great Seljuk (Figure 1). The newspaper clippings in the initial sketchbook predominantly feature photographic documentation of Anatolian urban centers and their architectural heritage. As Sedad Hakkı had not yet traveled to Anatolia in 1924 and 1925, it can be inferred that he obtained information about Anatolian cities and buildings from newspapers and magazines and subsequently archived the ones that piqued his interest. The newspaper clippings include general views of Anatolian cities visited by Mustafa Kemal Atatürk, examples of Anatolian Seljuk and Ottoman architecture,

**Figure 1**. A Selection of Drawings in Sedad Hakkı Eldem's Sketchbooks.

factory buildings, and especially the construction activities of the new Republic of Türkiye and its capital, Ankara. Additionally, the clippings predominantly feature photographs of buildings associated with the First National Architecture Movement (Figure 2).

In 1924, when Sedad Hakkı returned to his country, the Republic of Türkiye, which had been established on October 29, 1923, as a result of the events that had taken place both within the borders of the Ottoman Empire and around the world since the beginning of the 20th century, it had not yet completed its first year. Mustafa Kemal Atatürk, the leader of the Turkish War of Independence and the founder of the Grand National Assembly of Türkiye, which opened in Ankara on April 23, 1920, was elected the first President by the Grand National Assembly. Under Atatürk's leadership, the Republic of Türkiye began a comprehensive modernization and structural transformation, and architecture inevitably took an important position. Bozdoğan (2001) posits that high modernism was embraced as an ideological tenet in the nascent years of the Republic. She elucidates this assertion by stating, "Modern architecture was imported as both a visible symbol and an effective instrument of this radical program to create a thoroughly Westernized, moden, and secular new nation dissociated from the country's own Ottoman and Islamic past." Sedad Hakkı Eldem's diary entries from 1925-26 indicate that he was also influenced by the extensive and comprehensive reconstruction activities undertaken by the Republic of Türkiye. The entries in his diary dated June 1925, "Ah! If only I could go to Anatolia, I am so curious!" and January 1926, "But something very big happened this year: I became Turkish! And I became such a fanatic!" expresses his excitement and interest (Eldem, 2008). As an extention of these interests, in the newspaper clippings he kept among his sketchbooks, Sedad Hakkı mostly collected examples of the First National Architecture Movement.

Following the death of Mustafa Kemal Atatürk on November 10, 1938, a project competition was announced on February 18, 1941, by the Prime Ministry Commission of Anıtkabir for the mausoleum planned to be built in the Rasattepe area of Ankara. The next day, it was publicly announced in the newspapers that an international free architectural project competition for Mustafa Kemal Atatürk's mausoleum would be opened to local and foreign architects (Anonymous, 1941). The 'Instructions for the Competition' section of this specification, which consists of 24 articles, explains that the project will be built at the highest point of Rasattepe and that participants can apply with a single project. Additionally, it includes the conditions of participation, the jury committee, awards and project submission conditions. In the second part of the specifications, 'Program', which consists of 30 articles, the principles according to which the Memorial and Mausoleum to be built for Mustafa Kemal Atatürk are specified (Boran, 2011). In particular,

**Figure 2**. A Selection of Newspaper Clippings found in one of Sedad Hakkı Eldem's Sketchbooks.

the program items listed requests the design of Anıtkabir as a visitors' center consisting of a large hall of honor with Atatürk's mausoleum, where a large number of visitors can show their respects at the same time, and that the building should be seen clearly in the city skyline from a distance. The competition, which was stated in the specifications to be completed on October 31, 1941, was completed on March 2, 1942 with a decision taken during the process. The foreign jury members of the competition were Prof. M. Tenghom from Sweden, Prof. Karoly Wickinger from Hungary and Prof. Paul Bonatz from Germany, while the Turkish members were Prof. Arif Hikmet Holtay, the Head of Building and Construction Affairs at the Ministry of Public Works, Engineer Muammer Çavuşoğlu, and the Director of Construction of Ankara, Architect Muhlis Sertel. There were 47 entries to the competition. The jury, held its first meeting on March 12, 1942 and announced its decision on March 21, 1942. According to the competition specifications, the jury was required to recommend three projects, from which the government had the right to choose the one to be built. Among the 11 finalists, the jury selected Prof. Johannes Kruger's project number 9, Prof. Emin Onat and Assoc. Prof. Orhan Arda's project number 23, and Prof. Arnoldo Foschini's project number 44. In addition, five projects received honorable mentions among the finalists. Among the three projects selected by the jury as the finalists, the project designed by Emin Onat and Orhan Arda was chosen to be built (Boran, 2011).

Sedad Hakkı Eldem's design proposal competed with number 28, but did not receive any awards. However, his project was published in the 3-4th issue of *Arkitekt* Magazine in 1943 as a part of an article that concentrated on the projects that did not win a prize in the competition. In the article, which was written by Zeki Sayar (1943), Sedad Hakkı Eldem's project is described as "Prof. Sedad Hakkı Eldem wanted to create the Anıt-Kabir based on the old Turkish architectural works, of which there are many examples. In this respect, both in the organization of the plan and in the architectural motifs and masses, the influence and expression are completely Turkish." Wilson (2009), on the other hand, compares Eldem's project to the Kharragan Twin Tombs (Figure 3), an example of Great Seljuk Architecture in Iran, and the Zeynel Bey Tomb in Hasankeyf (Figure 4). Octagonal planned Kharragan Twin Tombs are examples of brick tradition of Great Seljuks; the oldest one was built by the architect Muhammed ibn Makki of Zinjan in 1067-68 and other one was built by either his brother or his son in 1093 (Hoag, 1975). Zeynel

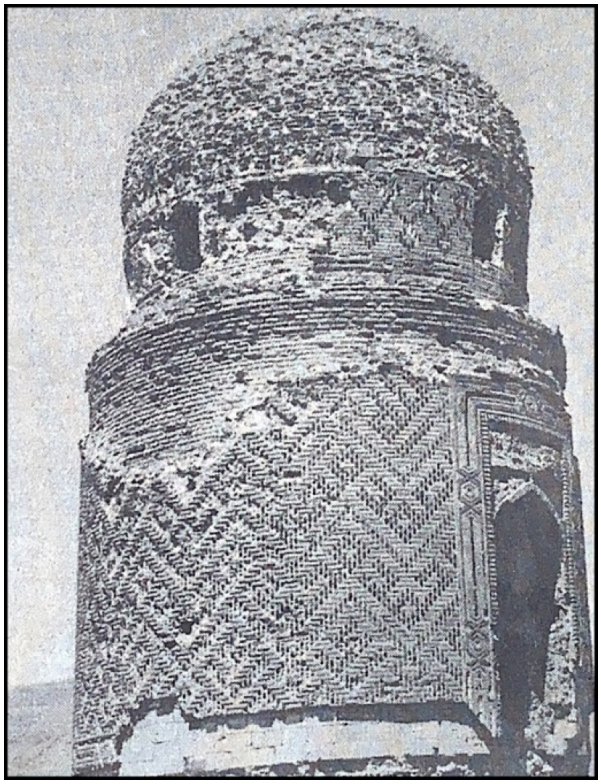

**Figure 4**. Zeynel Bey Tomb in Hasankeyf (Aslanapa, 1984).

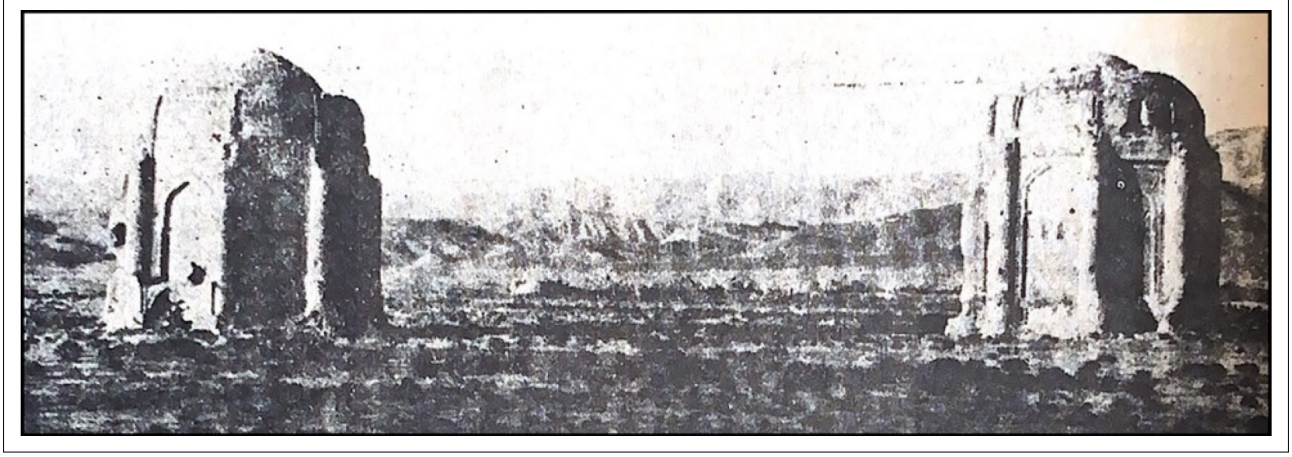

**Figure 3**. Kharragan (Harekkan) Tombs (Aslanapa, 1984).

Bey Tomb was built after his death in 1473 as a diagonal patterned circular brick kümbet with a hemispherical dome (Archnet, 2024).

Sedad Hakkı Eldem's published design proposal for Anıtkabir is a domed mass placed on top of the Rasattepe with a square base and a cylindrical body. The hall of honor is centrally positioned on a rectangular platform reached by stairs from its long sides. A small version of the hall of honor was placed on one of the short sides, in line with the central axis. At the four ends of the rectangular platform, which was apparently intended for outdoor ceremonies, torch towers are placed, rising up to the starting level of the dome of the hall of honor. The plan of the hall of honor is square on the outside and circular on the inside. The square base with entrances on all four sides is connected to the cylindrical body with a chamfered transition seen in the architecture of the *kümbet*. The high body carrying the dome is divided into twenty-eight slices to give the effect of a colonnade and is supported by long thin window openings (Figure 5 and Figure 6). Atatürk's words "My humble body will surely one day turn to dust, but the Republic of Türkiye will remain forever." are placed around the body of the dome, which can be fully felt from the interior. As can be seen from the drawings, it is understood that a dramatic light beam was intended to be received from the sliced long thin window openings starting just below this text. In addition, on both sides of the mausoleum in the hall of honor, there are scaled versions of the torch towers, which we also find in the corners of the outer platforms of the building.

Before analyzing Sedad Hakkı Eldem's Anıtkabir design proposal in the light of his sketchbooks, it is important to concentrate on his childhood and youth to understand his design and architecture philosophy better. Sedad Hakkı Eldem was born in 1908 in Istanbul to a family of bureaucrats. On his mother's side, he is a descendant of Ibrahim Edhem Pasha, who served in many high-level government positions such as grand vizier, minister and ambassador. Osman Hamdi, an archaeologist, museologist and painter, was his great-uncle. His father Ismail Hakkı was a state official who served as a writer, diplomat and translator. His cousins are Mustafa Vahid Bey, one of Ottoman Empire's first art historians, and Cemal Reşit Rey, one of the most important composers and conductors of the Republican Era. It is remarkable that Ibrahim Edhem Pasha's descendants almost never engaged in military service and commerce but embraced intellectual pursuits such as bureaucracy, culture,

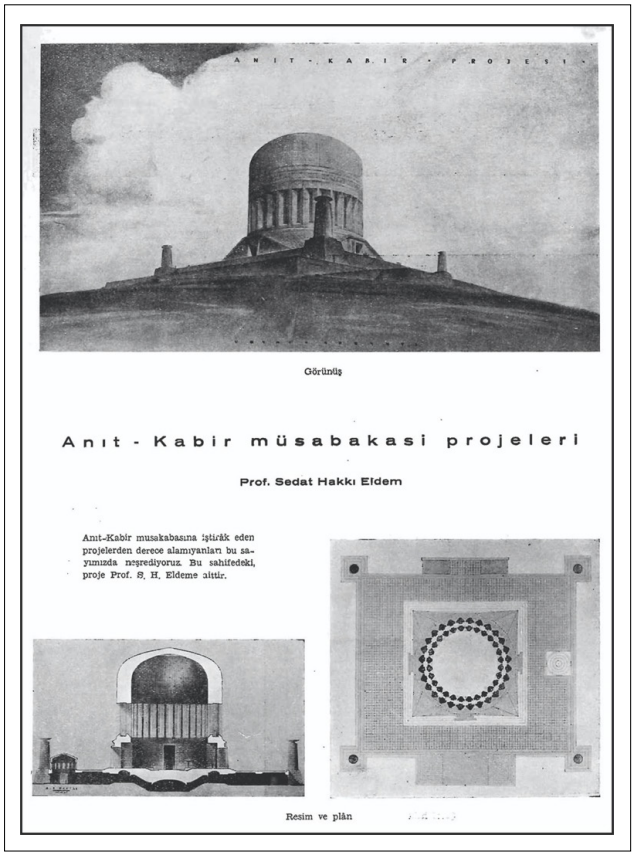


**Figure 5**. Sedad Hakkı Eldem's Anıt-Kabir competition project proposal published in Arkitekt, 1943, issue 3/4, Page 59; view, section and plan.

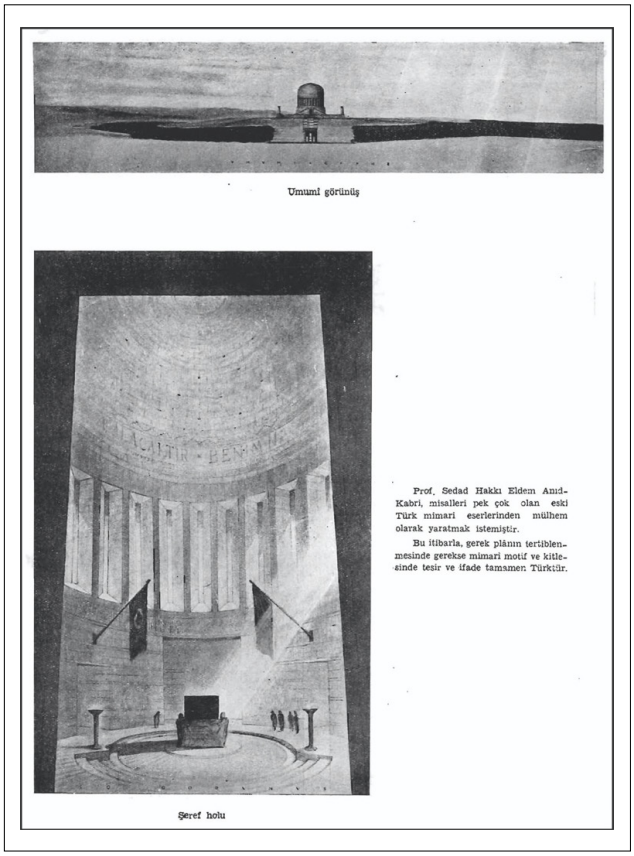


**Figure 6**. Sedad Hakkı Eldem's Anıt-kabir competition project proposal published in Arkitekt, 1943, issue 3/4, Page 60; view and interior.

art, literature and music. Having spent his childhood and youth in France, Switzerland and Germany until the age of sixteen, Sedad Hakkı returned to Istanbul with his family in 1924. He found Istanbul different than what he imagined through his learnings from books or narratives of his family members. The city as well as the whole country was in the middle of a great structural change. The effort to understand both the Republic of Türkiye, which was established as the end point of these changes, and the local architecture as an extension of his education, are important factors shaping Sedad Hakkı's early understandings of architecture. Sedad Hakkı, who moved to Istanbul from Germany, said in his memoirs that he wanted to study architecture and for this purpose, he was introduced to Vedat Tek by his family and thus he was accepted to the Sanayi-i Nefise Mektebi, which was in Cağaloğlu at that time. When he started his architectural education, his interest in the construction processes of buildings that he observed while living in Munich, his admiration for the construction styles and detailed workmanship that are influenced by the Arts & Craft movement in Germany, and his interest in various art and architecture magazines and architects such as Kral Friedrich Schinkel, Bruno Taut, Adelbert Niemeyer, Bruno Paul, Le Corbusier and Emile Ruhlmann are noteworthy. Sedad Hakkı wrote in his memoirs that "*... I was not an architect 'out of the blue', I had a background in architecture before I came to Türkiye. My background was in both traditional and modern architecture. Therefore, I had a lot of knowledge about the buildings that Le Corbusier and other masters, who come to mind when it comes to 'modern architecture', had built or started to build. I had studied them all.*" (Özkan & Yenal, 2014). As Sedad Hakkı repeats many times in his memoirs, he was familiar with the works of many famous architects from Schinkel to Le Corbusier when he started his architectural education and that he personally observed the new buildings that were constructed in Europe, especially in Munich, Germany. In addition, in the budget books kept by her mother, the expense items of book bindings, newspapers, magazines and especially the magazine 'Kunst' in the last four months of 1924 shows his familiarity with the discourse around the new architecture (Eldem, 2008). It could easily be concluded that that Sedad Hakkı, coming from a family interested in art and architecture and frequently expressing this interest himself, studied these publications and was aware of the international art movements and discussions of the period.

In 1924, the year Sedad Hakkı began his education at the Sanayi-i Nefise Mektebi, the 1924 Regulation, the first comprehensive change the school sees in the Republican Period, is published. This regulation also proposes changes in the architecture education. The most important change in the program, in which the old courses are updated with some corrections and additions, is the addition of a course on the history of Turkish and Islamic architecture to the curriculum (Gençel, 2021). Along with these changes, Celal Esad Arseven was assigned to take over the history courses in 1924, the year Sedad Hakkı began his education. The school also housed design studios of Vedad Tek and Mongeri. Sedad Hakkı attended Mongeri's studio, not Vedad Tek's, who was the reason for his admission to the school. He also took architectural history courses from Celal Esad Arseven.

In the third of the five sketchbooks that Sedad Hakkı is thought to have kept for his studio studies and history classes show a building with a plan sketch, a front view sketch, perspectives from the front and rear facades, and a silhouette drawing showing its positioning within the city in two consecutive pages (Figure 7). From its massing and plan configuration, it could be concluded that this building was designed for an accommodation function. The building has an entrance portal and a dome, which are also clearly visible in the plan scheme. The dome has a high drum, which is common in Turkish Architecture in Central Asia. The shape of the dome and the entrance portal are reminiscent of the Gūr-i Amīr Mausoleum, an example of Timurid Architecture (Figure 8 and Figure 9). The wide surfaces placed on both sides of the entrance portal protruding forward from the main door give the impression of a pilaster and do not continue horizontally on the upper part. This design can also be clearly seen from the plan scheme. In the perspective drawing of the

**Figure 7**. Sedad Hakkı Eldem's sketches of a building designed for an accommodation function in sketchbook-3.

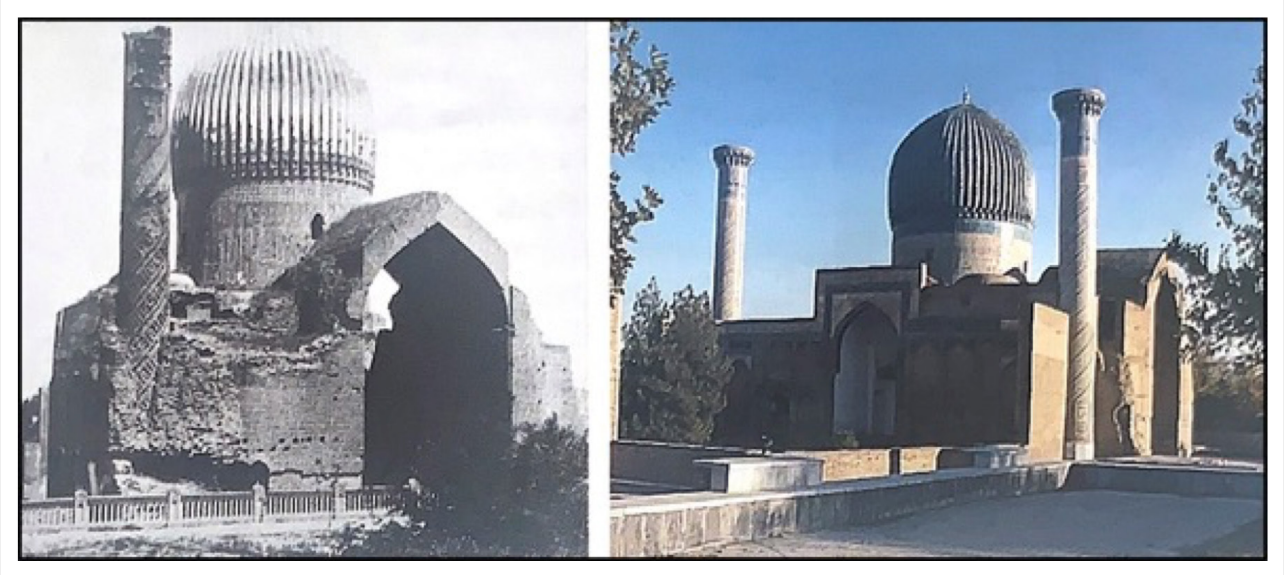

**Figure 8**. Gūr-i Amīr Mausoleum; Left image is showing its condition before restoration in 1974, and on the right side is a photo after restoration (Stierlin, 2006).

façade of the building, it is understood from the traces of erasure that weight towers or a miniature version of the main dome were positioned on these pilaster-like parts on both sides of the crown gate and then discarded. The large pointed arch on the central axis tapers upwards and forms a muqarnas junction. Rosettes are placed on both sides of the arch. On both sides of the façade, there is a lower mass that probably continues for two floors. The layout of this lower mass consists of long rectangular openings with pointed arches that continue throughout the two floors. The plan scheme of the building placed on the left edge of the sketch is similar to the layout of the *Gūr-i Amīr Mausoleum*. While in the *Gūr-i Amīr*, the entrance portal that is aligned with the mausoleum opens into a large courtyard, in Sedad Hakkı's design, the courtyard between the entrance portal and the mausoleum has evolved into a large corridor-like closed volume (See Figure 9 and Figure 7). The drawing shown in Figure 10 is a detail sketch of the rear façade of the building in Figure 7. The dome with a high drum, which is common in Turkish Architecture in Central Asia, stands on a square base. It is understood from the drawing that the corners of this base are chamfered in a triangular shape. This arrangement suggests that it was influenced

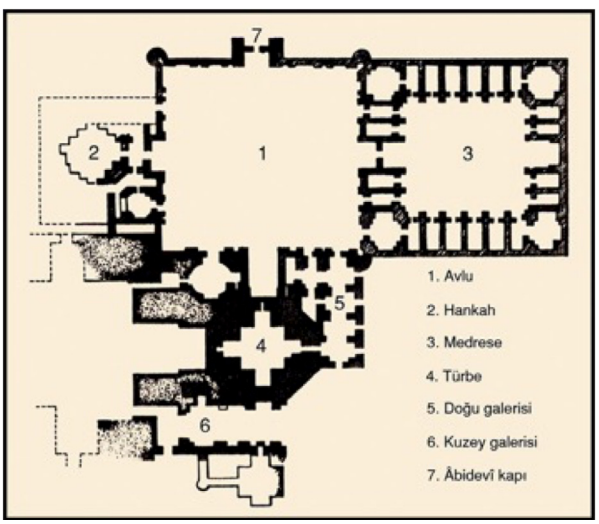


**Figure 9**. Gūr-i Amīr - Plan (Beksaç, 1996).

**Figure 10**. Sedad Hakkı Eldem's rear perspective drawing of a building designed for an accommodation function in sketchbook-3.

by Seljuk kümbet architecture. As it is understood from the perspective, the central axis of the rear façade of the building ended with a volume resembling the exterior appearance of the apse sections of the Byzantine churches in Istanbul. In the lower parts next to the main mass in the center, the triple arch composition and wide eaves and buttresses, which are the characteristics of the First National Architecture Movement, were used.

In Sketchbook-1, spread over two consecutive pages, is the study for a mausoleum design (Figure 11 and Figure 12). These drawings include a perspective view of the building, a perspective of the interior, a plan diagram and a roof plan. The sketch on the first page shows a perspective drawing of a square-planned and very tall, monumental structure on a platform of steps (See Figure 11). The main part of the building, which is carried on four square piers, rises as a prism. A crescent star motif with its star pointing towards the sky is placed on flat facades of these prism, and the radial patterns emerging from the ridge of the crescent continue along the facade. The dome, which refers to the domes of mosques, is centered on this mass by backing away from the beams. The drum carrying the dome is formed by placing an octagon with four short and four long sides at an angle of 45 degrees to the square base. A monumental sculpture and three cannons are placed on the entrance/approach axis of the building. The second page shows the interior perspective, plan scheme and roof plan of the mausoleum (See Figure 12). From the plan diagram, it is understood that it is a baldachin-type building with a square plan carried on four square piers with a dome placed at the center. The square-planned building sits on a rectangular base formed by steps similar to the stylobate in Roman temples. The building was positioned by pulling back from the long side of the rectangular base and a monumental sculpture and three cannons were placed on the empty entrance/approach axis. This design suggests that the building is a mausoleum study for the martyrs of the War of Independence. The above two project studies selected from his sketchbooks suggest that Sedad Hakkı was inclined to use traditional motifs and masses from Anatolian and Asian geography for

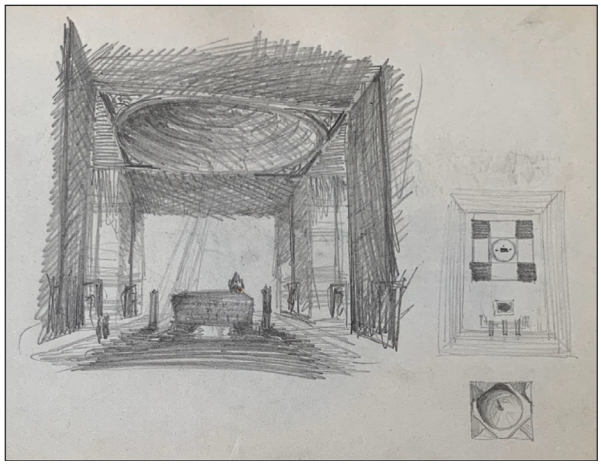

**Figure 12**. Sedad Hakkı Eldem's interior perspective and plan drawings of a mausoleum design in sketchbook-1.

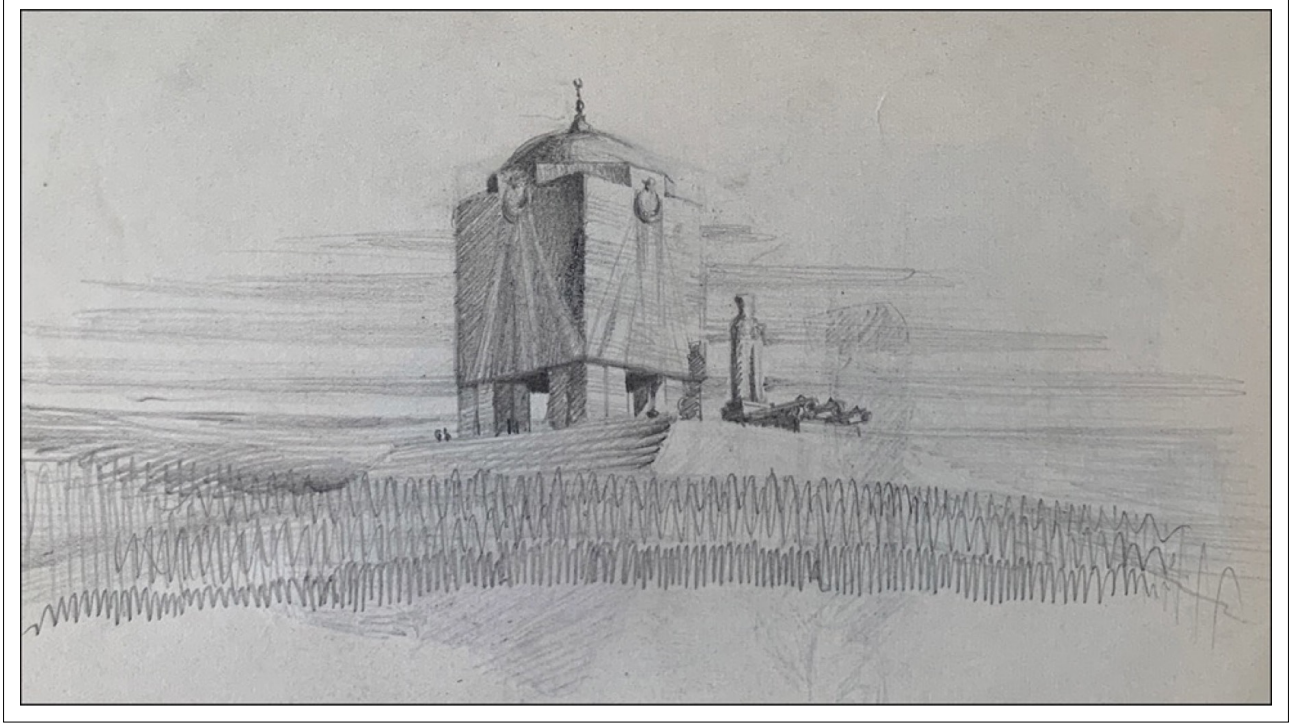

**Figure 11**. Sedad Hakkı Eldem's perspective drawing of a mausoleum design in sketchbook-1.

**Figure 13**. A newspaper clipping showing Kabul, Afghanistan, preserved in Sketchbook-1 by Sedad Hakkı Eldem.

monumental buildings that would be prominently visible in the city skyline since his student years. It could be said that he returned to this approach with his Anıtkabir proposal, where the competition specifications demand that the silhouette of the building, which will be located at the highest point of Rasattepe, should be clearly visible from within the city.

The newspaper clippings which were collected by Sedad Hakkı in the Sketchbook-1 are mostly dated to 1925 or earlier and include photographs of Ankara and cities from Anatolia. These photographs show the early construction of the Republic of Türkiye, as well as Ottoman and Anatolian Seljuk architecture such as mosques and *külliyes*. The majority of the photographs showing the landscape of the cities and/or construction activities were published on the occasion of President Mustafa Kemal Atatürk's visits to those cities, as evidenced by the captions. In addition, a small number of newspaper clippings from cities outside the borders of the Republic of Türkiye, such as Kabul, Madras, Damascus and Warsaw, can be seen.

One of the newspaper clippings shows a photograph of the city of Kabul (Figure 13). The caption under the photograph reads in Ottoman Turkish: "General view of the city of Kabul, the new throne of Afghanistan". Within the cityscape, the mausoleum of the Durrani ruler Timur Shah, built in the first half of the 19th century, draws attention with its octagonal main volume and its large high-drummed and stepped dome in the upper right corner of the photograph with a dominant presence in the city skyline. As can be seen from the photograph in the newspaper clipping, the tomb has a high ground floor with an octagonal plan, large and wide iwans serving as entrance gates on four sides and a combination of smaller iwans and niches on the remaining four sides. The ground floor was finished with a terrace roof and a high-drummed dome was placed on it, pulling back from the facades (Archnet, n.d.). A dome rises above this drum.

Two of the newspaper clippings in Sketchbook-1 contain photographs of the general view of Konya (Figure 14). In one of the photographs, where Mevlana Complex could be seen clearly on the foreground, the caption reads in Ottoman Turkish: "The public view of Konya, which His Excellency the President of the Republic arrived yesterday". As seen in the photograph, the Mevlana Complex occupies a dominant place in the city silhouette. Here, the tiled mausoleum dome finished with a conical cone on the sixteen-slice high body of the complex draws attention together with the minaret.

In the caption of the photograph, which shows Konya Alaeddin Hill and Alaeddin Mosque in the distance, it is written in Ottoman Turkish: "A view of the city and the park

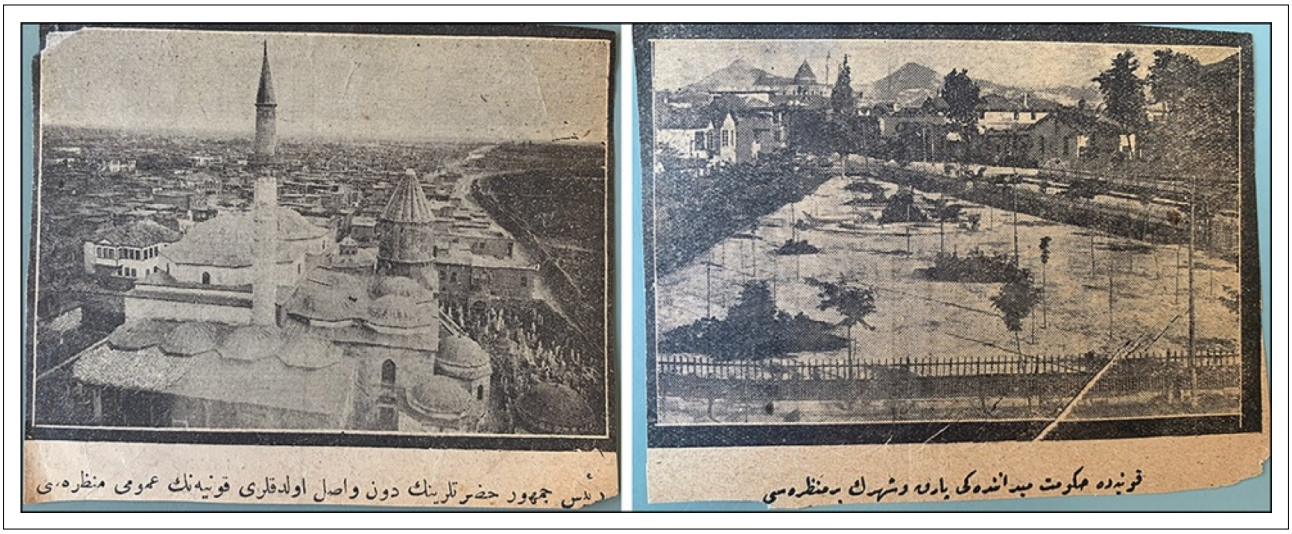

**Figure 14**. Two newspaper clippings showing Konya cityscape, preserved in Sketchbook-1 by Sedad Hakkı Eldem.

in Konya government square" (See Figure 14). Although the main subject of the photograph is stated as the government square and the park in front of it, the *kümbet* with a ten-sided cone on a ten-pointed cut-stone body built by Kılıç Arslan II, which is part of the Alâeddin Mosque, is clearly seen in the distance.

Another newspaper clipping shows a detail photograph of the newly opened 4th Vakıf Han (Figure 15). The photograph shows the prominent and exaggeratedly emphasized corner tower of the 4th Vakıf Han, designed by Architect Kemalettin. In addition, triple arch compositions, wide eaves and buttresses were used on the upper floor of the building, continuing along the facade after the corner tower. When the newspaper clippings are analyzed, it could be observed that Sedad Hakkı was very interested in photographs that show city views with buildings that are prominent in the skylines. The four clippings selected for this study include domed masses from three cities, at different scales and from different periods.

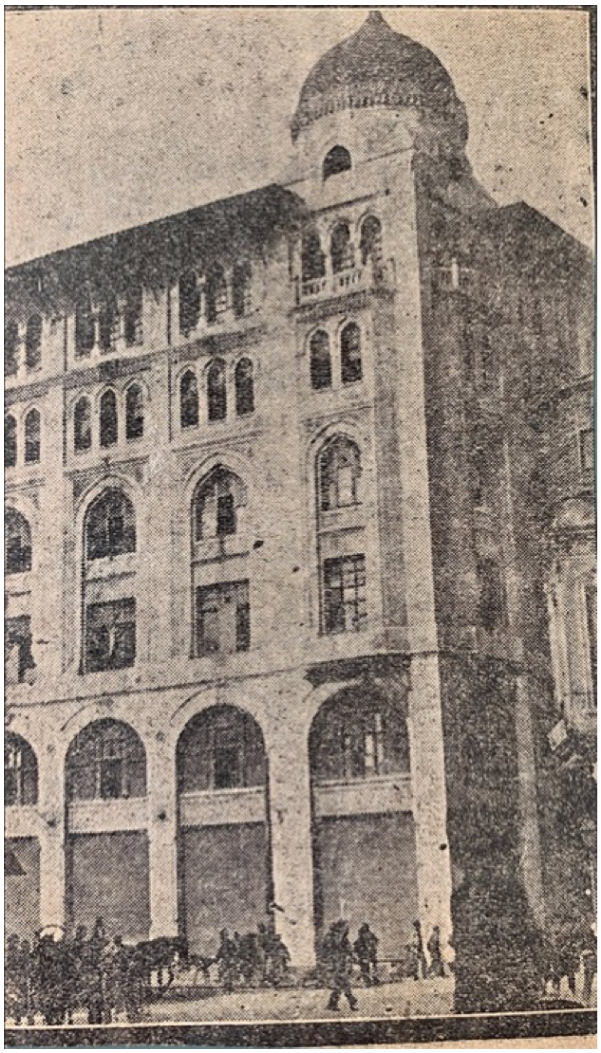

**Figure 15**. A newspaper clipping showing 4th Vakıf Han, preserved in Sketchbook-1 by Sedad Hakkı Eldem.

It is possible to discuss that Sedad Hakkı's inspiration of this proposal to the Anıtkabir competition could be mapped by analyzing the drawings and the photographs in these sketchbooks. It is understood from the drawings and photographs that the inspirations are in the scales of mass, plan and detail. It could be observed that Sedad Hakkı was especially inspired by the examples of Great Seljuk and Anatolian Seljuk Architecture in the design of Anıtkabir. Figure 16 shows the similarities between the Anıtkabir, which he designed in 1942, and his sketches and the newspaper clippings he collected in his early years as a student. When we look closely, the similarities between the mass-effect of the city of Kabul in the previously mentioned photograph and the sketch of a building that is thought to be for accommodation could be easily seen (See Figure 7 and Figure 10). However, in this sketch, the shape of the dome and the entrance portal are reminiscent of the *Gûr-ı Amîr* Tomb, an example of Timurid Architecture. In addition, in the sketches of this building, traces of the cylindrical body on a square base with triangular chamfered corners, which is frequently used especially in the architecture of *kümbets*, are also noticeable. The sketch showing the rear façade of the building, on the other hand, shows traces of various periods, from the apse sections of Byzantine churches to the wide eaves and pediments, elements of the First National Architecture Movement. Especially in the newspaper clipping showing the 4th Vakıf Han from a perspective that emphasizes the corner tower (See Figure 15), the triple arch composition, wide eaves and buttress details that continue along the facade on the last two floors are also seen on the rear facade sketch of the building. From this point of view, it can be observed that the shaping of the corner towers and the wide eaves and buttress section of the 4th Vakıf Han, designed by Architect Kemalettin, was transferred to the massing of Sedad Hakkı's design of the accommodation building in his student years, and from there to the design of the Anıtkabir proposal years later. On the other hand, from the sketches and newspaper clippings analyzed in this study, it can be said that Sedad Hakkı's interest in Anatolian Seljuk *kümbet* and tomb architecture began to be formed during his student years, when he had not visited Anatolia yet (See Figure 14).

The similarities at plan level, between Sedad Hakkı's sketches, which are the source of this study, and the project proposal for the Anıtkabir Competition are shown in Figure 17. As can be understood from there, the inspirations at the plan level are most evident in Eldem's sketch for the mausoleum design (See Figure 12). In this sketch, as mentioned above, the square-planned building with a dome is placed on a rectangular base. It is seen that the sculpture and three cannons placed on the

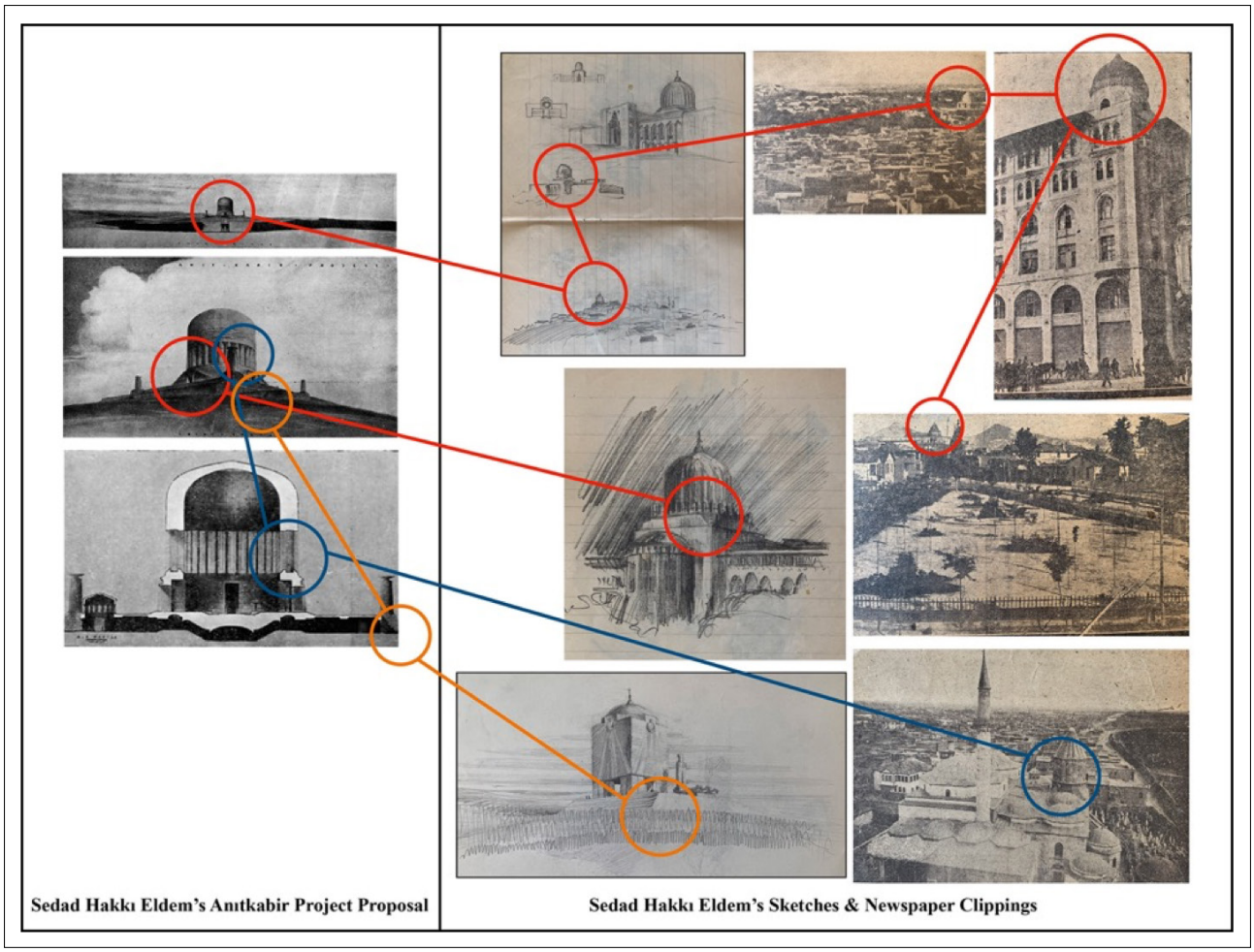


**Figure 16**. Similarities of mass-effect between Sedad Hakkı Eldem's proposal for Anıtkabir and his sketches and newspaper clippings.

rectangular platform of the building, which is thought to be designed for the Martyrs of the War of Independence, have turned into a miniature version of the main hall of honor in the Anıtkabir project (See Figure 5). However, in this design, the square-planned main building was placed in the center of the rectangular base and the miniature version of it, which was designed to replace the statue and three cannons, was placed close to the short edge. It is also seen that the plan scheme of the main building in Sedad Hakkı's sketch (See Figure 7), which is thought to be designed for accommodation, reminiscent of the Gûr-ı Amîr Tomb, is also carried to the Anıtkabir project. In the competition proposal, the square base connected to the high cylindrical body with a beveled transition, which can be easily read in the plan and mass, and which is frequently seen in the architecture of the *kümbet*, is very prominent and similar to the design of the building that is mentioned above, especially to the sketch that shows the building in perspective (See Figure 10).

The multiplicity of subjects, functions and styles in Sedad Hakkı's sketches and newspaper clippings, which are the basis of this study in general, constitute important data in terms of showing the excitement of his new interest in the Islamic architecture in addition to his knowledge of European culture and architecture. We can see this most clearly in his early sketches that include a wide variety of building details. As an extension of this, Sedad Hakkı's Anıtkabir competition proposal also shows inspirations of Islamic architecture in the details. His sketches of the building for accommodation, show the inspirations from the *Gûr-ı Amîr* Tomb, one of the examples of Timurid Architecture where the experimented with the design of a high-bodied dome sitting on a square base. It is seen that he strengthened this design approach with the Mevlana Tomb and Kılıç Arslan Tomb, examples of Anatolian Seljuk *kümbet* and mausoleum architecture, which he had photographs of in the newspaper clippings he had collected, and reached the design of a slightly flattened dome on a body divided into twenty-eight slices and supported by long thin window openings in the competition project (Figure 18).

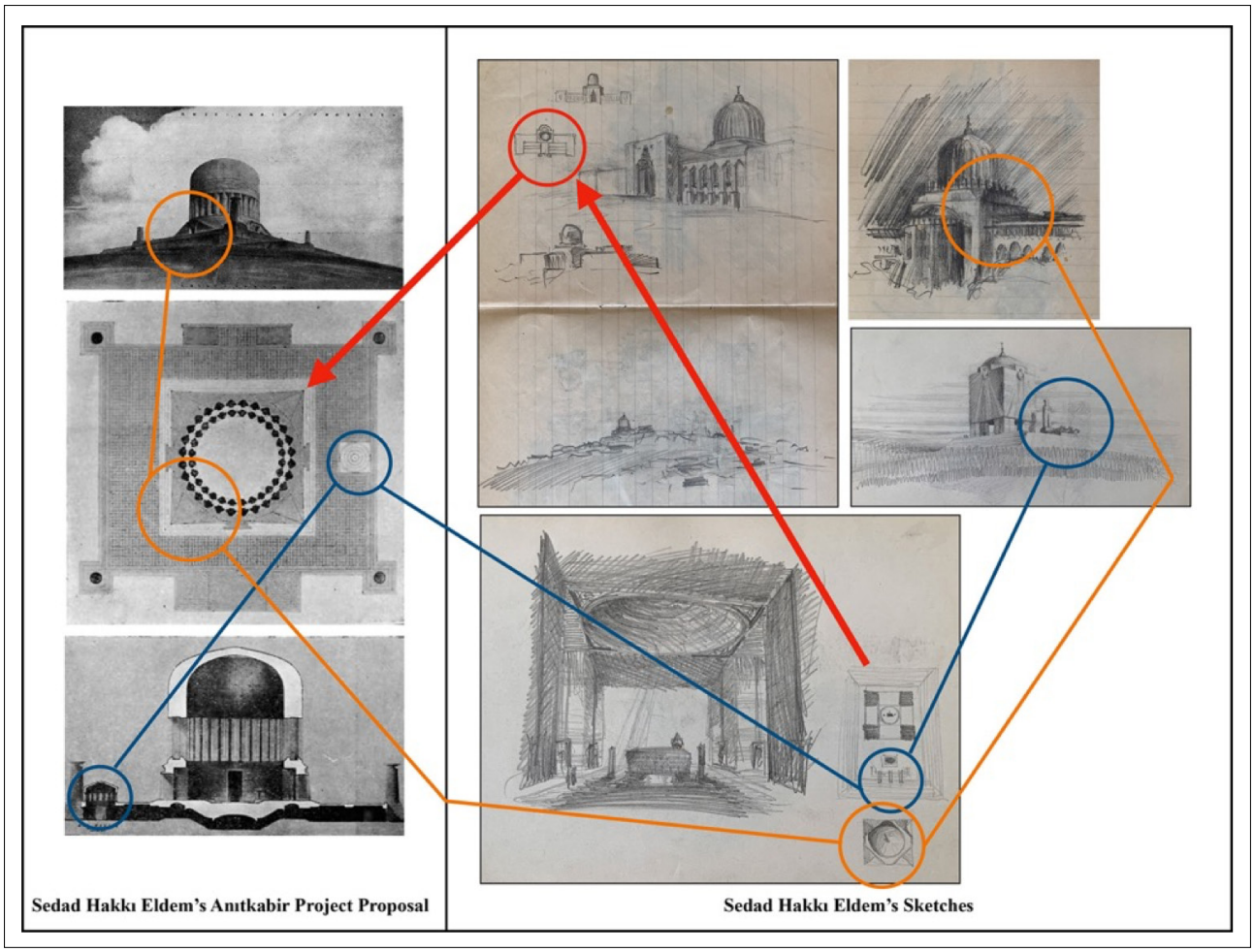


**Figure 17**. Similarities at plan level between the Sedad Hakkı Eldem's proposal for Anıtkabir and his sketches.

## CONCLUSION

In conclusion, this paper discusses that Sedad Hakkı Eldem's sketchbooks dated 1924-1925, which he kept during his student years, as well as the building and city photographs, he cut out from newspapers, formed a visual library in his mind. The traces of this visual library can also be seen in the proposal for the Anıtkabir Competition Project, as explained above with examples. It is understood that Sedad Hakkı, in the design of the Anıtkabir Project, was inspired by religious buildings from every region and period of Anatolia and its nearby geography, especially in terms of mass, plan and detail, and tried to Turkify them. This effort of Sedad Hakkı is clearly stated in the evaluations of Zeki Sayar and Christopher S. Wilson on his competition proposal. On the other hand, in the diaries he kept in 1924 and 1925, Sedad Hakkı also mentions that he himself had become Turkified. It can also be said that Celal Esad Arseven's lectures had an influence on the characterization of the traditional buildings in the borders of the Republic of Türkiye as Turkish, and that he, as both an educator and an architect, produced works using definitions such as Turkish House and Turkish Architecture[2]. However, Sedad Hakkı Eldem (1940) emphasizes the importance of each country having an architectural style of its own in his article titled "Yerli Mimariye Doğru – *Towards Local Architecture*" written in the magazine *Arkitekt* one year before the competition project. In the same text, he states that this architectural style should be local and suitable for the history, climate and soil of the region. In addition, as an answer to the question of how the Turkish House should look like, he suggests that houses of Anatolia should be researched and classified in terms of climate, type and size[3]. As can be understood from the sketches and clippings analyzed in this study, the visual library mentioned above consists of studies in mass, plan and detail, and different cities, periods, styles and functions. It is seen that the knowledge he gathered since his student years as a result of his efforts to study the geography he lived in, the cultures and architectures that developed in that geography, was the source of his designs in the following years. When the details and sketches in the newspaper clippings are evaluated together, which may

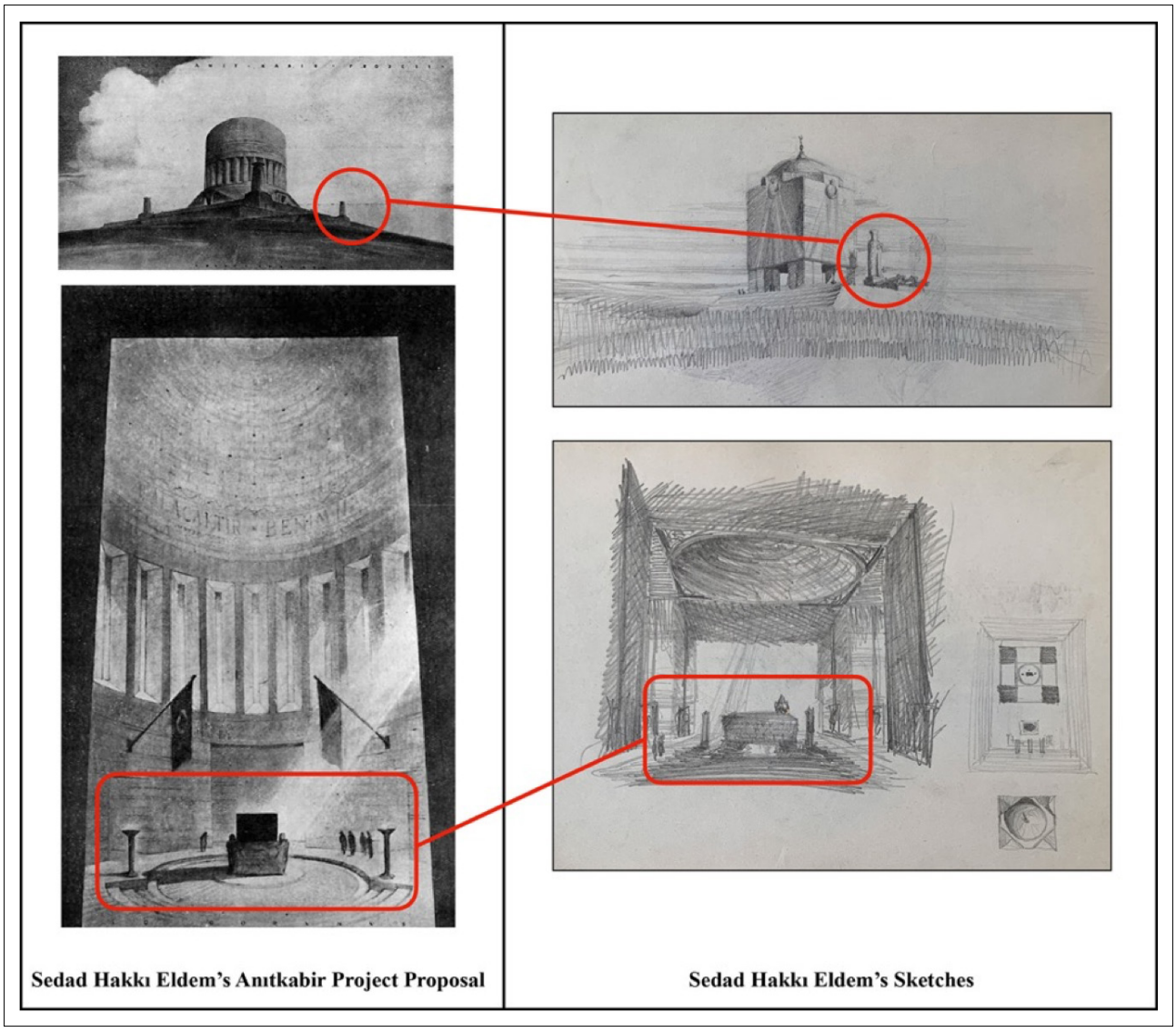


**Figure 18**. Similarities in details between Sedad Hakkı Eldem's proposal for Anıtkabir and his sketches.

have inspired the Anıtkabir proposal, it becomes clearly evident that they are explanatory documents about the origins of Eldem's interest in Anatolian geography, Islamic Architecture, the history and architecture of Istanbul. We can say that this interest started in 1924 and 1925 and continued throughout his professional architectural life. When the materials handled within the scope of this study are evaluated; it is clearly seen in the proposal for the Anıtkabir Competition Project that Sedad Hakkı Eldem's research and documentation studies continued in a consistency with the effect of the relationship he established with Istanbul, which he met for the first time in 1924, and later with the Anatolian geography, and that he was in an effort to understand and abstract the architecture of the region in a continuity, in its historical context, in mass, plan and detail scales.

## NOTES

[1]The sketchbooks are from the personal archive of the first author of this article. They were found in a junk shop near Sedad Hakkı Eldem's office building in Harbiye during a moving in 1990s. When they were bought, five sketchbooks were kept together, wrapped in a plastic bag.

[2]Sedad Hakkı Eldem's published books: Türk Evi Plan Tipleri (1954), Köşkler ve Kasırlar I (1969), Köşkler ve Kasırlar II (1974), Türk Mimari Eserleri (1975), Türk Bahçeleri (1976), Türk Evi I (1984).

[3]Thermal Hotel Yalova (1934-37), Presidential Residence Büyükada (1935), Fethi Okyar Mansion Büyükada (1936-38), Ağaoğlu Masion Teşvikiye (1936-38), Günel Mansion Yeniköy (1936-1939), Ayaşlı Mansion Beylerbeyi (1938), Mosque Project Washington (1937), Turkish Pavillion at New

York Expo (1937-39) and Beyazıt & Çamlıca Coffee Houses (1941-42) can be given as examples of the Turkish House and National Architecture concepts designed by Sedad Hakkı Eldem during this period (Tanju & Tanyeli. 2009).

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**PEER-REVIEW:** Externally peer-reviewed.

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**Article**

# Comparative evaluation of public space activities of older individuals in terms of gender and settlement typology: Case of Sinop (Türkiye)

**Neşe KÖSE GÖRGÜLÜ[1*], Nilgün ÇOLPAN ERKAN[2]**

[1]*Istanbul Metropolitan Municipality, Istanbul, Türkiye*
[2]*Yildiz Technical University, Istanbul, Türkiye*

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## ABSTRACT

This study examines the active aging potential of the elderly population in Sinop, the Turkish province with the highest proportion of elderly residents (TURKSTAT, 2024a), under the pandemic conditions of 2020. Given the intrinsic relationship between activity and environment, the research explores how the daily activities of the elderly vary by rural-urban settlement type and gender within the framework of the Person-Environment-Activity Model. By analyzing these factors, the study provides planning recommendations for active aging at both local and national levels.

Aging and activity remain underexplored topics in Türkiye. This study aims to contribute to aging research in the country while engaging with global discussions on activity theory.

The research involved structured interviews with 209 rural and 323 urban elderly individuals, with data analyzed using SPSS. Elderly individuals in urban areas engage more in shopping (46.6%) and exercise (38.3%), while those in rural areas participate more in work (22%), gardening/farming (10.1%), and religious activities (3.9%). Gender-based analysis revealed that men participate more frequently in public sports and recreational activities (41.9%), while women are more engaged in garden/farm maintenance (14.5%) and artistic/cultural activities (4.5%).

Enhancing societal awareness of active aging and improving the quality and accessibility of physical environments could foster greater participation in diverse activities among the elderly. This would promote well-being and social integration.

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## INTRODUCTION

Today, in parallel with technological advancements and developments in geriatric science, improvements in quality of life have led to increased life expectancy from birth and, consequently, a proportional rise in the elderly population within the overall population average. The impact of this shifting demographic structure on the physical form of settlements remains a subject that has not yet been adequately addressed. The starting point of this research is to identify how the daily life activities of the elderly are shaped by space and gender, in order to ensure that this

***Corresponding author**
*E-mail adres: nesekose@gmail.com

growing segment of the population can age in a more livable environment in the future. Based on these findings, the study aims to highlight what can be done in urban planning and urban design to support active aging.

Aging is a significant and contemporary issue, increasingly affecting many disciplines worldwide, yet it remains a phenomenon without a definitive definition. When reviewing approaches to aging, they are generally categorized into three groups: biological aging theories (Semsei, 2000), social aging theories (Bengston et al., 1997; Marshall, 1996), and psychological aging theories (Özcan, 2019). Among these, Havighurst's Activity Theory (Havighurst, 1961) stands as a key component within environmental gerontology studies. Although the theory has faced various criticisms (Victor, 2005; Lemon, 1972; Tufan, 2001), it remains a psycho-social theory that presents positive assertions about aging and continues to evolve. In this context, one of the secondary objectives of this study is to contribute to these global discussions and explore how elderly activities vary based on space, culture, society, and personal characteristics.

Aging is a process characterized by changes in functional capacity and abilities, which sometimes bring elderly individuals to the threshold of disability. A decline in functional capacity restricts their activities and can lead to dependence on others. Therefore, this study aims to contribute to activity theory research by assessing the functional capacities of the elderly through their daily life activities.

Current demographic data and projections regarding the elderly population indicate that older adults are rapidly becoming an increasingly large segment of society. Projections suggest that this growth will vary across different countries and regions in the future (see Figure 1).

In developing countries like Türkiye, where aging is occurring at a rate four times faster than in developed nations, an aging population is expected to emerge before achieving sufficient economic welfare (Yakar, 2014). Therefore, the adaptation between the elderly and their living environments must be addressed accordingly, and various physical, economic, and social infrastructures need to be established to support this transition. In Türkiye, the fact that the proportion of elderly women is higher than that of elderly men (see Figure 3) introduces another critical issue, referred to as the "feminization of aging."

When examining the aging rate by settlement type, one of the study's key topics, it is predicted that rural aging will surpass urban aging in developing and underdeveloped regions worldwide (UN, 2018). In Türkiye, due to various economic factors, including the migration of the younger population to urban centers and declining fertility rates (Öztürk, 2015), the rate of rural aging has shown a rising trend, particularly over the past 15 years (see Figure 3).

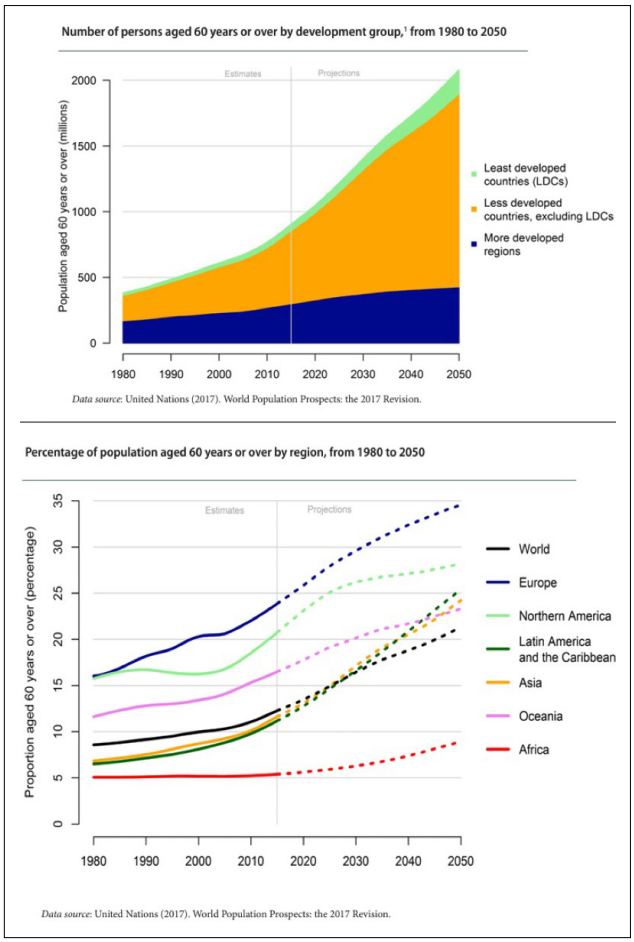


**Figure 1**. Population aged 60+ by development regions and continents, 1980-2050 (UN, 2017).

To draw attention to issues related to aging and reduce potential future problems that the elderly may face by strengthening the relationship between the elderly and their environment, a study within the framework of active aging was conducted. The study area was selected using the location quotient method, based on elderly concentration maps from 2012, which were then overlaid with the elderly population density map from 2020 (see Figure 4 and Figure 5). Accordingly, the province of Sinop stands out as the settlement with the highest values in both the elderly concentration map and the current elderly population density map.

To explain the conceptual connections between aging, activity, space, and gender, the theoretical background of the study has been outlined. This foundation was established by integrating key concepts from aging theories, environmental gerontology, and the Person-Environment-Activity Model, providing a comprehensive framework for understanding how the daily activities of the elderly are shaped by both their environment and gender.

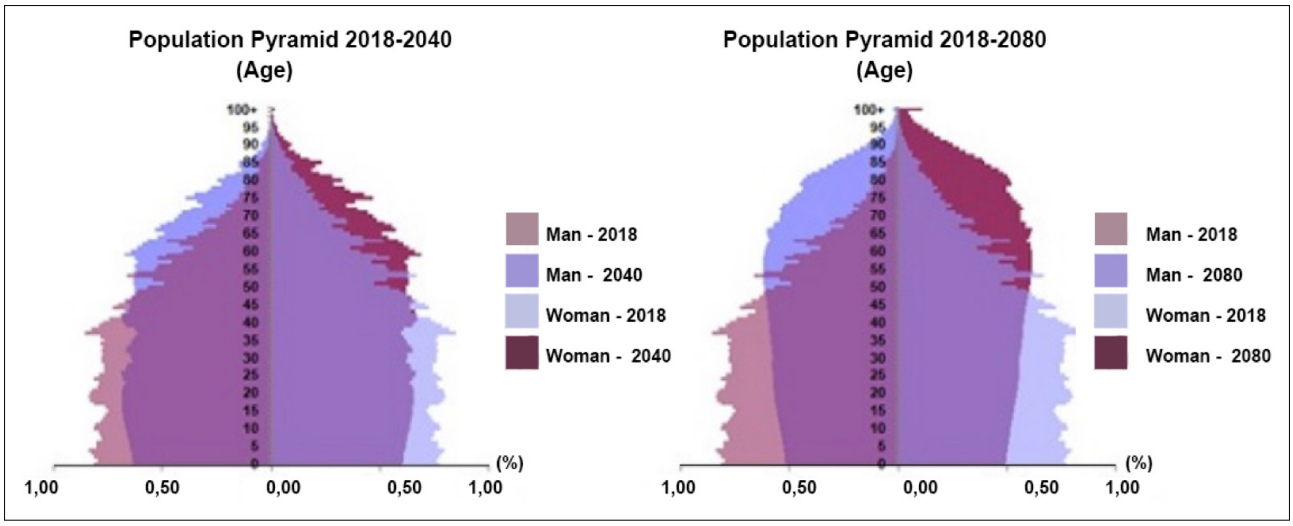


**Figure 2**. Population projection of Türkiye for the years 2018-2080 (TURKSTAT, 2018).

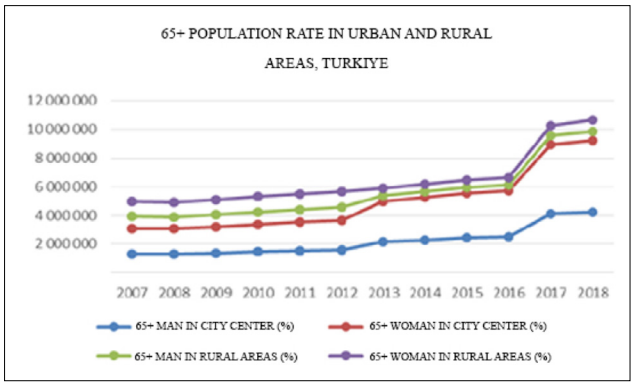


**Figure 3**. Türkiye's 65+ population in urban centers and rural areas by year (TURKSTAT, 2024a).

## Theoretical Background

This study was initiated with the aim of understanding the tripartite relationship among the "elderly – environment – activity" within the framework of Havighurst's (1961) Activity Theory, considering the rising trend of rural aging in Türkiye (TURKSTAT, 2024b) and the importance of activity in old age. The relationship between the elderly and their environment was examined within the scope of environmental gerontology (Peace et al., 2007), while Carlson's (2002) Person-Environment-Activity Model was also taken into consideration.

## The Concept of Aging and Environmental Gerontology

The concept of aging is a phenomenon that shapes many personal and societal issues and is connected to various disciplines. However, it remains a phenomenon with unclear boundaries and no definitive definition (Vina et al., 2007; Tauste et al., 2018).

While the threshold of old age is currently accepted as 65 years and older by many global organizations, including the WHO and OECD, Japan— which has the highest proportion of elderly population—advocates for a new threshold of 75+. According to data from the Japan Gerontological Society and the Japan Geriatrics Society in 2013, there is currently a 5- to 10-year difference in the aging stage, based on changes in physical functions such as walking speed and grip strength (Ouchi et al., 2017). This suggests that the chronological threshold for old age can be variable. WHO acknowledges that aging is both a personal attribute and highly dependent on the environment, arguing that functional abilities in the elderly population can increase in connection with the opportunities provided by the environment (WHO, 2015).

Recent studies (Peace et al., 2007; Clarke and Nieuwenhuijsen, 2009) demonstrate that while genetic inheritance plays a role in the aging process, the environment significantly influences aging through epigenetic effects (Garrett and Poulain, 2018). Collectively, these approaches underscore the importance of environmental gerontology, which aims to define the relationship between the elderly population and their socio-physical environments within an interdisciplinary framework (Wahl and Gitlin, 2007).

In the context of environmental gerontology, the Person-Environment-Activity Model, which examines the relationship between activity and the environment in old age, posits that individual-level activities influence the elderly's functional capacity at the societal level. It also argues that individual activities are accessible and usable to the extent that they align with environmental demands (see Figure 6).

To support the theory that examines the relationship between the elderly and their environment in connection with their activities, it is also necessary to explain the concepts of activity theory and active aging.

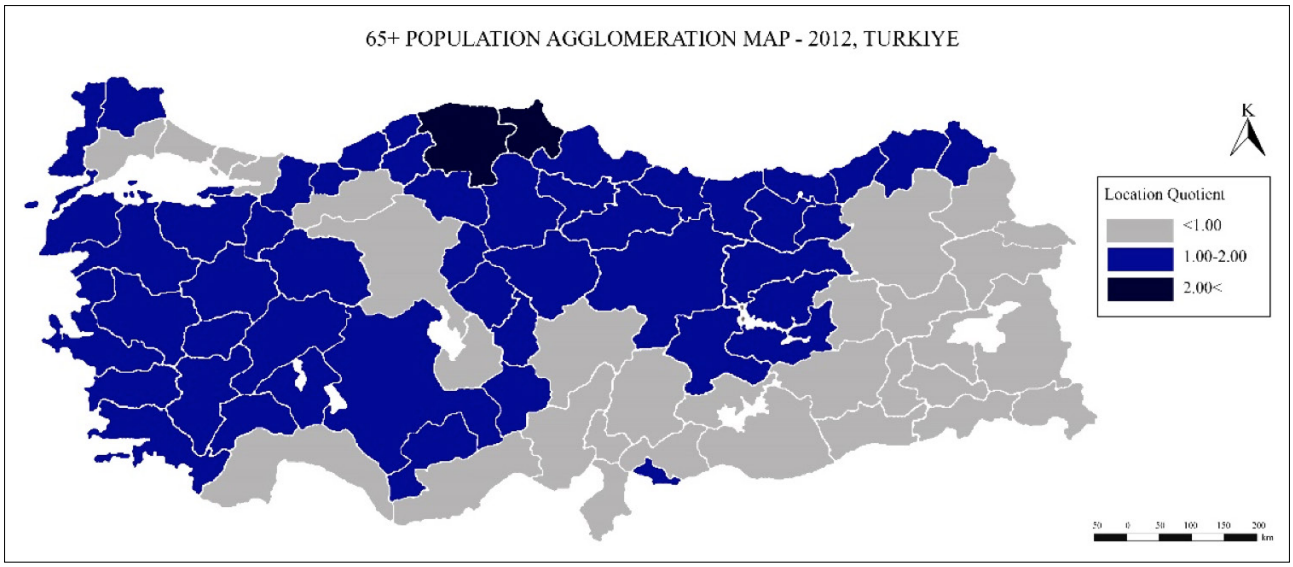


**Figure 4**. Türkiye's elderly population concentration map - 2012 (TURKSTAT, 2024a).

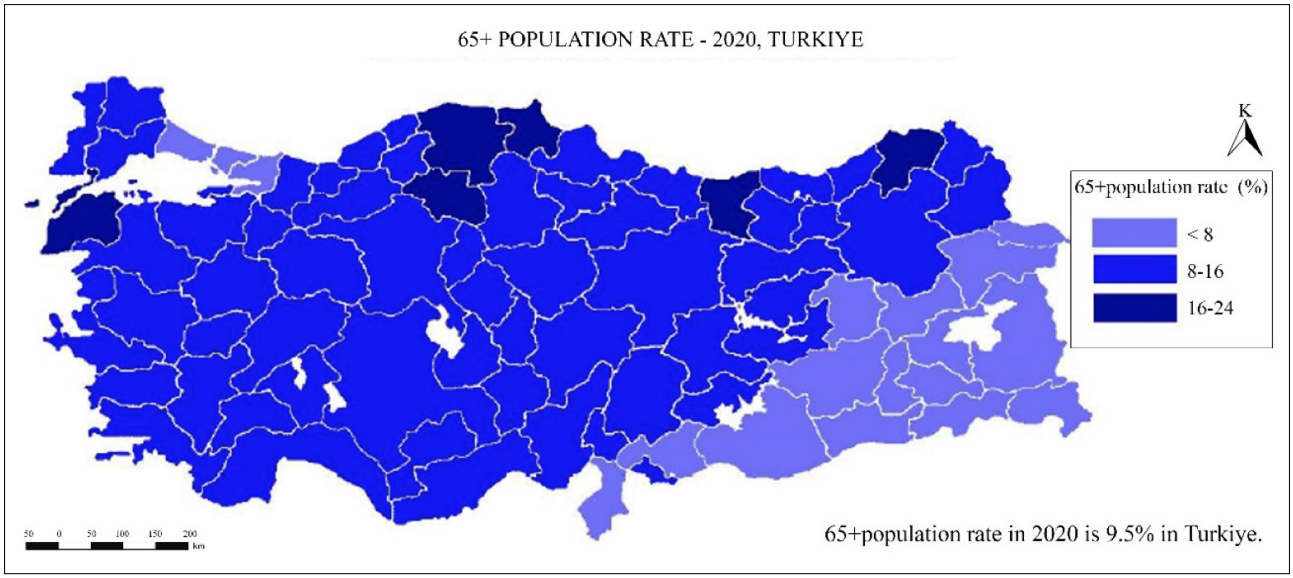


**Figure 5**. Türkiye's elderly population ratio map - 2020 (TURKSTAT, 2024a).

**Activity Theory and Active Aging**

As a counter to Disengagement Theory, Robert J. Havighurst (1961) proposed the Activity Theory, which asserts that individuals should continue the physical exercises, movement, and meditation/worship activities they engaged in during middle age into their later years (Victor, 2005; Formosa, 2020; Jancewicz, 2001; Low et al., 2009; Di Lorito et al., 2021).

Another study identified that a key component supporting these activities is organic social relationships. These social connections, particularly in small-scale settlements, are highlighted as playing a positive role in the aging process (Garcia & Miralles, 2017). In other words, strong organic social bonds contribute to keeping the elderly population active, opening the door to a happy and long life.

One of the criticisms of Activity Theory is its inability to provide a clear explanation for why some elderly individuals are passive yet happy, while others are active but unhappy (Tufan, 2001). Despite these critiques, many countries have begun to emphasize the positive outcomes of active aging, viewing it as an investment in the aging population and incorporating it into their national strategies (Formosa, 2020; Barbabella et al., 2022). According to a study on active aging in the United Kingdom (Bowling, 2008), elderly individuals defined active aging as physical health and functionality (43%), leisure and social activities (34%), cognitive functionality (18%), and social relationships and connections (15%).

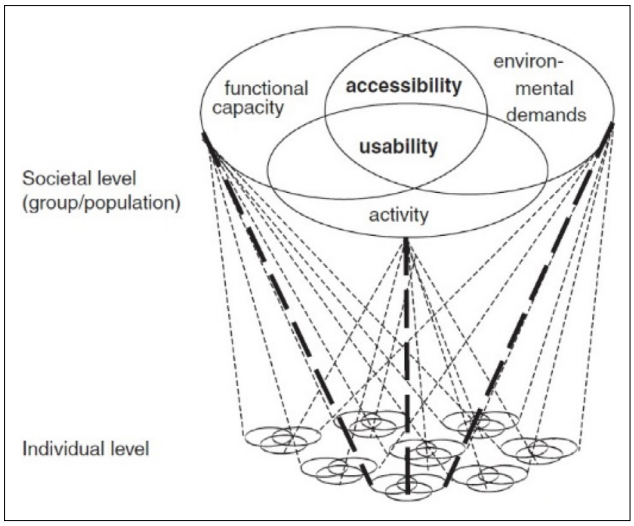


**Figure 6**. Person-Environment-Activity Model (Carlson, 2002, as cited in Scheidt and Windley, 2006).

The concept of active aging, associated with Activity Theory, was first accepted in the late 1990s as "the process of optimizing opportunities for health, participation, and security to enhance quality of life as people age" (WHO, 2002). Factors affecting active aging are closely linked to economic, social, behavioral, and physical elements, as well as the physical environment and social health services (Annear et al., 2014). The concept of active aging demonstrates that when elderly individuals remain active, they stay healthy, and this influences—and is influenced by—various factors such as social, economic, and environmental aspects (Walker, 2002).

Active aging has been criticized for promoting specific practices and lifestyles or for implementing biased policies (Pfaller & Schweda, 2019). However, all available data suggest that practices aligned with this approach positively impact the aging process and help reduce the signs of aging (Formosa, 2020; Barbabella et al., 2022).

Personal care in old age is categorized into six main areas: instrumental activities of daily living, leisure activities, social activities, paid activities, and rest (Horgas et al., 1998). This framework (see Table 1) was utilized in evaluating the data obtained from the survey conducted in the research.

A study on the daily activity levels of the elderly indicates that as the independence of elderly individuals increases—meaning they do not require assistance for their daily activities—their quality of life improves (Kankaya & Karadakovan, 2017). Therefore, while examining the concept of spatial and gender-based aging, elderly dependency has also been closely analyzed.

Accessible environments that encourage elderly individuals to spend time outdoors contribute to a more active lifestyle and improved quality of life (Sugiyama & Ward Thompson, 2007). Similarly, Gehl (2011) suggests that as the quality of the physical environment improves, non-essential activities increase and tend to last longer. This dynamic is influenced by three concepts: public health (community health), psychology, and environmental design. It is suggested that with a supportive environment, elderly activities can become more varied, and some activities may even become habitual (Owen et al., 2004). A number of studies by various organizations around the world explore the conditions required to create this supportive environment and how they can be developed. These include concepts such as successful aging, aging in place, active/healthy aging, and the WHO Age-Friendly Cities approach. Among these, the concept of aging in place and the WHO Age-Friendly Cities Network are particularly relevant to the elderly and their physical environment.

The "aging in place" approach, which includes the concepts of socio-spatial embeddedness and place attachment, and the "WHO Network of Age-Friendly Cities," which focuses on approaches specific to the city, social structure, and spatial character, aim to improve the physical, social, and economic conditions of the elderly and to increase their quality of life.

According to a study conducted in Finland (Rantakokko et al., 2010), when elderly individuals are dissatisfied with their ability to participate in physical activities, they turn to non-physical activities, and giving up meaningful activities results in high levels of depressive symptoms. Similarly, research conducted across seven rural regions in North Carolina concluded that social and environmental interventions—such as improving social support, safety, and accessibility—would increase physical activity among the elderly (Shores et al., 2009). One critical issue here is whether the motivating force for elderly individuals to engage in activity stems from obligatory daily tasks or voluntary activities. Therefore, it should be considered that rural and urban areas offer different spatial potentials for elderly individuals.

Rural settlements not only differ in terms of spatial opportunities but also show demographic variations. According to the Eurofound (2014) report, half of the single-person households in rural areas of Europe are composed of retirees. In Türkiye, 45.8% of single-person households consist of elderly individuals, with 76.5% of these elderly being women and 23.5% being men (Güler et al., 2016). When combined with disadvantages such as low education levels or lack of access to social security, this situation of living alone in rural areas makes elderly women more vulnerable to dependency. It also makes activities such as traveling to another city or participating in events more difficult for them.

**Table 1.** Daily Life Activities of the Elderly (Horgas et al., 1998)

| Main Category | Activity | Main Category | Activity |
|---|---|---|---|
| Personal Maintenance | Arising | Leisure Activities | Reading |
| | Personal care | | Watching TV |
| | Eating | | Cultural activities |
| | Preparing for bed | | Educational activities |
| | Miscellaneous other | | Sports |
| | | | Creative activities |
| | | | Gardening |
| | | | Walking |
| | | | Excursions |
| | | | Writing |
| | | | Playing |
| | | | Listening to radio/tape/record |
| | | | Church activities |
| | | | Political activities |
| | | | Other leisure activity |
| Instrumental Activities of | Shopping | Social Activities | Talking to people |
| Daily Living (IADLs) | Light household chores | | Visiting |
| | Heavy household chores | | Telephoning |
| | Handiwork/mending/sewing | Other social activities | |
| | Other housework | | Helping family members |
| | Banking | | Helping other people |
| | Dealing with authorities/institutions | Paid Word | Regular paid work |
| | Dealing with the post office | | Other work |
| | Dealing with other official institutions | Resting | Sleeping during the day |
| | Medical treatment (e.g., getting X-rays) | | Doing nothing |
| | Self-treatment (e.g., taking a foot bath) | | Planning |
| | Passive transportation (e.g., being driven) | | |
| | Active transportation (e.g., driving a car) | | |

## METHODOLOGY

The research methodology involved three sequential processes: selecting the settlement where aging studies would be conducted, determining the scope of the survey data collection, and implementing the survey itself. As explained above, Sinop Province was selected as the research area based on 2020 data, which showed that it had the highest population of individuals aged 65 and over. Without focusing on a specific settlement, Sinop's central district was selected to represent urban areas, while rural settlements from nine districts were included in the sample for rural areas. The survey participation rates are shown in Table 2 in the results section.

The method used for data collection from elderly individuals was a survey. The survey questions included both open-

**Table 2.** Survey Distribution by Districts

| District | Number | Rate (%) |
|---|---|---|
| Ayancık | 45 | 8,5 |
| Boyabat | 86 | 16,2 |
| Dikmen | 10 | 1,9 |
| Durağan | 34 | 6,4 |
| Erfelek | 32 | 6,0 |
| Gerze | 42 | 7,9 |
| Sinop (City Center) | 228 | 42,9 |
| Saraydüzü | 16 | 3,0 |
| Türkeli | 39 | 7,3 |
| Total | 532 | 100 |

ended and Likert-scale items, designed to understand how the daily life activities of the elderly differ by space and gender. The study was conducted between September 9, 2020, and September 17, 2020, in Sinop. In urban areas, elderly individuals were surveyed face-to-face in parks, seaside areas, coffee houses, workplaces, and mosque courtyards, while in rural areas, surveys were conducted in coffee houses, mosques, fields, and residential gardens.

As explained in the theoretical section, daily life activities in old age may vary depending on the opportunities provided by the environment, social ties, and gender. Therefore, the sample was stratified by rural–urban areas and gender. A total of 532 volunteers participated in the study, consisting of 209 individuals from rural areas and 323 from urban areas, with 200 women and 332 men.

### Limitations and Assumptions

Before interpreting the results of the fieldwork, it is important to clarify some of the study's limitations and assumptions. First, according to the World Health Organization (WHO, 2015), the threshold for old age is defined as 65 years and older. In Türkiye, individuals aged 65 and above are similarly defined as the elderly population and are considered economically dependent (Republic of Türkiye Ministry of Health, 2016). Therefore, participants aged 65 and older were considered part of the advanced age group, and the study was conducted accordingly.

It was assumed that the elderly individuals who actively participated in the study answered the interview questions with honesty and accuracy, and thus, they are considered representative of a randomly selected population of elderly individuals.

The COVID-19 pandemic, which emerged at the beginning of 2020 and spread worldwide, significantly affected the course of this study. Due to the impact of the pandemic on the elderly population, the study was conducted by professionals during a period when the pandemic had relatively subsided. The fieldwork took place under pandemic conditions in September 2020. Due to the circumstances at the time, elderly individuals avoided public spaces, which prolonged the data collection process beyond the initial plan. Additionally, difficulties were encountered in reaching the advanced age group, particularly elderly women. As a result, 72% of the participants were between the ages of 65 and 70, representing a physically active and dynamic elderly population group. Conducting this research again during a different period would be beneficial.

## RESULTS

Sinop is a province located in Türkiye's Black Sea region, comprising the central district, nine additional districts, 50 neighborhoods, and 465 villages. It was established as a fortress city on the Inceburun and Boztepe isthmus and has maintained its identity as a port city, historically expanding toward the east. When examining the spatial distribution of the elderly in Sinop, it was observed that the overall distribution is nearly homogeneous (see Figure 7). In terms of urban elderly concentration, Dikmen district stands out with 24.8%, while Sarayduzu district leads rural elderly concentration with 46.5%. The survey's urban data were evaluated based on Sinop's central district, while the rural data were assessed through the villages associated with the districts (see Table 2).

In the study areas, all elderly individuals in rural areas reside in detached houses with gardens, while those in the city center live in apartment-style housing. The elderly participants in the survey were selected from those who spent time in public open spaces within the city (see Figure 8). Due to the pandemic—particularly in rural areas—

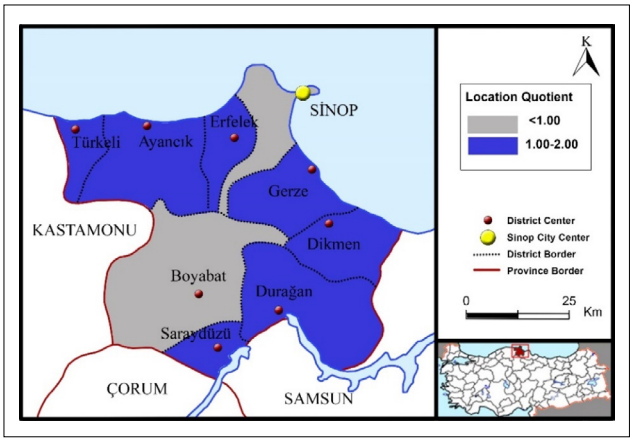


**Figure 7**. Sinop 65+ Population Agglomeration Map - 2020 (Köse Görgülü, 2022).

**Figure 8**. Images from the survey conducted with elderly individuals in public spaces in rural and urban settlements in Sinop.

elderly women did not leave their homes, and therefore, interviews were conducted in the gardens of their homes.

Since the goal of this study was to examine how elderly individuals use public spaces around their residences and what activities they engage in, plans and maps of public spaces were not included. Thus, public space behaviors were limited to how elderly individuals access and use certain places (such as shops or health centers). Before reviewing the data results, it is important to acknowledge that the available facilities in these spaces may limit the elderly users. For example, while an elderly individual in the city center may go fishing in their leisure time, a person in a rural area may engage in gardening or livestock activities. The purpose here is to assess the connection between elderly users and the spaces they inhabit through their activities, taking into account the opportunities or limitations provided by these environments. Where deficiencies are identified, space-specific measures and development strategies can be proposed.

The majority (approximately 27%) of the elderly participants in the survey are in the 65–70 age range, representing an early age group with a relatively high level of physical activity. According to the results, 76% of the elderly participants are married, and 72% live with their spouses. The proportion of those living alone is 15% (see Table 3).

When examining the educational status of elderly individuals, it is observed that the literacy rate among those in rural areas is lower compared to those in the city center. Although the percentage of women with high school or higher education is greater than that of men (39.6% for men and 50.75% for women) (see Table 4), elderly women living in rural areas have the lowest education levels among all participant groups.

In rural areas, the illiteracy rate among women is particularly high. This not only limits their engagement in leisure activities such as reading but also highlights their dependency on others for tasks such as traveling or accessing institutional, financial, or healthcare services in daily life.

**Relationship Between Activities, Space, and Gender**

When examining the activities of elderly individuals across different settlement types and genders, it is evident that women, both in urban and rural areas, spend less time in public spaces compared to men (see Table 5).

The results of the Chi-square test, conducted to examine the differences in reasons for going outside based on settlement type, are presented in Table 6. The findings reveal significant differences between urban and rural residents in terms of shopping, work, gardening, and participation in religious activities ($p<0.05$). While 50.8% of urban residents reported going outside primarily for shopping, this figure drops to 38.8% for rural residents. This difference may be

**Table 3.** Marital status and cohabitant(s)

| | Cohabitant | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Alone | | | With Spouse | | | With children | | | Other(s) | | | Total | | |
| | Number | Ratio % | Total rate % | Number | Ratio % | Total rate % | Number | Ratio % | Total rate % | Number | Ratio % | Total rate % | Number | Ratio % | Total rate % |
| Married | 10 | 12,0 | 2,5 | 381 | 100,0 | 94,5 | 12 | 27,9 | 3,0 | 0 | 0,0 | 0,0 | 403 | 75,8 | 100,0 |
| Single | 49 | 59,0 | 77,8 | 0 | 0,0 | 0,0 | 0 | 0,0 | 0,0 | 14 | 56,0 | 22,2 | 63 | 11,8 | 100,0 |
| Widowed | 21 | 25,3 | 42,9 | 0 | 0,0 | 0,0 | 23 | 53,5 | 46,9 | 5 | 20,0 | 10,2 | 49 | 9,2 | 100,0 |
| Divorced | 3 | 3,6 | 17,6 | 0 | 0,0 | 0,0 | 8 | 18,6 | 47,1 | 6 | 24,0 | 35,3 | 17 | 3,2 | 100,0 |
| Total | 83 | 100,0 | 15,6 | 381 | 100,0 | 71,6 | 43 | 100,0 | 8,1 | 25 | 100,0 | 4,7 | 532 | 100,0 | 100,0 |

Percentages are calculated based on the total number of participants (532). National averages are not available in the provided table.

**Table 4.** Education

| | Urban | | Rural | |
|---|---|---|---|---|
| | **Male (%)** | **Female (%)** | **Male (%)** | **Female (%)** |
| Illiterate | 0,5 | 0,0 | 3,4 | 6,5 |
| Literate | 0,9 | 2,8 | 1,7 | 6,5 |
| Primary School | 25,9 | 33,6 | 49,1 | 28,0 |
| Middle (Secondary) School | 16,7 | 9,3 | 22,4 | 11,8 |
| High School | 23,6 | 18,7 | 15,5 | 31,2 |
| College | 17,6 | 12,1 | 3,4 | 8,6 |
| University | 13,4 | 18,7 | 4,3 | 3,2 |
| Postgraduate | 1,4 | 4,7 | 0,0 | 4,3 |

**Table 5.** Duration of Time Spent in Public Spaces

| | Urban | | Rural | |
|---|---|---|---|---|
| | **Male (%)** | **Female (%)** | **Male (%)** | **Female (%)** |
| Every day | 80,1 | 59,8 | 84,5 | 64,5 |
| 6 days a week | 1,4 | 5,6 | 3,4 | 4,3 |
| 5 days a week | 3,7 | 4,7 | 4,3 | 4,3 |
| 4 days a week | 4,2 | 3,7 | 0,9 | 4,3 |
| 3 days a week | 3,2 | 8,4 | 2,6 | 3,2 |
| 2 days a week | 5,6 | 12,1 | 1,7 | 10,8 |
| 1 day a week | 1,9 | 5,6 | 2,6 | 8,6 |

**Table 6.** Purpose of Going Outside Based on Settlement Type

| | $X^2$ | p | Urban (%) | Rural (%) |
|---|---|---|---|---|
| *Shopping | 7,377 | 0,007 | 50,8 | 38,8 |
| Receiving healthcare services | 1,752 | 0,186 | 5,9 | 3,3 |
| *Working | 5,839 | 0,016 | 13,9 | 22,0 |
| Exercising | 0,717 | 0,397 | 35,6 | 39,2 |
| Meeting relatives, neighbors etc. | 0,116 | 0,733 | 13,3 | 14,4 |
| *Gardening | 27,590 | 0,000 | 4,3 | 18,2 |
| Artistic-cultural activities and enrolling courses | 1,016 | 0,313 | 1,2 | 2,4 |
| *Religious activity | 5,761 | 0,016 | 2,2 | 6,2 |
| Caring grandchildren or family members | 3,266 | 0,162** | 1,5 | 0,0 |
| Other | 1,485 | 0,223 | 7,4 | 4,8 |

*Significance ($p<0.05$); ** Fisher's Exact Probability Test is applied.

attributed to the limited shopping facilities in rural areas and the ability to source certain food items directly from home gardens. Furthermore, work (22.0%), gardening (18.2%), and participation in religious activities (6.2%) are more common among rural residents.

The distinct spatial characteristics of each settlement type contribute significantly to the diversity and nature of activities among elderly individuals. In other words, the lack of cultural amenities (such as cinemas, theaters, and exhibition halls) in rural areas, and the limited open spaces for gardening in urban settings (for example, growing plants in pots on balconies), play a crucial role in shaping the types of activities elderly individuals can engage in.

The results of the Chi-square test analyzing the differences

in reasons for going outside based on gender are presented in Table 7. The findings indicate statistically significant differences between men and women with respect to exercise, gardening, and artistic/cultural activities ($p<0.05$). Men are more likely to go outside for exercise, whereas women demonstrate a greater tendency to engage in gardening and artistic/cultural activities.

These results suggest that gender significantly influences the nature of outdoor activities among the elderly, likely reflecting differing preferences and societal roles typically associated with men and women. If additional specific Chi-square values are available, they can be incorporated into the analysis.

A significant portion of elderly individuals reported going outside primarily for shopping, with shopping activities in urban settings (46.6%) also serving as opportunities for social interaction. On the other hand, elderly individuals living in rural areas are more likely to go outside for gardening (10.1%), work (22%), and religious activities (3.9%). The combined high rates of gardening and work-related activities in rural areas suggest that elderly individuals are employed in family businesses, actively participate in production activities, or contribute to subsistence farming.

The overall rate of elderly individuals going outside for work is notably high (see Table 7). In urban areas, this rate stands at 13.9%, while in rural areas it is 22%. Among women, 13% go outside for work, compared to 19.6% among men. These figures clearly indicate that even during the pandemic, many elderly individuals faced economic difficulties, which compelled them to continue working.

It has been found that participation in artistic and cultural activities among elderly individuals increases with higher levels of education, a finding supported by previous studies (Canatan & Boz, 2019). In this context, the fact that women in Sinop have a higher education level compared to men and participate more frequently in artistic activities aligns with these results (see Tables 4 and 7).

All findings indicate that spatial opportunities play a significant role in shaping the activities of elderly individuals, particularly in facilitating discretionary activities rather than compulsory ones.

## CONCLUSION AND DISCUSSION

This study was conducted in 2020 under pandemic conditions in Sinop, the city with the highest elderly population concentration in Türkiye, to assess the active aging potential of the elderly population and to examine how their activities are shaped. It is crucial to acknowledge that the COVID-19 pandemic significantly influenced the approach and trajectory of this research.

Considering the impact of lockdowns on outdoor activities, elderly individuals without access to outdoor spaces in their homes may have become inactive and passive indoors. During the pandemic, the elderly population may have engaged in activities that differed from their usual daily routines. Therefore, potential changes in behavior compared to the pre-pandemic period should be considered when interpreting the results.

It may be beneficial to repeat this study using longitudinal tracking methods, along with observation and measurement techniques, for several years after the pandemic has ended. This would provide valuable insights into long-term trends and changes in the activity patterns of the elderly population.

According to the research findings, the daily life activities of elderly individuals in public spaces vary based on settlement typology and gender. Significant differences were observed

**Table 7.** Purpose of Going Outside Based on Gender

| | $X^2$ | P | Male (%) | Female (%) |
|---|---|---|---|---|
| Shopping | 2,01 | 0,156 | 43,7 | 50,0 |
| Receiving healthcare services | 3,078 | 0,079 | 3,6 | 7,0 |
| Working | 3,809 | 0,051 | 19,6 | 13,0 |
| *Exercising | 8,862 | 0,003 | 41,9 | 29,0 |
| Meeting relatives, neighbors etc. | 2,909 | 0,088 | 11,7 | 17,0 |
| *Gardening | 8,115 | 0,004 | 6,9 | 14,5 |
| *Artistic-cultural activities and enrolling courses | 15,197 | 0,000** | 0,0 | 4,5 |
| Religious activity | 0,511 | 0,475 | 4,2 | 3,0 |
| Caring grandchildren or family members | 3,869 | 0,069** | 0,3 | 2,0 |
| Other | 0,425 | 0,514 | 6,9 | 5,5 |

*Significance (p<0,05); **Fisher's Exact Probability Test is applied; The study reveals that more than half of the elderly population living in urban areas go outside

in specific activities such as shopping, exercise, gardening, and caregiving. When examining the distribution of these activities, the most common daily activities among elderly individuals in Sinop's urban areas were shopping (46.6%) and exercise (38.3%), whereas gardening (10.1%), work (22%), and religious activities (3.9%) were more prevalent in rural areas.

In terms of gender differences, men were more likely to go outside for sports and exercise (41.9%), while women were more inclined to engage in gardening (14.5%) and artistic/cultural activities (4.5%). Additionally, the presence of elderly individuals caring for grandchildren or other family members, with this responsibility being more common among women (2%), indicates that elderly activities in Türkiye are influenced not only by spatial and gender factors but also by various sociocultural dynamics.

It is noteworthy that, despite the pandemic conditions, 91 elderly individuals in Sinop were still employed. Providing elderly individuals in Türkiye with fair income and social security rights after retirement, along with opportunities for voluntary or paid work, is particularly important for those who are physically able and wish to continue working (Demirbilek & Öktem Özgür, 2017). Ahtonen (2012) emphasizes that the healthy active aging market presents a significant potential opportunity to transform the "silver economy" into a profitable venture.

The decline in elderly individuals' incomes during their working years, coupled with the poverty they face—especially among rural women—highlights their vulnerability. In this context, "rural women's poverty," which is intricately linked to active aging, is an important issue that warrants further investigation and attention.

Previous research has shown that elderly individuals with lower education levels experience a decline in physical activity in the early stages of aging (Shaw & Spokane, 2008). Additionally, as education levels increase, participation in activities such as cultural and artistic events tends to rise (Canatan & Boz, 2019). Similarly, this study reveals that elderly women in rural Sinop have lower literacy levels and participate less in artistic activities compared to their urban counterparts. However, in Sinop, women show higher rates of education and participation in artistic activities compared to men (see Tables 2 and 4), which aligns with existing research. Given the evidence that participation in artistic activities can alleviate loneliness among older adults (Tymoszuk et al., 2019; Köse & Erkan, 2024), there is a need for organizations in Sinop that can connect the 15% of elderly adults living alone with cultural and artistic activities. Furthermore, the higher participation rate in religious activities in rural areas compared to urban settings may be attributed to the fact that religious involvement, especially in small social groups, has been found to enhance subjective well-being (Yoon & Lee, 2004).

The study emphasizes the need to increase individual awareness of active aging among elderly individuals and to support a variety of activities through social policies. At the local level, physical and social arrangements should be implemented in both urban and rural areas to encourage the elderly population to be active, strengthen their social relationships, and meet their needs. Specifically, in rural areas, lifelong education—particularly for elderly women—should be supported. Special employment opportunities should be created for elderly individuals who are physically capable and wish to continue working, and at the national level, the principles of active aging should be incorporated into strategic plans. It is expected that individual-level recommendations will yield short-term results, local and social interventions will have medium-term effects, and national plans will produce long-term outcomes.

This study highlights the significant impact that the available opportunities and potential of a given space have on elderly activities, especially discretionary activities. As previously emphasized, social connections play a positive role in the activities of elderly individuals (Garcia & Miralles, 2017). Therefore, creating spaces that encourage social activities and foster new relationships will help shape discretionary activities among the elderly.

Elderly individuals—often referred to as the "living memory" of settlements that carry traces of spatial changes—play a unique role that distinguishes them from other types of public space users. It is crucial to acknowledge that just as people shape places, places shape the people who inhabit them. Recognizing that formal and spatial changes in cities, which are living organisms, inevitably affect people's lifestyles is essential. Addressing the diverse needs of individuals from different backgrounds in the cities we shape contributes to a better, more efficient, and impartial understanding of urban design and planning. This approach is seen as a crucial step toward creating more livable cities.

Considering all the data, this study should be regarded as a significant contribution to aging studies in Türkiye and to global research on Activity Theory. The findings are expected to aid landscape architects and urban designers in developing age-sensitive design strategies, assist sociologists and social scientists in understanding the role of daily functions within societal roles for the elderly, and contribute to geriatric and health-related studies regarding the effects of daily activities on elderly health. Given the multifaceted nature of aging as a concept—shaped by physiological, psychological, socio-cultural, economic, and environmental factors—it is imperative to consider these elements when developing age-sensitive designs.

For instance, it is essential to account for both the physical capabilities of the environment and prevailing socio-cultural norms. This includes increasing the number of socialization venues for the elderly to prevent social

isolation. Additionally, the development of transportation networks that are accessible and user-friendly for the elderly is crucial in ensuring their autonomy in reaching these venues. Furthermore, it is important to facilitate interactions with individuals of various age groups within these settings.

The results of this research aim to promote active aging by highlighting key areas where local governments and the national government should focus in terms of planning and design. It is hoped that this study will also lay the groundwork for future research on this topic.

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