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Article

The effect of window configuration on passive cooling in mosque interiors

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ABSTRACT

Cooling energy demand in buildings has more than doubled since 2000. Typically, the energy cost of a naturally ventilated building is 40% less than that of an air-conditioned building. Especially, a typical mosque's cooling energy needs are the biggest part that is consumed in the summertime. Mosque buildings are designed as buildings where the floor height is 5-6 times higher than the human scale. This height allows openings at various levels to be designed that can be used for natural ventilation. However, today, the windows that are at higher elevations in mosque buildings in Türkiye are designed as fixed windows with aesthetic concerns, and the potential for natural ventilation is ignored. Within the scope of the study, three different window configuration scenarios were modeled in ANSYS Fluent software, and the effect of natural ventilation on temperatures was tested. The first is the type in which openings close to the ground are designed, which represents the common design used in Türkiye; the second is ventilation with openings designed only at a higher level; and the third is ventilation with openings designed at two separate levels. In three different models, the inlet and outlet openings are the same size, but their places change. Velocity and temperature contour maps show that stack ventilation is quite efficient for mosque buildings. This study indicates that designing openings at higher elevations in mosque buildings creates significant differences in natural ventilation and lowers the air conditioning needs.

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INTRODUCTION

Buildings and the building construction sector account for 30% of total worldwide final energy consumption and 27% of total energy sector emissions, according to the International Energy Agency's "Buildings" report (2022). Cooling energy demand in buildings has more than doubled since 2000, making it the fastest-growing end-use in buildings, driven by a combination of warmer temperatures and increased activity. It is crucial to make sure that cooling demands are fairly met as the world warms. One of the most important criteria for avoiding ineffective activities is efficiency standards. Efficiency standards, along with better building and district design,

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and passive, natural, and alternative solutions to air conditioners, which need to be prioritized where possible to mitigate the growth in demand for active technologies, are key measures to avoid the lock-in of inefficient air-conditioning units in the coming decades (International Energy Agency, 2022). Natural ventilation is now gaining popularity as an alternative to building air conditioning. The most economical and environmentally friendly method for ventilation of buildings is natural ventilation (Darçın, 2008). The energy cost of a naturally ventilated building is 40% less than that of an air-conditioned building (Allocca et al., 2003). Natural ventilation especially provides cooling when it is designed properly. Lowering the cooling loads is important as it is the most energy-consuming operation in summertime. Brager & De Dear (2000) measured and compared the thermal intervals of people in buildings with mechanical ventilation and natural ventilation. It has been determined that people are satisfied with a narrower temperature range in air-conditioned buildings, while satisfaction is provided in a wider range in naturally ventilated buildings. This can be seen as another advantage of natural ventilation.

Mosques are buildings that were born from the need of people to worship collectively in the religion of Islam. The use of these buildings is in the form of short-term uses at certain time intervals (five times a day), but when it is occupied, many people worship in the same space and the occupancy rate is 0.5 m^2/person. Compared to other building types, mosques have a higher occupancy rate, so it is important to provide the indoor environmental quality at the desired level in the sanctuary section. In almost all mosques in Türkiye, air conditioning is used for cooling in summertime, and it consumes a huge amount of energy. Budaiwi et al.'s (2013) study shows that 73% of the total energy consumed in mosques is for cooling in summer. In contrast to other building types, such as office, institutional, and residential buildings, little research has been conducted on the energy and thermal performance of mosque buildings.

Studies on natural ventilation in mosques are as follows: Imam (2003) suggested that sufficient flow rates can be achieved by testing with various thermodynamic equations that the minarets of mosques can be used as wind chimneys for the city of Dhaka, Bangladesh. It has been proposed that a technical function be assigned to the minarets, which today have only a visual function. Al-Homoud et al. (2009) conducted an energy consumption analysis on three existing mosques in Saudi Arabia. Cooling and air conditioning devices have had the largest share in energy consumption. For this reason, energy consumption has increased significantly, especially in the summer months. Asfour (2009) measured two types of mosques, classical Ottoman style and Arabic style, for thermal performance in Ecotect software. The results of the study revealed that the Ottoman-type mosque performed better in the summer months, but the Arabian-type mosque gave more successful results in the winter months. In the study by Maarof (2014), the effect of different roof designs on thermal comfort in Malaysian mosques with typical natural ventilation was evaluated. The hipped roof and the domed type were compared. The study was carried out on four existing mosques. As a result, while the dome type gave better results in mosques with 5000 people or more, the hipped roof type gave more positive results in mosques with a capacity of less than 5000 people. Al Sudany (2015) evaluated the minaret of a mosque in Baghdad as a windcatcher, adding a water spray system to the minarets, and both humidification and cooling effects were tested with computational fluid dynamics (CFD) simulation. The results revealed that this system is a sustainable and successful system for mosques. Mushtaha and Helmy (2017) examined the effects of the forms of mosque structures on thermal performance in a hot humid climate with simulation modeling via Ecotect software. Square, rectangular, and polygonal plans were evaluated. The results revealed that the building form with the least surface area gives the best temperature performance. Nordin & Misni (2017), in their study in Malaysia, selected a historical and a newly built existing mosque and examined their thermal performance. The study was carried out by measuring the airflow rate, temperatures, and humidity with the help of devices. While temperatures fluctuate throughout the day in the new mosque, a certain temperature increase was observed in the old mosque in the afternoon. Ray et al. (2017) evaluated natural ventilation design in the design process of a real mosque project with CFD analysis models. Nordin & Misni (2018) evaluated the thermal performance of three mosques in Malaysia by making device measurements. Alhasan & Yuning (2019), in their research on mosques in China, measured the thermal performance of mosque courtyards with CFD analysis and evaluated which courtyard types are more efficient according to directions. Atmaca & Gedik (2019) conducted a comparative study by examining the energy consumption and thermal comfort conditions of two mosques in a temperate humid climate. Othman et al. (2019) tested how the interior comfort of the building is affected by different opening types in a typical domed mosque in Malaysia in Flow Design software. It has been observed that the flow rate in the building increases when small inlet and outlet openings are used. On the other hand, it has been observed that the speed decreases slightly when small inlet and large outlet openings are designed. Consequently, it would be more appropriate to prefer large inlet openings in areas with high prevailing wind speed, and smaller inlet openings in areas with low wind speed. Rahim & Marassabessy (2019) examined in detail the natural ventilation features of an existing mosque in Indonesia. Sanusi et al. (2019) evaluated three mosques built during the British colonial period in

Malaysia in terms of environmental performance. Thermal performances were measured with the help of devices, and ventilation performances were obtained by simulation.

Yusoff and Jaafar (2019) selected a historical mosque in Malaysia and evaluated the thermal comfort conditions by measuring them with the help of devices. Mohammed et al. (2020) modeled an existing historical mosque structure in Egypt and tested it in a wind tunnel. Yüksel et al. (2021) made an indoor comfort assessment by measuring CO_2 and temperature values in an existing mosque. Azmi et al. (2021) collected the factors affecting energy efficiency in mosques in a review article. Diler et al. (2021) evaluated the thermal performance of a historical mosque in Manisa through measurements. In addition, simulations were carried out in the Design Builder program and evaluated together with real measurements. Raslı et al. (2021) studied the thermal performance of 21 mosques in Malaysia. It has been seen that the factors affecting thermal comfort the most are the window-to-wall ratios and the type of ventilation. Yüksel et al. (2021) compiled studies on thermal comfort, indoor air quality, and energy consumption in religious buildings.

The literature review shows that thermal comfort and natural ventilation research in mosque buildings were mostly carried out as experimental studies with the help of devices. Evaluation studies with simulation software are very few and have started to increase in recent years. Azmi & İbrahim (2020) stated that with CFD analysis, mosques can be examined more comprehensively, and accurate results can be achieved. In this context, it is important to investigate the effect of different window configurations on ventilation, which will be examined within the scope of this article, in terms of its contribution to the literature.

The sanctuary of the mosques is usually arranged as a single and large volume for collective worship. For this volume to provide a three-dimensional space effect, the ceiling height is determined by its scale. For this reason, mosque buildings are designed as structures where the floor height is 5-6 times higher than the human scale. This height allows openings at various levels to be designed in the shell of the mosque that can be used for natural ventilation. However, today, the windows on these surfaces in mosque structures in Türkiye are not designed as operable windows; they are designed with aesthetic concerns, and the potential for natural ventilation is ignored.

Examining the effect of windows designed at different heights on natural ventilation will encourage designers to evaluate the potential for the evacuation of hot and polluted air by utilizing the interior height of the building. Within the scope of the study, three different window configuration scenarios were modeled in ANSYS Fluent software, and the effect of natural ventilation on temperatures was tested. The data obtained as a result of the study is important in terms of presenting data that can be used by architects in the early design stage of mosque design. As stated in the literature, the thermal comfort performance of mosques is an area that has been started to be investigated in recent years, and further studies will contribute to the literature.

MATERIALS AND METHODS

Natural Ventilation and Passive Cooling of Building Interiors

Natural ventilation is the use of the natural driving forces of wind or temperature difference to achieve ventilation for buildings (Ji et al., 2009). Air flows from a high-pressure point to a low-pressure point. In order to ensure air movement in an interior space, a pressure difference must be created between the point where the air enters the space and the point where it leaves the space. The higher the pressure difference, the more air will flow inside. Airflow within the space is important for the user to sense air movement and to remove air pollutants from the space. The air which is used becomes dirty and hot. As it heats up, it expands, becomes lighter, and thus rises. The rising hot air is replaced by cold and clean air which comes from inlets. Accordingly, in an interior, clean and cold air is located near the floor, and dirty and hot air is located near the ceiling. Precise and slow modification of air movement maintains the orderliness of the airflow, while sudden changes create turbulent currents where airflows swirl and split into unpredictable directions. If the speed of an air stream increases relative to the speed of the adjacent air stream, the pressure of this air stream decreases. Airplane wings take off with this principle. This is called the Bernoulli effect. When a stratified airflow is compressed to pass through an opening, its speed increases, and its pressure decreases. This situation is called the Venturi effect (Darçın, 2008).

Passive cooling is the use of natural wind for ventilation to disperse heat through convection and increase occupants' perception of thermal comfort through evaporation. Cooling occurs in the building by evacuating the hot air from the building with the natural movement of the prevailing wind within the building. The main purpose of passive cooling is to reduce the fossil fuel required to cool the space using a mechanical system (Jaffe et al. 2020).

Wind entering from the surface of a building creates positive pressure on the surface it encounters and negative pressure on the other surfaces. Therefore, air will want to enter through the openings on the surface with positive pressure and go out through the openings on the surface with negative pressure. Temperature differences between the indoor and outdoor environments lead to changes in air density, which causes pressure differences. When the indoor air temperature is higher than the outdoor environment, the indoor air goes out from the highest elevation of the building, and the cooler outdoor air enters from the lower

elevations of the building. Thus, passive cooling occurs. Buildings are naturally ventilated to cool the space with three basic principles: single-sided ventilation, cross-ventilation, and stack ventilation.

Single-Sided Ventilation

Single-sided ventilation occurs in cases where the building is in contact with the external environment through a single surface. For the single-sided or single-opening ventilation method to be successful, the room depth should not exceed 2.5 times the interior height (Küçüker, 2019; Yavaş, 2019).

Cross Ventilation

The cross-ventilation system occurs by creating two different pressure zones on two sides of the building. Airflow moves from the high-pressure area to the low-pressure area, meaning air currents around a building create high-pressure areas on the front where the wind comes from and low-pressure areas on the other side. The most effective cross ventilation occurs when windows (inlets and outlets) are located in the high-pressure and low-pressure zones of the building (Habibzadeh, 2018). Cross ventilation occurs efficiently when the depth of the space is at most five times the interior height.

Stack Ventilation

The stack effect uses a combination of convection techniques: Bernoulli's principle and the Venturi effect to ventilate a building. Air moves as a result of air pressure differences, which vary due to temperature and moisture differences throughout the building. Warm air rises through the building to escape through a window at higher elevations or a roof vent (Jaffe et al., 2020). Natural ventilation has been shown to affect substantial reductions in cooling energy by over 40-50% in some metropolises in Europe and the USA (Li & Chen, 2021). Passive cooling and natural ventilation reduce the need for fossil fuel energy-based mechanical HVAC (heating, ventilation, and air conditioning) systems to provide cooling and air circulation. Therefore, carbon emissions decrease, and building operational costs are reduced, which supports the fight against global warming.

The most efficient ventilation and passive cooling strategies are:

- Designing buildings with more openings for natural ventilation,
- Designing openings on opposite sides to have cross ventilation,
- Carefully designing the window-to-wall ratio (WWR) to avoid overheating,
- Using shading strategies,
- Well-designed thermal insulation to reduce heat transfer (Jaffe et al., 2020).

Basically, there are three approaches to studying natural ventilation: empirical models, experimental measurements, and computational fluid dynamics (CFD) simulations. Each of these approaches has its advantages and limitations. Empirical models are often developed from analytical solutions and experimental data. While they are useful for natural ventilation design, they may not provide sufficiently detailed or accurate information about natural ventilation. Experimental measurements are effective in obtaining realistic information about natural ventilation. However, they can be expensive, time-consuming, and may not always provide the level of detail needed to fully understand the natural ventilation mechanism. CFD simulations are gaining popularity due to their ability to provide informative results, lower labor costs, and reduced equipment requirements. CFD simulations can offer detailed insights into natural ventilation processes (Jiang, et al., 2004).

Computational Fluid Dynamics and Architecture

CFD involves expressing partial differential equations with discretized algebraic equations that approximately represent these equations. These equations are then solved numerically to find the flow field at the discretization points created in a certain space and time. Since the Navier-Stokes equations are valid for the flow field at every point in the space occupied by the fluid, an analytical solution of these equations gives the solution for the flow at an infinite number of points. However, analytical solutions are available for a limited number of simplified flows and geometries. To overcome this limitation, the equations representing the flow can be discretized and expressed in an algebraic form that can be solved on a computer. CFD simulations find relevant flow variables only for discretization points. Values at points that do not correspond to discretization points are obtained by interpolation methods (Young et al., 2018).

Computational fluid dynamics (CFD) can be thought of as a numerical experiment. CFD calculates the properties of airstream such as direction, velocity, pressure, and temperature by using partial differential equations. In a typical fluid experiment, an experimental model is created, measurements are taken from the places where the model and the fluid interact, and the results are analyzed. In CFD, model building is replaced by the formulation of equations representing the flow and the development of the numerical algorithm. The process of making measurements is replaced by simulating the flow by creating an algorithm on the computer. One of the most important advantages of using CFD modeling is the time and cost savings it provides in design. In the past, designs required manufacturing and testing many prototypes, but with CFD, flow problems can be revealed without manufacturing the prototype. Another advantage is that complex flows can be demonstrated visually with CFD (Young et al., 2018).

CFD has been extensively used in the aerospace and automotive sectors since the 1970s. Therefore, it has potential for architectural design. Structural load testing, lateral winds, wind uplift forces, and natural ventilation design are just a few of the potentials to use CFD in building design. Airflow has a direct effect on designing a building form, opening, and different spaces.

CFD was introduced to the architectural field in the 1990s, and the number of studies using CFD has been increasing since 1997 (Zhai, 2006). The increase in numbers related to CFD in research shows that architects are realizing the potential of CFD. It also appears that CFD can be used not only to evaluate a finished project but also in the architectural decision-making phase. Figure 1 shows the studies that are CFD-related in the architectural field (Jo et al., 2018).

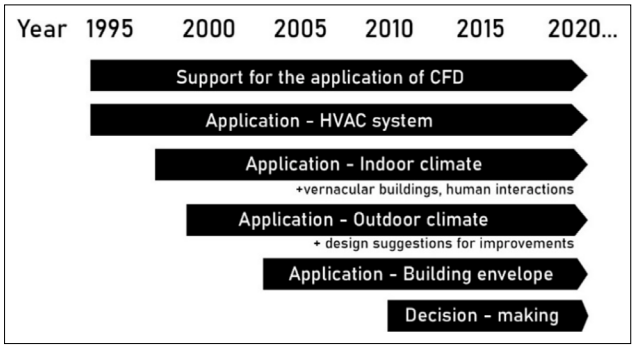

Figure 1. CFD-related research in the architectural field in years (Jo et al. 2018).

Method

The study focused on the cooling effect of natural ventilation in mosques during the summer months. The methodology in Figure 2 was applied to evaluate natural ventilation potentials suitable for mosque buildings and to create design criteria for architects by finding the right window configuration.

The primary aim of the study is to evaluate the natural ventilation potentials of mosques and to create a design criterion for architects by finding the most suitable window configuration for wind-driven natural ventilation. Initially, a prototype mosque was designed based on current practices and regulations in Türkiye and the international literature. Wall, floor, and roof details of the building were drawn, and the U-values of these surfaces were calculated according to TS825. The U-value is the amount of heat passing per unit of time through 1 m² of a building element consisting of different material layers. Thermal insulation applications aim to reduce the U-value as much as possible. The smaller the U-value, the less heat loss the building has. Five-year climate data (wind and temperature) for July, which represents the hottest time of the year in Konya province, were obtained. The model loaded into the CFD software was shaped in line with these data, and analyses were

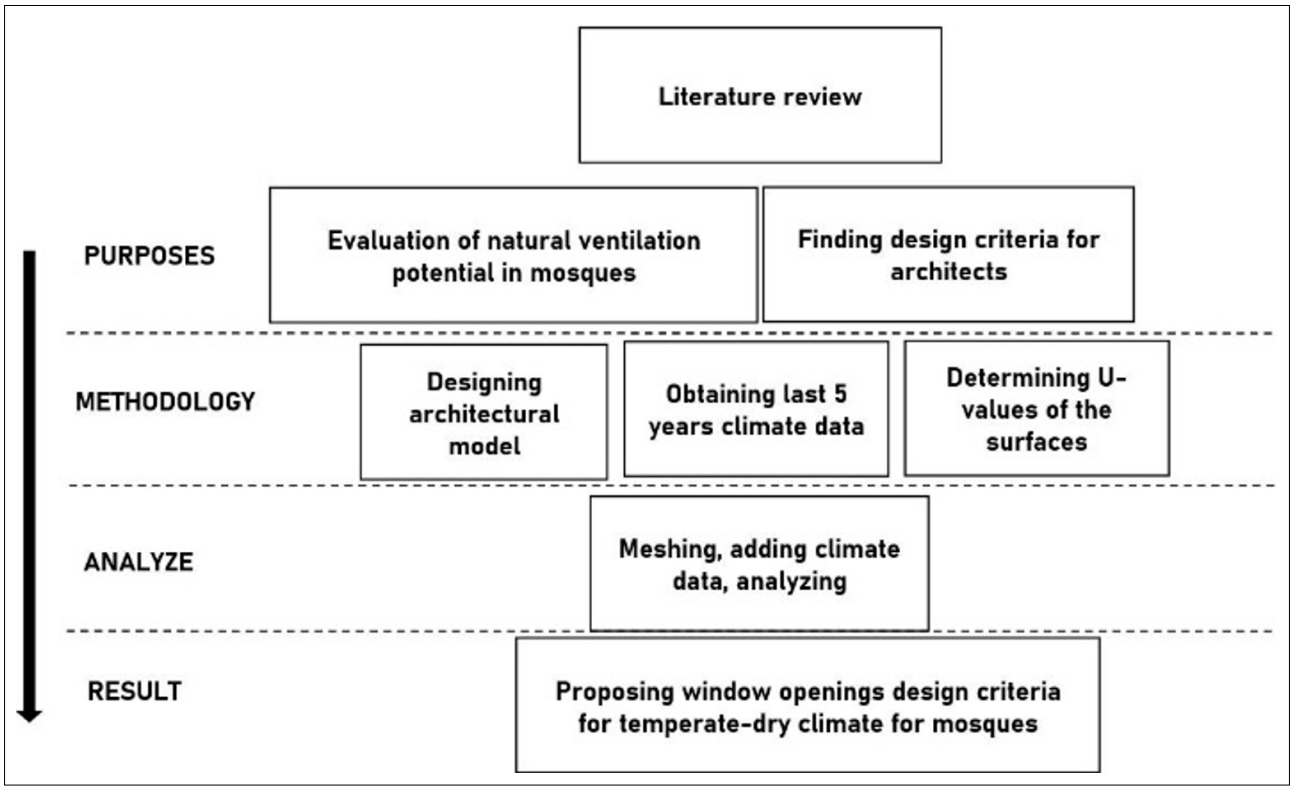

Figure 2. Methodology of the study.

carried out. Finally, the analysis outputs were interpreted comparatively, and a design criterion that architects could use at the design stage was proposed.

Within the scope of the study, a prototype mosque was designed to be analyzed in the climatic conditions of Konya, which represents a temperate dry climate in Türkiye. The size of the mosque was determined after a meeting with the Turkish Presidency of Religious Affairs. The Presidency of Religious Affairs stated that the most commonly used type is mosques with a capacity of 500 people. A mosque with a central square plan, the most used plan type in Türkiye, and a capacity of 500 people, was designed for the study. According to the "Mosque Planning and Design Guide" of the Presidency of Religious Affairs, when designing mosques, it is necessary to allocate 0.5 m^2 of space for each person. Therefore, a 250 m^2 prayer area was designed for the prototype building that can accommodate 500 people.

Windows are considered weak points in the structure because they offer less resistance to heat transfer than opaque parts of the structure. Therefore, by reducing the window-to-wall ratio (WWR), unwanted overheating can be minimized. However, reducing the window ratio also risks increasing the energy consumed by artificial lighting as the daylight received into the building will decrease. Thus, using the optimum WWR is crucial for reducing energy consumption (El-deeb, 2013). For this study, the WWR was set at 35% for the north, east, and west directions based on the value determined for a temperate dry climate from Goia's (2016) study. The southeast direction in Türkiye is the qibla direction for mosques. During worship, prayers are performed facing this direction (qibla), and since there should not be any distracting elements in this direction, there are generally no windows. In the prototype mosque, no openings were arranged in this direction either. The mosque's building height was designed using the ratios determined by the General Directorate of Foundations of Türkiye, compiled in the study by Gürsoy (2018).

Since natural ventilation and cooling in mosques are being examined, the analysis was carried out for the hottest month of the year. The temperature and wind data for five years (2018-2022) of July, which is the hottest month of the year for Konya, Türkiye, were obtained from the General Directorate of Meteorology. The average daytime temperature for these five years in July is 25.7 °C, and the average wind speed is 3.8 m/s with the prevailing wind direction being northwest. This means the prevailing wind will enter from the mosque's entrance façade, which is on the northwest side that air inlets are three doors and three windows on the entrance façade. Air outlets are designed as windows on other facades, except the qibla façade. Mosque thermal insulation details were drawn to obtain each surface's U-values. The U-values are determined as 0.275 W/m^2K for walls, 0.255 W/m^2K for ceilings, 0.363 W/m^2K for floors, and 1.80 W/m^2K for windows (12-4-12 mm double-glazed low-E coating). These values comply with the ranges specified for Konya in TS825:2013 (Turkish Standards Institution, 2013), which is the standard in Türkiye that indicates thermal insulation requirements.

Mosques are buildings that are used intermittently at five different times during the day. During these times, the usage duration is between 15 minutes and half an hour on average. Intermittent use is a characteristic feature that distinguishes mosque buildings from other building types and creates the potential for effective natural ventilation. During the summer months, windows can be kept fully open except during prayer times. In this way, the prevailing wind can be harnessed and effective cooling achieved inside the mosque. During prayers, the openings that let the prevailing wind in will be closed to prevent unwanted rapid airflow inside, and only the windows on the upper level will be kept open, which will allow for the evacuation of the heated air. However, the common practice in Türkiye is to provide ventilation with windows arranged close to the floor level. Since this type of ventilation is not supported by the stack effect, it is insufficient in the worship area and results in the use of intensive air conditioning. Traditionally, windows are not designed at upper elevations of the walls, which average 10-15 meters in height, because it was believed that occupant access was needed to open and close the windows. However, with the advent of automation technology, these windows can now be controlled remotely, which may significantly reduce the need for air conditioning in mosques by utilizing the high ceiling height to enhance the stack effect.

Based on this hypothesis, three different types of ventilation scenarios were prepared (Figure 3). The first scenario features openings close to the ground, representing the common practice of ventilation used in Türkiye; the second involves ventilation with openings designed only at the upper level; and the third includes ventilation with openings designed at two separate levels. In the three different models, the inlet and outlet openings are the same size, but their locations vary. As mentioned previously, the air inlet is at the prevailing wind's direction, which is

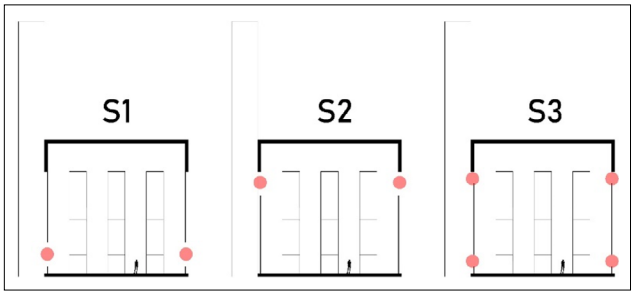

Figure 3. Three ventilation scenarios prepared with different window configurations.

the mosque's entrance façade. Air outlets are the windows designed on the northeast and southwest façades, which are three large windows that allow natural light inside. The evaluation considered how ventilation was affected when the openings' positions changed, including airflow velocities and interior temperatures.

All analysis processes were carried out in ANSYS 2022. Flow and structure geometries were drawn, edited, and made suitable for meshing with the SpaceClaim module. Its geometry and mesh structure were created in the ANSYS mesh module. The total number of elements of the model transferred to the solution is approximately 2.5 million. Models were created from quadrilateral cells only. The mesh structure of the model was created so that all edges, surfaces, and volumes had a minimum element size of 0.2 m. Conservation, energy equations, initial, boundary conditions, and loadings are determined in the Fluent module. The "Shear-stress transport (SST) k-ω model" was used as the turbulence model as it gives better results and convergence in viscous regions. The "Solar ray tracing" model was used for solar radiation, which helps to see both the effects of direct solar illumination and diffuse solar radiation in the model.

The coordinates of Konya province were entered into the solar ray tracing model, and the direction and intensity of solar rays were determined for the specified date and time. The time determined for this study is July, which is determined as the hottest month of the year, obtained from the General Directorate of Meteorology. The time has been determined as 14:00. This time was chosen to represent the afternoon hours when mosques are used intensively. Additionally, it aims to see the effect on the mihrab façade, which is heated by the afternoon sun, in the analysis.

RESULTS

Flow velocities and indoor temperatures are measured with the help of the software. Velocity contour maps and temperature contour maps were obtained. The color range of maps was arranged to represent the same temperatures with the same colors and the same velocities with the same colors to compare the scenarios accurately. Temperatures and air speeds are taken at an altitude of 1.10 meters since the measurement height is determined as 1.10 m in the ASHRAE-55 standard (Al-Homoud et al., 2009; ASHRAE, 2004; Çalış et al., 2017).

Flow Velocities

Scenario 1 (S1)

Scenario 1 represents the common design in mosques in Türkiye. At the southwest and northeast façade, six window openings were designed in total (three windows for each façade). The air enters from the windows and doors of the entrance façade and exits through these six windows. To make an accurate evaluation, the total size of the openings was kept the same in all scenarios. Only the positions of the windows change to understand how it affects air circulation and lowers interior temperatures.

S1's flow velocity diagram shows that air enters at approximately 5 m/sec speed (Figure 4). The airflow that comes from the middle door reaches the Mihrab area and bends towards the ceiling, creating circulation inside the mosque and flows out from the windows at +0.90 cm elevation. The airflow from the other doors decelerates faster compared to the airflow from the middle door. This scenario forms cross ventilation.

Scenario 2 (S2)

Scenario 2 has windows close to the ceiling to provide stack ventilation. The windows from S1 were simply moved to a higher elevation to assess the difference. S2's flow velocity diagram shows that the airflow on the southwest side of the interior is faster than the other two main air streams (Figure 5). Since the southwestern façade heats up more than the northeastern façade and there are no openings at ground level in this scenario, the airflow accelerates and increases due to the low pressure formed in this area.

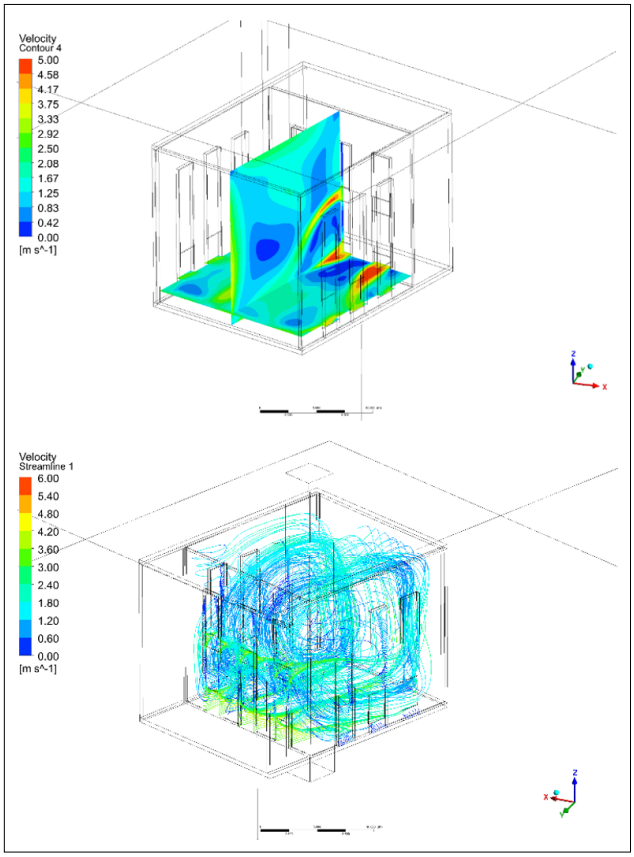

Figure 4. S1 flow velocity diagram and velocity streamline.

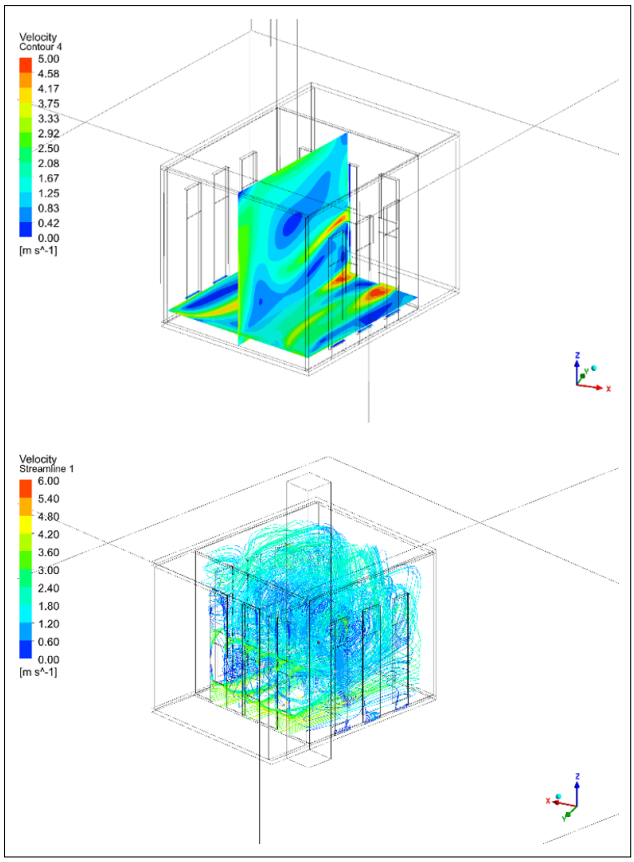

Figure 5. S2 flow velocity diagram and velocity streamline.

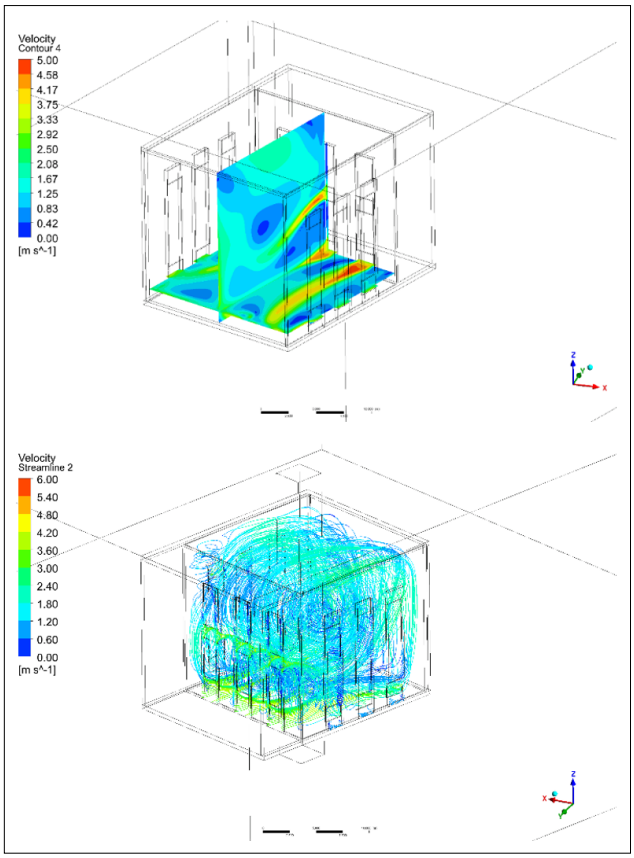

Figure 6. S3 flow velocity diagram and velocity streamline.

Scenario 3 (S3)

Scenario 3 has more openings compared to S1 and S2, but the sizes of the openings are smaller. It is important to note that the total size of the openings remains unchanged. In this design, each opening of a single window is split into two, with one at ground level and one at a higher elevation, effectively forming both stack and cross ventilation (Figure 6). S3's airflow velocities are higher than those in S1 and S2, as the two main air streams that enter from the middle door and the door near the northeast façade reach the mihrab wall at higher speeds, indicating more effective ventilation.

Scenario 1 (S1)

The analysis results indicate that the minimum interior temperatures start at 25.7 °C, which was established as the average outdoor temperature for July during the daytime, as obtained from the General Directorate of Meteorology. The solar model heats the building to higher temperatures, while the prevailing wind enters at 3.8 m/s, the average wind speed for July, which helps to cool down the temperatures. Figure 7 illustrates the building's exterior surface temperatures, which are significantly high.

Figure 8 displays S1's temperature contour diagram. The temperature map indicates that the entrance area of the mosque is cooler than other parts due to the faster airspeed. The air temperature increases towards the Mihrab wall. The diagram reveals that 37.09% of the space registers temperatures between 27.80-28.33 °C, which constitutes the largest percentage, while 29.25% of the space falls within 28.33-28.85 °C. Additionally, 17.05% of the space is within 27.27-27.80 °C, and 11.49% is within 26.75-27.27 °C. The remaining parts comprise less than 10% of the space.

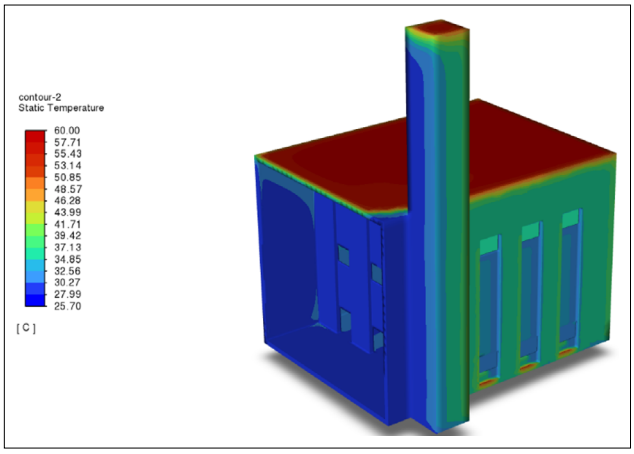

Figure 7. Exterior temperatures.

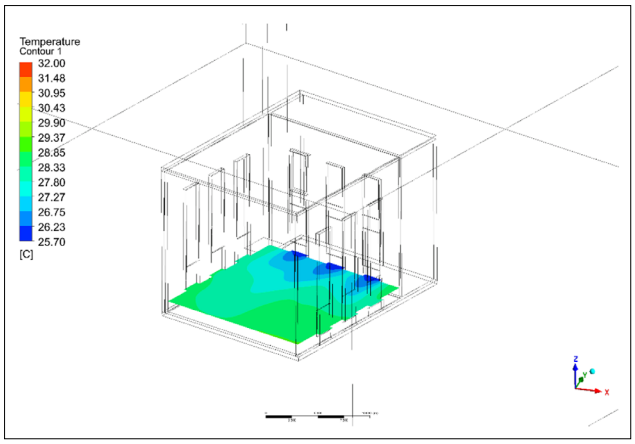

Figure 8. S1 temperature contour diagram.

Scenario 2 (S2)

Figure 9 presents S2's temperature contour diagram. The temperature map reveals that the southwest façade heats up more, indicating that measures must be taken at this façade to prevent overheating and to help achieve a more uniform temperature distribution throughout the building. According to the diagram, 42.93% of the space falls within the range of 27.27-27.80 °C, which constitutes the largest percentage. Furthermore, 25.96% of the space is between 26.75-27.27 °C, and 17.36% is between 27.80-28.33 °C. The remaining parts comprise less than 10% of the space.

Scenario 3 (S3)

The S3 temperature contour diagram is depicted in Figure 10. The interior temperatures are similar to those in S2, but the temperature map for S3 is more uniform. The ground floor level window openings, absent in S2, have helped to prevent overheating at the southwest façade by facilitating airflow. According to the diagram, 37.97% of the space falls within the range of 27.27-27.80 °C, which constitutes the largest percentage. Additionally, 31.99% of the space is between 27.80-28.33 °C, and 20.83% is between 26.75-27.27 °C. The remaining areas comprise less than 10% of the space.

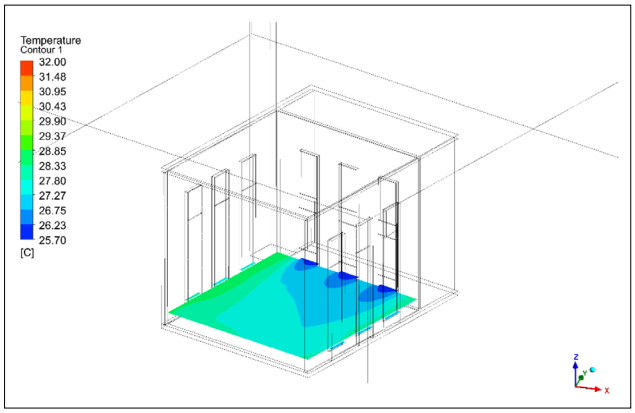

Figure 9. S2 temperature contour diagram.

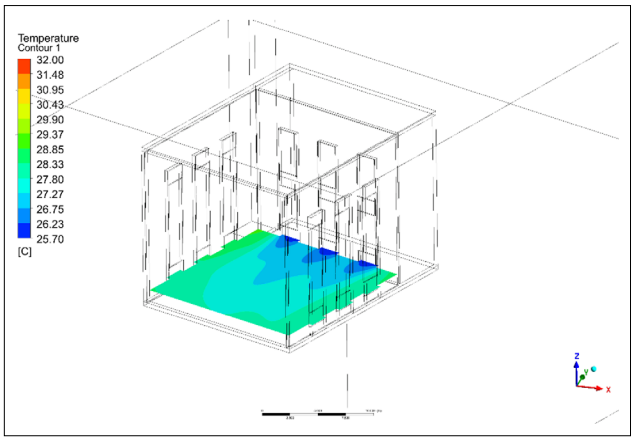

Figure 10. S3 temperature contour diagram.

Comparing the window configurations, temperature contour maps and velocity contour maps demonstrate that the S2 and S3 scenarios provide better ventilation and lower temperatures than the S1 scenario (Figure 11). This highlights the significance of stack ventilation for mosque buildings. The S1 scenario, which relies solely on a cross-ventilation strategy at ground floor level, is insufficient for achieving efficient air circulation to reduce temperatures effectively. The temperature maps for S3 are more uniform than those for S2, yet the temperatures are comparable. Air velocities in the S3 scenario are higher; the three main air streams reach the Mihrab wall more quickly than in the other scenarios.

Figure 12 presents a comparative view of the percentage of space within each temperature range for all three scenarios. As can be seen, S2 and S3 have similar temperature distributions, but S1 exhibits higher temperatures. When comparing the temperature ranges where most of the space in the different scenarios falls, 86.25% of the space in the S2 scenario and 90.79% of the space in the S3 scenario are within the range of 26.75-28.33 °C. In contrast, 83.39% of the space in the S1 scenario falls within the range of 27.27-28.85 °C.

CONCLUSION

Within the scope of this study, three different window configurations on a mosque prototype were examined. The first configuration (S1) featured ground-level openings, reflecting the common practice in Türkiye. In the second configuration (S2), openings were positioned near the roof to test the stack effect. The third configuration (S3) investigated the impact of windows at both ground and upper levels on passive cooling. Temperature comparisons show that S2 and S3, which utilize the stack effect, maintain lower temperatures than the S1 configuration. Specifically, 86.25% of the space in S2 and 90.79% of the space in S3 fall within the temperature range of 26.75-28.33 °C, while 83.39% of the area

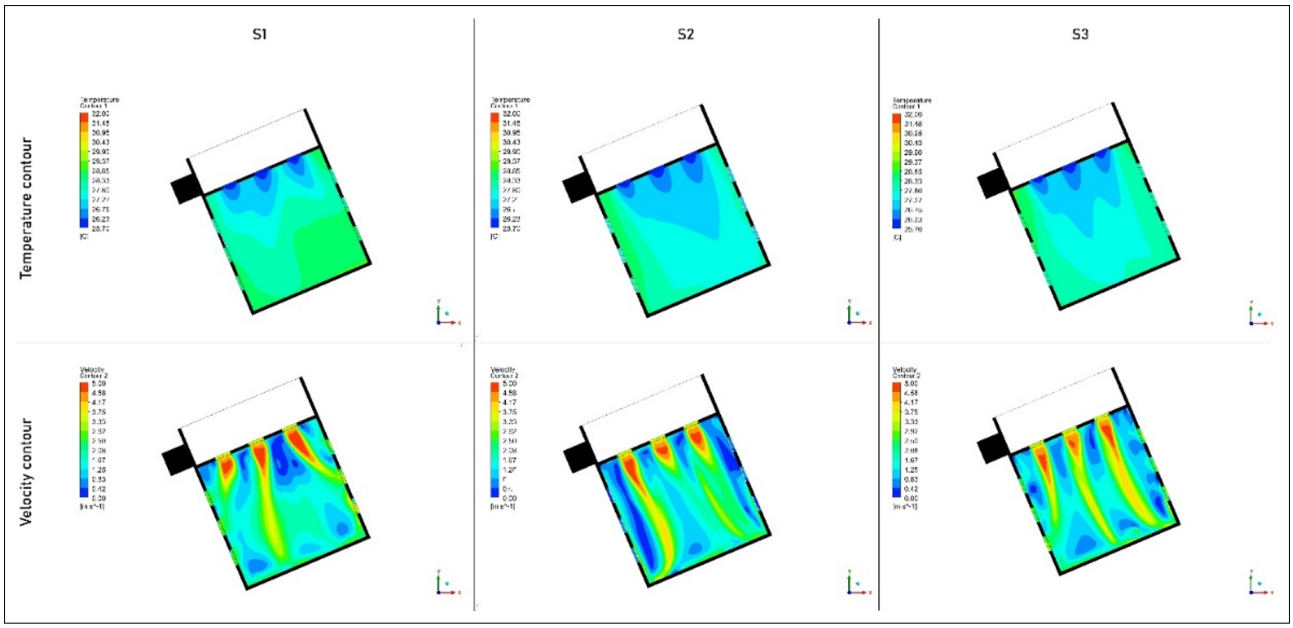

Figure 11. S1, S2, S3 temperature contour and velocity contour diagrams.

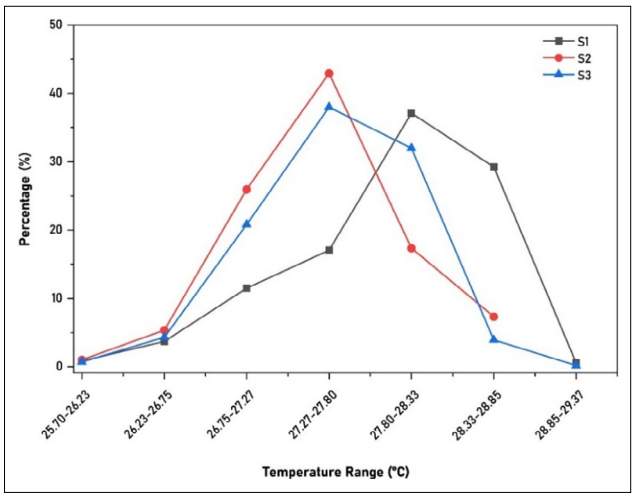

Figure 12. Temperature range – percentage of the space chart.

in S1 is within the range of 27.27-28.85 °C. These findings underscore the significance of incorporating stack effect ventilation in mosque designs. The S1 scenario, with only ground-level cross-ventilation, does not provide adequate passive cooling for mosque buildings. The results indicate that stack ventilation is highly effective for mosques, which typically have much taller floor heights than other building types. Therefore, this study suggests that designing openings at higher elevations in mosque buildings significantly enhances natural ventilation and reduces the reliance on air conditioning. Architects can utilize this criterion to design more sustainable mosque buildings.

For future research, analyses could be extended to include strategies to prevent overheating, such as the implementation of sunshades on the southwest façade or the creation of a protective shell around the building. Such modifications could further improve the efficiency of natural ventilation and cooling.

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Article

A cultural geography review on understanding the mechanisms of transformation in rural settlements: The case of İzmit district

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ABSTRACT

Rural areas, shaped by their internal dynamics, confront interconnected challenges such as an aging and sparse population, declining rural labor force, land division during inheritance transitions, and insufficient public services, including education, healthcare, commerce, and culture. Migration from rural to urban areas exacerbates pressures on rural areas, particularly heightened during crises such as epidemics, earthquakes, droughts, floods, regional conflicts, wars, and migrations with global repercussions. These challenges negatively impact communities and urban areas, increasing vulnerability to subsequent crises. The legislative framework for rural settlement planning in Türkiye is lacking, leading to the adoption of urban planning tools in rural contexts. However, rural areas, closely connected to nature, possess distinct knowledge. Unfortunately, this unique knowledge, akin to Bourdieu's habitus, is swiftly eroding. This study uniquely explores the analysis of rural areas through the lenses of habitus and cultural geography, combining two theoretical frameworks. The focus on İzmit as the sample field enhances its distinctive value in shedding light on these dynamics. This study delved into the impact of changing global dynamics on rural areas, particularly in İzmit. Uncontrolled transformations stemmed from central decisions, rural labor shifts, and urban migration, impacting culture, agriculture, and public spaces. To address these challenges, planning methodologies must adapt, incorporating on-site analyses and direct engagement with local inhabitants. Striking a balance between urban culture and rural sustainability is crucial. Efforts to understand the unique characteristics of a place, its inhabitants, and global trends are essential for fostering a harmonious transformation amidst the ongoing rapid changes in rural areas.

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This article is based on the ongoing PhD Dissertation entitled A Cultural Geography Review: Conservation Management in Rural Settlements of Kocaeli, Izmit by Esra Ekşi Balcı under the supervision of Prof. Dr. İclal Sema Dinçer at Yıldız Technical University, Department of Urban and Regional Planning.

INTRODUCTION

Cities and rural areas embody diverse forms of human-specific cultural production, persisting through the transformation of the opposing elements they harbor. Rural areas, shaped by their internal dynamics, confront interconnected challenges such as an aging and sparse population, a declining rural labor force, land division during inheritance transitions, and insufficient public services, including education, healthcare, commerce, and culture (Kaya, 2020). The migration from rural to urban areas exacerbates pressures on rural areas, particularly heightened during crises such as epidemics, earthquakes, droughts, floods, regional conflicts, wars, and migrations with global repercussions. On the other hand, as mentioned by McCarthy (2008), the contemporary countryside is becoming a global commodity, produced to standardized specifications across diverse locations. Notably, architects, designers, builders, and manufacturers contribute to this trend in various rural settings. This postproductivist rural landscape caters primarily to consumption-oriented uses for elites, driven by shared aspirational representations. These challenges negatively impact communities and urban areas, increasing vulnerability to subsequent crises. The COVID-19 pandemic underscored that, in times of difficulty, rural areas become the first refuge for urban dwellers (TC Resmi Gazete, 2021). On February 6, 2023, a similar scenario unfolded in the aftermath of earthquakes in Kahramanmaraş. Masses (Association for Migration Research, 2023), seeking to mitigate the disaster's material and moral destructive effects temporarily or permanently, relocated to rural areas (Sert, et al., 2023). Various studies, both in academic and practical realms, advocate that a crucial means of coping with aforementioned crises is a shift from current consumption culture to a cyclical, nature-friendly lifestyle emphasizing localism. Rural areas harbor clues for this transformation (Bilgin, 2022; Tondelli, et al., 2020). The final declaration of the Culture Summit 2021 held by the UCLG (United Cities and Local Governments) network in İzmir emphasized the potential of "circular culture" as a new concept, aligning with nature, the past, each other, and change, suggesting that "another culture" is possible (UCLG, 2021). In this context, the planning discipline plays a crucial role in shaping the function of transforming "place" into space, determining activities within these spaces, human production, and the ensuing culture. The analysis phase, the initial step of planning, requires an understanding of existing culture, analysis of mechanisms, and identification of relevant phenomena. This study presents findings from the first-stage field studies associated with the question 'What kind of information do cultural landscapes provide about the economy, governance structure, materials, and cultural practices of the period in which they were formed, to be used in planning?' Accordingly, the mechanisms of change in rural neighborhoods of İzmit district are defined and discussed within the framework of four basic phenomena described in the following sections.

CONCEPTS: HABITUS, NEW CULTURAL GEOGRAPHY, AND NON-REPRESENTATIONAL THEORY

In the theoretical framework, this study integrates Bourdieu's concept of "habitus," the new cultural geography approach in geography, and non-representational theories from the social sciences. The planning discipline plays a crucial role in transforming places into spaces, determining activities within these spaces, presenting human production, and consequently shaping culture—a fact underscored in planning literature (Ersoy, 2016). Based on Bourdieu's discussion of cultural capital, it is possible to say that understanding the existing cultural structure, which is the first step of planning, is not easy in general. The practice emerges when the habitus, bestowed by cultural capital, combines with economic capital and manifests in a given field (Bourdieu, 1986). In this context, analyzing the practice requires comprehending habitus formation and an accurate interpretation of cultural capital. Bourdieu defines habitus as "the social inscribed in the body of the biological individual" (Cresswell, 2002) and categorizes cultural capital as embodied, objectified, and institutionalized. Embodied cultural capital, acquired involuntarily, varies depending on the period, society, and social class but cannot exceed the individual's capacity for appropriation; it may diminish or disappear with its carrier (Bourdieu, 1986). Consequently, planning assumes the challenging task of reading and advancing cultural capital acquired inadvertently and unaccumulable.

The primary question motivating this manuscript is, "Is it possible to formulate a method for analyzing, informed by the theory of cultural geography, to improve planning methodology and management frameworks in rural areas?" On the other hand, this article is predominantly shaped by the related question, “What kind of information do cultural landscapes provide about the economy, governance structure, materials, and cultural practices of the period in which they were formed to be used in planning?”[1]

The current state of historical rural settlements and the rapid transformations they have undergone for various reasons are thought to find their most meaningful interpretation through the perspective of the residents, who are the primary actors in all these dynamics, marking a significant starting point. Drawing on Bourdieu's idea “Only by constructing the objective structures...is one able to pose the question of the mechanisms through which the relationship is established between the structures and the practices or the representations which accompany them, instead of treating these 'thought objects' as 'reasons' or 'motives' and making them the determining cause of the

practices," quoted by Cresswell (2002), this study seeks to reveal specific phenomena and the mechanisms underlying these phenomena to trace the practices of change in rural areas and answer the aforementioned questions.

This study adopts the new cultural geography approach within the framework of cultural geography theory. In the late nineteenth and early twentieth centuries, geography primarily focused on environmental determinism and possibilism in an attempt to comprehend the intricate relationship between humans and their environment. Environmental determinists contended that the physical environment, including climate and landforms, played a decisive role in shaping culture. Conversely, possibilists asserted that humanity held the central position and was the dynamic force in the interaction between humans and the environment, with human power to alter the environment being more influential than the environment's impact on humans (Arı, 2005).

Carl Sauer, the founder of the traditional cultural geography school, introduced a paradigm shift by placing culture at the forefront rather than the environment. Sauer's fundamental principle proposed a geographical science approach that viewed space not merely as a physical entity but critically examined and analyzed the landscape elements within that space, uncovering the human imprint on the landscape. His research emphasized the explanatory aspect of spatial relations, advocating that attention should be directed toward understanding culture (Mathewson, 2009). This approach necessitated revealing changes in the landscape over time by collecting region-specific information. John Brinckerhoff Jackson, a significant proponent of the cultural geography approach, stood out for his focus on understanding how a landscape was formed and deciphering the clues it could provide about its creator, irrespective of aesthetic judgments. Jackson perceived the landscape not as a natural feature of the environment but as an artificial space—a human-made system of spaces on the land's surface, functioning and evolving to serve a community based on cultural, not natural, laws. He defined the collective character of the landscape as something agreed upon by all generations and points of view (Jackson, 1984). In the 1980s, influenced by criticisms of the traditional cultural geography paradigm and the prevailing social science paradigm, a new cultural geography school emerged. This school[2] emphasized landscape interpretation through the lens of social and cultural theories (Kayserili, 2010).

From a cultural geography perspective, places are formed through the intricate interplay of culture and context, constituted by a complex web of traces—marks, residues, or remnants left by cultural activities. Traces, encompassing both material elements like buildings and non-material aspects such as emotions and performances, are influential in shaping the meanings and identities of places. Cultural geography, in scrutinizing these traces, examines their interactions, motivations, and consequences, providing a critical appraisal of the cultural ideas and preferences that contribute to the dynamic composition of places (Anderson, 2021). Studies and discussions within the evolving field of cultural geography continue to unfold dynamically. The emergence and widespread application of non-representational theories in the realm of social sciences has significantly impacted discussions on cultural geography, prompting a reconsideration of space as a continuous flow, a series of becomings (Anderson, et al., 2003). A crucial aspect of these discussions underscores the necessity of understanding the body and its emotions within this becoming for the accurate interpretation of geography, encompassing both place and space. Hayden Lorimer's trilogy of articles in Progress in Human Geography (2005, 2007, and 2008) serves as a valuable resource for exploring the various facets of this debate and assessing the current stage of its development. These articles also offer insights into the contributions of influential thinkers in geography, including Bourdieu, Thrift, and Tuan (Lorimer, 2005, 2007, 2008). The evolving landscape, marked by accretion, change, and lingering forms, serves as a cultural memory bank, reflecting the reciprocal relationship between the land and its inhabitants. This concept, seen as layers or a temporal process, sheds light on the dynamic interplay shaping both the physical environment and cultural practices. While valuable for understanding landscapes, it leans toward regional generalizations and requires consideration alongside the spatial diffusion of change to comprehensively grasp the temporal evolution of a place (Crang, 2013). While studies on the application of cultural geography and non-representational theory in Türkiye are limited, the theoretical introduction of these concepts dates back to the 1980s. Some authors note that these discussions have not yet reached the level of the international academic environment due to limited adoption and practice in the field (Arı, 2017; Okur, et al., 2021). A notable recommendation for incorporating non-representational theories into planning in Türkiye comes from Prof. Dr. İlhan Tekeli. In his speech titled "What kind of changes does the development of non-representational theories make in our understanding of planning and our view of the city?" delivered in 2019, Tekeli states, "The concept of non-representational theories functions as a kind of umbrella. These theories are not entity-based; they are emergent/being-based. By concentrating on how life will take shape, these theories acquire expression within shared experiences." Additionally, he emphasizes the importance of non-representational theories on subjectivity when looking at a place, body, or work of art (Tekeli, 2019). Tekeli's approach, supported by Nigel Thrift's (2007) views, contains the clues of a different perspective in the interpretation of space. Recent discussions on new perceptions of space and

time highlight three interconnected characterizations that have gained prominence. The concept of relative space emphasizes a more flexible understanding of space and time, portraying them as dynamic and animated, akin to a river with perpetual motion, challenging the traditional surveyor's static depiction on maps. This viewpoint sees space as continuously evolving, framed by serpentine movements and patterns of vortices (Thrift, 2007).

METHODOLOGY

Rural settlements in Türkiye have evolved under diverse legal, historical, economic, and political conditions (Eres, 2023). Notably, literature from the 2010s has frequently emphasized the insufficient inclusion of ancient rural knowledge, traditional modes of production, and locally shaped culture in conservation planning studies on Türkiye's historic rural areas (Kayın, 2012; Öğdül, 2019; Güler, 2019; Bilgin, 2022). In this study, we aim to understand the mechanisms of rapid rural settlement transformation, shedding light on ancient knowledge still preserved in rural areas, to contribute more prominently to the planning discipline. The theoretical framework of the aforementioned study integrates the concepts of the cultural landscape from cultural geography and Bourdieu's concept of habitus from cultural capital into the application of non-representational theories within the planning field. Based on these approaches, which emphasize the importance of subjectivity and people's experiences in a particular place, the fieldwork is intended to be enriched with qualitative methods such as oral history and guided tours. Through this approach, and in line with the reasons mentioned in the introduction, the goal is to uncover the mechanisms driving change in the rural settlements of Kocaeli, İzmit, and similar regions across Türkiye, emphasizing place-specific realities. The incorporation of oral history in cultural geography studies serves as a valuable method for capturing and comprehending the human experience within a distinct cultural and spatial framework. This approach not only introduces diverse perspectives but also unveils personal narratives, establishing a profound connection to the lived experiences of individuals in rural settlements. By doing so, it enhances research by filling gaps and enriching the exploration in dimensions that may otherwise be overlooked (Riley, et al., 2007). In the initial phase of oral history interviews for this study, participants were identified by reaching out to local administrators known as 'mukhtars'. Subsequently, during the second phase, the snowball method was employed to expand the pool of interviewees. Oral history interviews were conducted with middle-aged or older individuals who have devoted a significant part of their lives to the rural environment in which they were born, using a semi-structured questionnaire that emphasized the exploration of life narratives. Within these interviews, pertinent details concerning the settlement and its resident community were gathered through inquiries that delved into social practices, traditional agricultural methods, traditional handicrafts, and the community's connection with the landscape. In the initial phase of the study, we examined the booklet, "History and Nature of İzmit Neighbourhoods (Villages)", published by İzmit Municipality in 2018 for 50 neighborhoods (previously in village status before the Metropolitan Law) (İzmit Municipality, 2018). The information conveyed through these booklets was used to create a database. Simultaneously, we examined the web pages of TUIK, Kocaeli Metropolitan Municipality, İzmit Municipality, Ministry of Environment, Urbanisation and Climate Change, and Ministry of Transport and Infrastructure. Then, the information gathered from these resources about the physical structure, socio-cultural and economic context, and planning history was systematically incorporated into the database. The data categorized under the headings[3] of physical structure, socio-cultural and economic status, and planning history were then visually represented through mapping in the ArcGIS program (Figure 1). This spatial representation allowed for the geographic revelation of important clues about the phenomena associated with the current mechanisms of change.

The narratives of rural neighborhood residents utilized in this study were extracted from analyses of oral history interviews conducted by a team, including the first author, as part of the Inventory of Intangible Cultural Heritage in İzmit Rural Neighborhoods Project initiated by İzmit Municipality.[4] These analyses were approached through the lenses of representation, identity, landscape, individual-public dynamics, and heritage concepts shared between cultural geography theory and the planning discipline (Atkinson, et al., 2005). This approach facilitated a nuanced understanding of the site-specific and individual-specific dimensions of the phenomena's mechanisms, shedding light on diverse facets that had been explored in earlier analyses.

FINDINGS AND DISCUSSION

Kocaeli, situated in the Marmara Region, is bordered by Sakarya to the east, Istanbul to the west, Yalova and İzmit Bay to the south, and the Black Sea to the north. İzmit, founded initially as Astakos in the Başiskele District on the south side of the Gulf in the third century B.C., later relocated to its current position. Acting as the capital of the Roman Empire between 284 A.D. and 330 A.D., İzmit endured invasions during the Byzantine period and fully came under Ottoman rule in 1333 (Çalık, 2007). Becoming a pivotal hub for caravans from Anatolia in the second half of the 16th century, Kocaeli played a crucial role in the shipment of goods to Istanbul. Following a major earthquake in 1776,

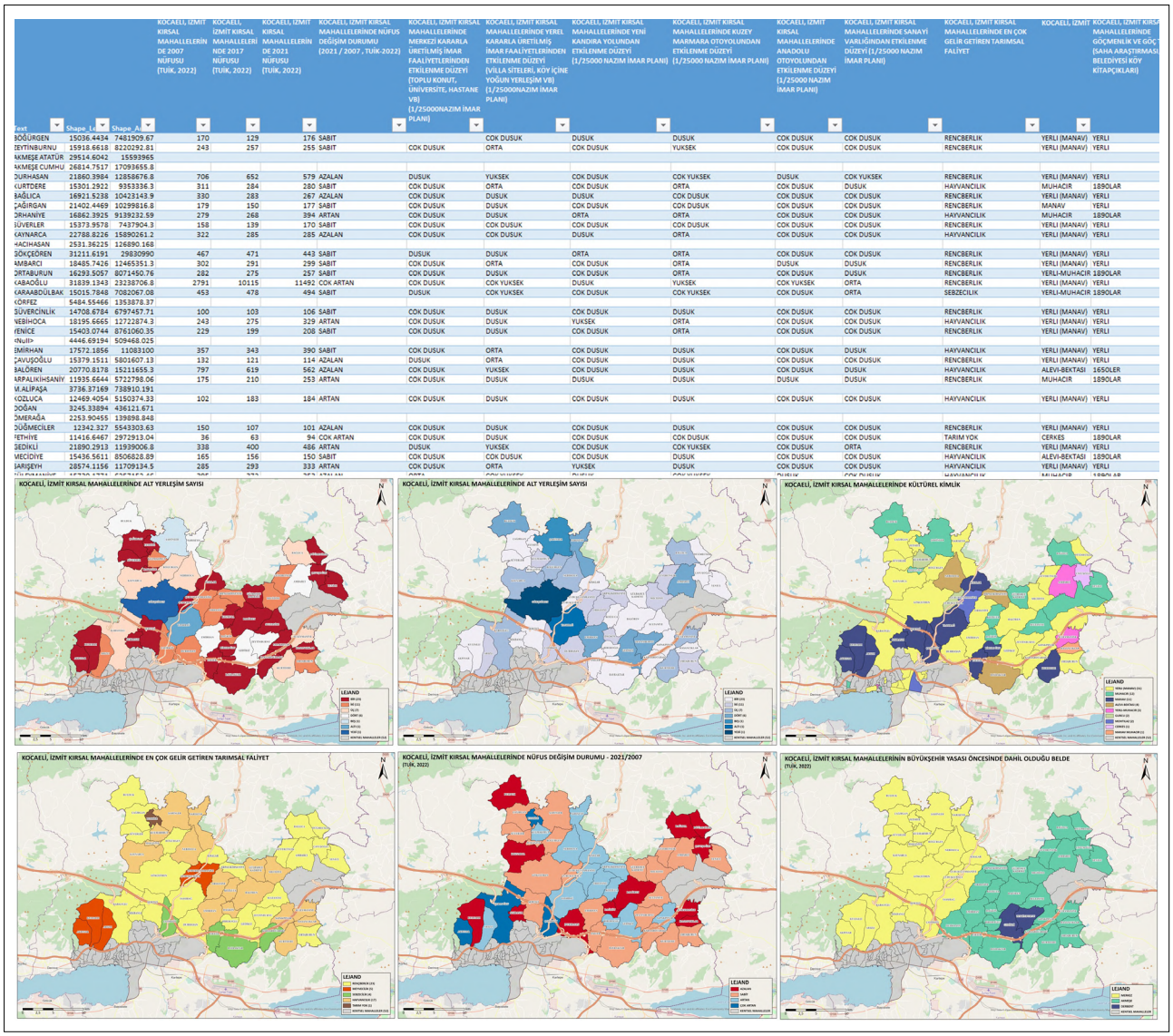

Figure 1. Above is the database created using the Excel program to provide map information. Below are a few examples of the 15 maps produced with the ArcGIS program using the database.

the city, momentarily deserted, experienced revitalization with the establishment of çuha, fez, and chintz factories in the 19th century. In 1888, İzmit gained autonomy as a sanjak and witnessed significant reconstruction movements (Çetin, 2000; Ulugün, 2002). After the establishment of the Republic of Türkiye in 1923, İzmit became the central district of Kocaeli province, comprising 12 districts. Ranking fourth in industrial and commercial significance after Istanbul, Ankara, and İzmir based on various development indices, Kocaeli has been subject to numerous transformations, leading to the formation of its current administrative structure (Acar, et al., 2019). İzmit Metropolitan Municipality was initially declared in 1993, later changing its name to Kocaeli Metropolitan Municipality in 2005. After this, all town municipalities within Kocaeli's provincial borders were dissolved in 2008, bringing all districts and villages under the jurisdiction of Kocaeli Metropolitan Municipality. In 2012, villages were reclassified as neighborhoods and transferred to district municipalities (Güney, et al., 2020). Presently, İzmit District comprises 52 rural neighborhoods. As of December 2022, according to TUIK data, 10% of the district's total population, 376,047, resides in these rural settlements. Notably, while 90% of the population resides in central neighborhoods covering 30% of the district's territory, the remaining 10% lives in rural neighborhoods spread across 70% of the district's territory (Figure 2).

Modernism and the economic system that prevails in most of the world already produce reasons that will transform rural areas without any crises. It is observed that İzmit rural settlements have experienced significant transformations as a result of the mechanisms that will be analyzed in detail

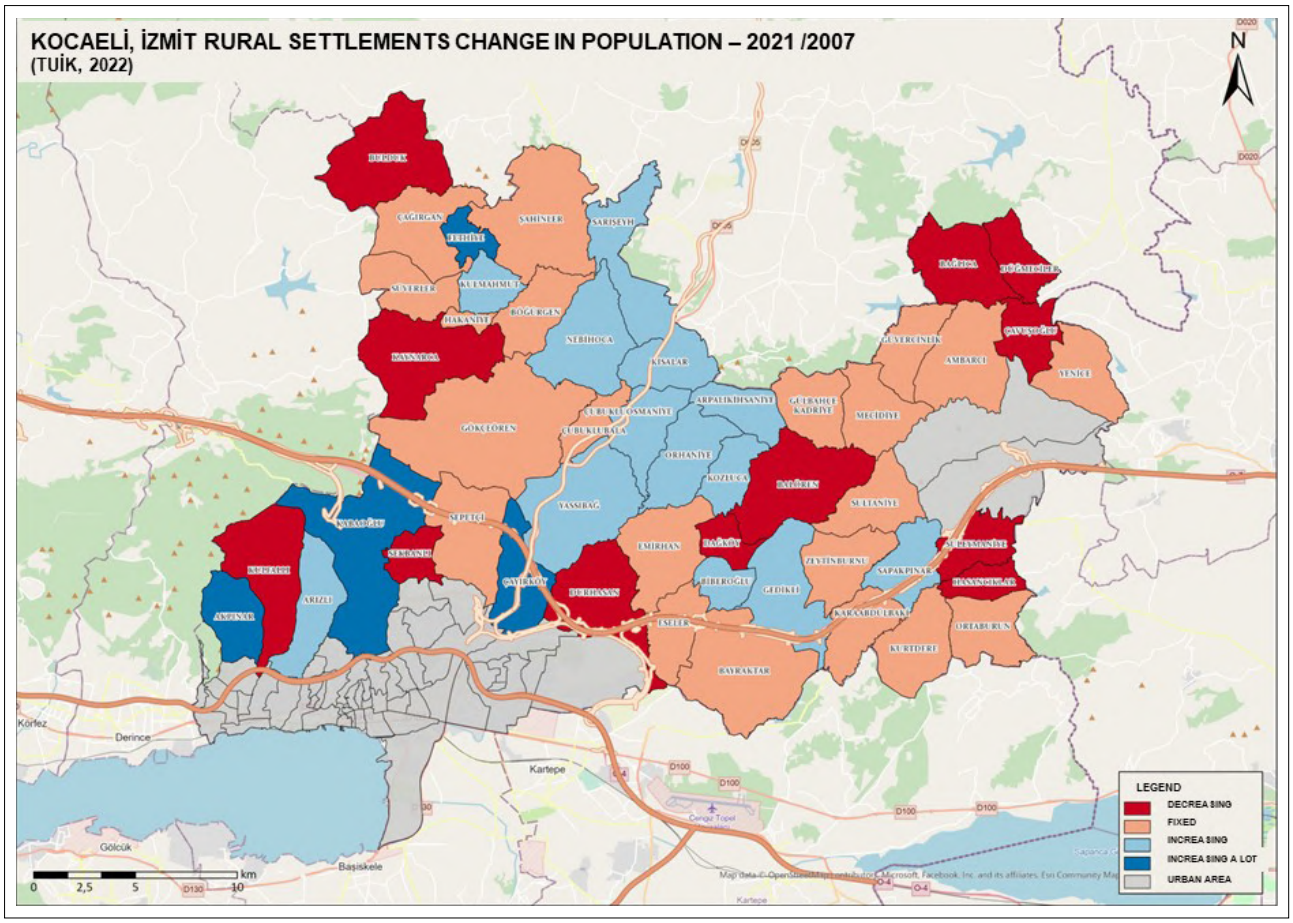

Figure 2. Map showing population change in İzmit rural settlements.

below. The approach of analyzing these mechanisms within the cultural context of the locale is substantiated by Andrew Sayer's discussion titled "Narrative versus Analysis" in his book Method in Social Science. Here, it is posited that explaining phenomena with mechanisms derived from general analyses may not universally apply (Sayer, 2010). In revealing the mechanisms of the transformation experienced in the rural neighborhoods of İzmit, first of all, the general data mapped were evaluated, and the transformation was revealed in terms of the physical environment. Oral history interviews were then analyzed in terms of representation, identity, landscape, individual, public, and heritage. This integrated approach, with findings of the extensive first stage analyses and intensive second stage narratives, has yielded four phenomena, combining general transformation data and site-specific analysis informed by non-representational theory:

1. Space utilization practices of old villagers and new urbanites (landscape, identity)
2. Decisions of the central government and local responses (representation)
3. Coexistence of concrete houses and adobe haystacks (heritage, identity)
4. Individualized society and spaces losing public significance (individual, public, heritage)

This study serves as a first step towards making inferences based on cultural geography and non-representational theories that can be applied in rural areas for the analysis phase of the planning discipline. With the method used in this study, the aforementioned phenomena have been obtained through mechanism analysis and factualization with the first stage results of the analysis studies.

Space Utilization Practices of old Villagers and New Urbanites

The spatial practices within İzmit's rural landscapes exhibit a rich cultural texture, reflecting both historical diversity and the transformations brought about by recent migrants. A myriad of cultural backgrounds, including Manavs (local Turkmen), Muhajirs, Mübadils (settlers between 1890 and 1980), Alevis, Laz, and Georgians, contribute to the vibrant social fabric. Muhajirs and Mübadils, settling in İzmit's rural areas from 1890 onward due to various social and political factors, established villages, primarily engaging in agriculture and animal husbandry. Interviews with these groups reveal that their initial settlement locations, chosen by the administration,

were often rejected due to unfavorable conditions, prompting them to explore and settle in areas with better environmental features, such as ample trees and fresh air.

The attractiveness of İzmit as an escape, especially for those from earthquake-prone metropolises like İstanbul, intensified post the COVID-19 pandemic and the February 2023 earthquakes. The categories of local, settled, and newcomers are proposed as concepts that can be used in studies to understand such areas that have received migration in the distant and recent past (Demirtaş, et al., 2023). Despite newcomers arriving by chance, through acquaintances, or real estate transactions, fundamental conflicts between them and the locals are notably scarce. Nevertheless, subtle distinctions in their relationship with space and the local community become evident, reflecting their status as newcomers. For instance, while the locals are familiar with the invisible yet acknowledged borders between long-cultivated and fallow fields, newcomers often demarcate their newly acquired agricultural plots, where temporary constructions are allowed, with visible wire fences or walls (Figure 3). This signifies a shift in attitude, behavior, and culture, introducing practices that may not align with the established trust systems, oral memory-based social consensus structures, and communal production norms of the village. Recalling the statement that "a practice is realized when the habitus, bestowed upon society members by cultural capital without explicit notice, combines with economic capital and comes to life in an area," disparities emerge when comparing local practices with those introduced by foreign communities. In instances like the example mentioned above about the borders of the fields, where the cultural capital (and habitus) shaping the practice is imported by a foreign community, it becomes apparent how these divergent cultural elements influence and reshape the rural landscape.

These differences are reflected across various facets of daily life, particularly in land utilization. The newcomers do not have the habitus to sustain traditional agricultural practices, such as cultivating wheat, oats, clover, barley, and sunflowers in the fields they buy. This shift causes alterations in the landscape texture that result from traditional agricultural production. Newcomers' ability to acquire property in rural İzmit is only possible through the disposal of fertile fields, divided by inheritance, to meet the "urban" needs of the local younger generations. Older local individuals frequently but reluctantly consent to the sale of their hard-earned fields by their descendants. This circumstance is exemplified by the words of an elderly female resident in the Sapakpınar neighborhood: "...there is no field or anything left; we sold them all. They divide them all, they are sold, and nothing is left. Only this garden was left, and we divided it among them all. Now, they have each built a house. However, they have nothing to share with their children. They will fill one pot of earth each and divide it among their children" (İzmit Municipality, 2022).

Figure 3. New borders on the lands of İzmit rural settlement Güvercinlik.

In the past, a significant group of individuals from the rural neighborhoods of İzmit had resettled in the city center, another city, or abroad for work. After retirement, they resettled with their families in the rural neighborhoods where they were born and grew up. There is also tension between this group, which has a continuous and satisfactory pension, and the group that needs to earn income from the land by laboring in the village despite their old age. The lifestyle of retirees, attempting to recreate urban comforts in the village, influences and transforms the existing village community. Intriguingly, in some interviews, local women who have never left the village perceive themselves and their lifestyle as "more urban than city."

It is essential to think about the phenomenon of the old villagers and the new urbanites' use of the space together with the question of how the newcomers and the local young generations will affect the future of İzmit in order to grasp the importance of the issue in the planning discipline. However, with the current property law, this resource of land is on the brink of depletion. This has widespread consequences not only in rural İzmit but also across the entire country. The absence of indications regarding a potential revision of property laws to safeguard agricultural land and the traditional culture rooted in agriculture raises concerns. Simultaneously, the rapid changes in ownership interrupt the continuity of the habitus concept, playing a transformative role in the landscape distinct from traditional norms.

Decisions of the Central Government and Local Responses

Its proximity to İstanbul, being a significant industrial city, and its location at the intersection of transportation networks have often led the district of İzmit in the province of Kocaeli to transform, primarily due to central government decisions. In 1936, the initiation of the SEKA factory marked a turning point for the city, diverging from the Jansen plan of 1939, which envisioned the city as a resort city and deviating from the decisions outlined in that

plan. This substantial industrial investment by the central government not only reshaped the city but also triggered cultural changes in the rural areas of İzmit. Following the 1950s, as industrial investments increased, there was a swift shift from agriculture to industry in the region (Binici, 2012). The subdivision of agricultural land ownership and the diminishing size of land per household for the new generation resulted in the migration of the rural workforce to newly established industrial zones.

Nonetheless, İzmit presents an interesting case where villagers could commute from rural areas to the factory, returning in the evening to engage in agricultural work and reunite with their families (Figure 4). As recounted by an elderly resident of Kulfallı, a village renowned for its grapes and cherries, those times were described: "My family used to live on grapes and cherries. Retirement has only recently become prevalent in this village in the last 10-15 years. Previously, everyone relied on grapes and cherries, engaging in animal husbandry. For instance, my father had a job in a factory and he worked together with us on grapes and cherries. We returned from work at 4 o'clock and spent our weekends in the vineyard. We do not have a holiday at the seaside, here or there. We had toiled in the vineyard and garden from March to November, laboring and struggling..." (İzmit Municipality, 2022).

This theme emerged consistently in various interviews. While the rapid growth of industry in and around İzmit might initially seem detrimental for the rural parts of the district, the fact that industrial facilities were within daily reach from rural areas facilitated the continuation of agricultural production. The generation born between 1950 and 1980 worked both in the industrial and service sectors in the city and continued their activities in the village, except for those who were constantly engaged in farming in the village. Consequently, this back-and-forth movement between the city and the village played a role in transforming rural culture. This aspect of cultural change in the rural areas of İzmit is different from the transformation in rural areas that have stood out with resort characteristics in Türkiye, requiring it to be handled as a unique typology.

On the flip side, the increasing trend of local institutions having minimal influence in the face of top-down planning and project decisions by the central government, coupled with the alteration of locally produced plans by central decisions, has become more prevalent in Türkiye since the 2010s. In the case of İzmit, investments such as the Northern Marmara Motorway, Kandıra Food Specialised Organised Industrial Zone, Kocaeli University Campus, and Small Industrial Site were initially not on the 1/50000 scale Environmental Plan but later added through amendment plans. An interviewee from Sekbanlı, a village that had lost some of its land to the university campus by expropriation, had shared an interesting memory of himself: "You are familiar with the location of the current university. Last night, when I became unwell, I visited the emergency room at the university hospital. I shared with one of the attending nurses, 'I used to herd animals and play ball here.' She glanced at me with surprise, eventually believing my words with some hesitation" (İzmit Municipality, 2022).

As of June 2023, construction is underway for settlement areas planned by the Housing Development Administration

Figure 4. Seka Paper Mill is in the foreground, and the villages on the hills where workers live and walk to work are in the background (Kocaeli Metropolitan Municipality, 2013).

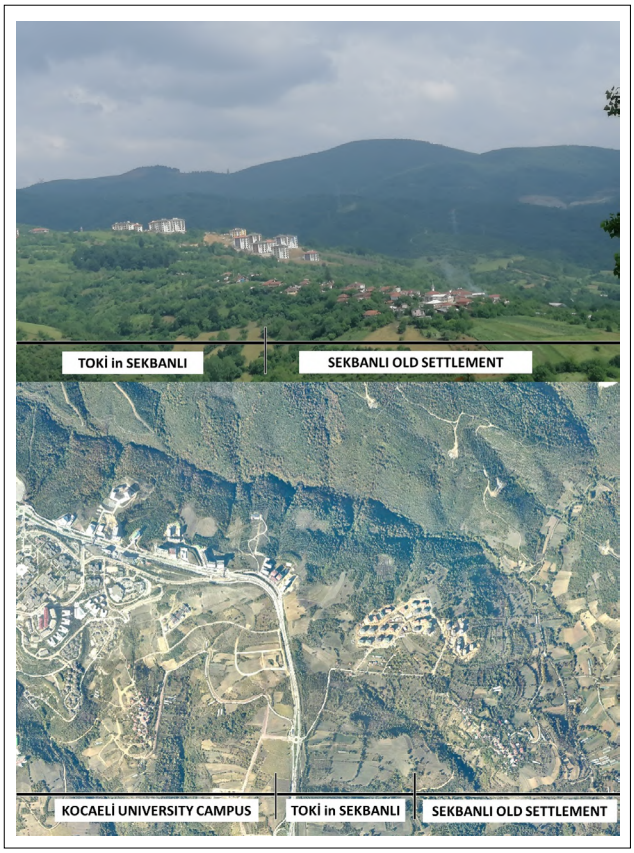

Figure 5. Sekbanlı aerial view and photography showing the contrast between TOKİ houses and the Kocaeli University settlement.

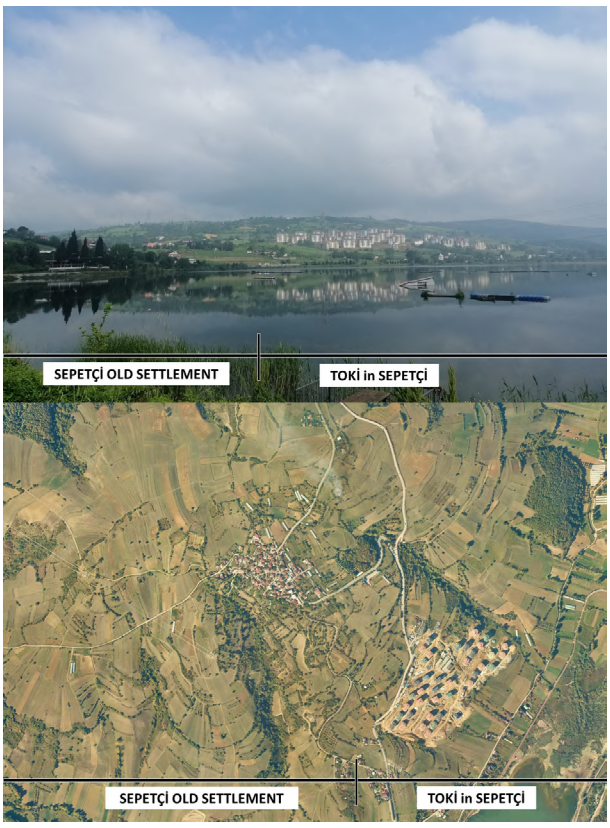

Figure 6. Sepetçi, a nearby neighborhood to Sekbanlı, its aerial view and photography showing the contrast with TOKİ houses.

(TOKİ) in Sekbanlı, based on a central decision (Figures 5 and 6). It is anticipated that the issues arising from this practice, leading to the expropriation of some agricultural lands in areas suitable for farming, may exacerbate in the future. Numerous narratives echo this sentiment, as expressed by a middle-aged male interviewee in Sekbanlı: "One year, two years later, this place will be finished. I mean, even if we plant, we will not get a crop; we will see that. This summer, my tomatoes in the greenhouse were so many. The next day I was going to collect them to sell in the local market. When we got there to the greenhouse, there was not a single tomato. This year, they harvested my peppers three times (he means other people he does not know)... So we will have more problems in the future. We cannot do this job, farming. Thank God we have a pension. I wish the children could get a job" (İzmit Municipality, 2022). Their words vividly convey their despair and resignation towards abandoning the production culture.

The mass resettlement of communities with different habitus to rural areas through centralized project decisions has the potential to affect not only the areas they are placed in but also the areas that are the crucial sources of livelihood for rural settlements. Conflicts in the socio-cultural sphere over time, as indicated by the narratives above and similar ones, are also within the realm of possibility.

Coexistence of Concrete Houses and Adobe Haystacks

This study explores both the material and non-material dimensions of unavoidable[5] changes in the cultural fabric of life. The disappearance of tobacco cultivation in rural İzmit, a decline in grape production, and the cessation of silkworm and flax cultivation have not only altered daily life but also reshaped traditional spatial constructs, aligning them more closely with urban frameworks. Instead of employing architectural construction techniques rooted in local resources like oak wood from nearby forests, wild hazelnut sticks, mud from the village's soil collection site, bricks from nearby quarries, wheat straw from the fields, flax stalks, a shift towards the reinforced concrete frame construction system has become prevalent due to its easy accessibility, affordability, cleanliness, and high insulation properties (Figure 7). While old houses constructed with traditional methods continue to be repurposed as haystacks or barns, constructing new reinforced concrete houses within gardens has become a common practice. The destructive impact of the 17 August 1999 Gölcük Earthquake in some parts of rural İzmit has further accelerated this transformation. In interviews, the decrease in the number of local craftsmen and cost considerations have emerged as significant factors influencing the preference for the reinforced concrete system, in addition to other features of reinforced concrete positively perceived by users.

An 85-year-old male interviewee from Hasancıklar village compared the reinforced concrete house he now resides in post-earthquake with the mudbrick house from his past, stating, "Do not be afraid that it will be cold in winter in that adobe house. In today's concrete houses, it is hot in summer and cold in winter. My house was timber-supported mudbrick." He narrated a visitor's positive experience, "A friend from İzmit visited me; there was a wedding here, and he stayed as a guest. We got up in the morning, and he said, 'I slept comfortably tonight! I slept warmly; I rested here. You cannot sleep in a concrete house where we live. It is cold! If the stove is lit, you can get warm; if not, you cannot!" (İzmit Municipality, 2022).

Significant changes have also occurred in the use of water and water-related spaces. In the past, the village's spring was often one of the main reasons for settling there; fountains and water-powered mills fulfilled physical needs and had social significance. Over time, factors such as meeting water needs from the urban water supply system, the withdrawal of spring waters with constructed dams, population thinning, and the mechanization of agriculture have led to a decrease in these places and their uses (Figure 8). The words of an 82-year-old female interviewee regarding an inactive mill in Akmeşe offer insights into the building and the production and consumption culture of that era. The 82-year-old female respondent, reflecting on the disused mill in Akmeşe, recalled, "Water used to flow through the gutter, making the mill wheels turn. In those days, people did not buy flour; everyone used to grind their

Figure 7. Old houses being used as haystacks in rural settlements of İzmit.

Figure 8. Unlike many water springs in İzmit, the one in Balören is still being used not only for drawing water but also for traditional practices.

corn and wheat there. Now, you buy it ready-made in sacks. How can you make 'kuskus' with a sack that costs 200 liras? The wheels were large and could produce flour, like henna. It stood there until recently, but now they have dismantled, poured, and demolished it. Nowadays, you have to buy everything" (İzmit Municipality, 2022). Her memories provide important information about the architectural and cultural practices related to production and consumption during that era (Akçakaya, 2019). The emotional connection that an 85-year-old woman interviewee from Dağköy expresses about the village spring is formulated with the words "Akpınar, our spring was there. We used to draw water from there. Now they have ruined it. I do not go there, and I do not see it. They demolished our fountain. You cannot go there. We had perfect water... It flows like ice in summer, and it flows hot in winter. We have such abundant water, but no one knows its value. Houses were also built there" (İzmit Municipality, 2022).

In questioning the mechanisms of the concrete houses and adobe haystacks occurring together in a place, it is imperative to explore how planning in this swiftly changing habitus should reorganize itself to sustain the culture of producing environmentally sustainable buildings and settlements rooted in local materials.

Individualized Society and Spaces Stripped of Their Public Nature

Social practices play a crucial role in acquiring habitus, and active participation in these practices facilitates the transfer of cultural capital. The evolving social structure and global influences speed up the changes in social practices, rendering traditional ones unapplicable over time. Consequently, places associated with these social practices lose their former significance and transform. In the rural settlements of İzmit, public places special for festivals are frequently cited in narratives as integral to social practices. Despite their proximity to the city, and perhaps because of it, villages now appear deserted during festival days. The younger generation, visiting their elders in cars, tends to return to the city before nightfall. Contrastingly, in the past, festival sites were vibrant with daily celebrations, featuring organized wrestling competitions and communal swings. Special preparations were undertaken for these festive occasions.

A 68-year-old male interviewee from Düğmeciler village vividly recounted the past state of the festival place: "Every village had its own feast day; neighboring villages visit the hosting village on that day. Tables were set up in the village square for catering, weather permitting, hosting guests. It was a festive atmosphere, with wrestling matches taking place where our school and football field now stand. Even though it is winter, this tradition continued; straw was spread on the snow, and the wrestling bouts unfolded there" (İzmit Municipality, 2022). A female interviewee from Sapakpınar village reminisced, "As the feast approached, we gathered chains and set up a swing. When the festival arrived, we took out our 'dayre' (tambourine), sat down, played music, and swung on the swings... There was a large oak tree down there, where we used to set up our swing. Another oak at the village exit was also a favorite spot for our swings" (İzmit Municipality, 2022). She not only described the crucial locations during the old festivals but also expressed her positive feelings about the swing set up by the municipality, recalling the old tradition during the previous festival.

To comprehend the phenomenon of an individualizing society and spaces losing their public nature, it is imperative to carefully examine whether the repurposing of public spaces in rural areas extends beyond superficial gatherings. Because social capital changes similarly to cultural capital, it prompts the swift transformation of habitus.

CONCLUSION

This study addressed the question: "What kind of information do cultural landscapes provide about the economy, governance structure, materials, and cultural practices of the period in which they were formed, to be used in planning?" The interviews conducted in the rural areas of İzmit were evaluated through this perspective, and the narratives were systematically categorized. This approach revealed insights into the unique dynamics of the studied site and its connection to the local culture. The results shed light on the points where the framework for controlled change was lost, unveiling underlying mechanisms. The rapid transformation in the rural areas of İzmit can be attributed to some key mechanisms:

- Decisions and practices originating from the central administration, disregarding local repercussions, lead to uncontrolled development, ignoring the habitus concerning physical, cultural, and social transformations in rural areas.
- Since the 1950s, the shift of the rural labor force to the city center, driven by the development of industry in İzmit, has accelerated the transformation of rural culture. However, the proximity of industrial areas and rural regions supporting agriculture allowed for continued agricultural production, albeit in a transformed manner, postponing long-term dehumanization.
- The settlement demands of urban residents, mobilized by the driving force of crises such as the COVID-19 pandemic and earthquakes, have diverse effects on the population, physical structure, and economy of rural areas.
- Newcomers significantly impact the transformation of existing culture in rural areas, reflecting an urban perspective and causing changes not only in physical aspects but also in the social and cultural fields of rural traditions.
- Since the 1980s, particularly after the 17 August 1999 earthquake, traditional architectural practices in rural İzmit have given way to the reinforced concrete construction system. Changes in agricultural production have also affected spaces related to water use.
- The individualization of society has led to decreased participation in social activities, diminishing the importance of public spaces associated with these practices.

The aforementioned mechanisms, derived from the field study and categorized under the themes of "practices in the utilization of space by old villagers and new urbanites," "central government decisions and local responses," "coexistence of concrete houses and mudbrick haystacks," and "the individualizing society losing its public spaces," underscore the impact of the changing world on rural areas, as exemplified in the rural areas of İzmit. While not a novel or unexpected scenario, the implications of uncontrolled, unplanned, and unpredictable changes extend beyond the rural landscape and its residents, affecting the broader environment and the city within its confines. In light of the significance of rural areas in terms of sustainability, locality, and self-sufficiency, addressing the downsides of such changes is imperative.

Planning methodologies must evolve to navigate this rapid transformation effectively. Analyzing the mechanisms underlying these phenomena on-site, supplemented by interviews with local inhabitants, fosters a direct understanding. Establishing a continuous, one-to-one relationship between users and those conducting planning activities for the public and developing implementation strategies for this symbiotic situation can contribute to a controlled realization of change in rural areas amidst the ongoing era of rapid transformation.

Understanding a place and the perspectives of its inhabitants, together with global trends, the unique characteristics of the area, and the habitus of the society that produces it, requires a significant effort. It is anticipated that such efforts will significantly contribute to reconciling oppositions inherent in the transformation. It is believed that when this effort is made, there will be a substantial contribution to transforming the contradictions within the phenomena into a meeting point and blending the facilitative aspects of urban culture with the sustainable and in harmony with nature aspects of rural culture.

NOTES

[1]This article is based on the first stage work of an ongoing thesis entitled "Bir Kültürel Coğrafya Okuması: İzmit Kırsal Yerleşmelerinde Koruma Yönetimi" by the first writer under the supervision of the second writer. The article is limited to exploring the mechanisms of the transformation of rural areas and expressing them as phenomena.

[2]Especially in this school, geographers such as Peter Jackson, James Duncan, and Denis Cosgrove have stated that Sauerian cultural geography is far from understanding the complex urban life, culture, and its complex relations with politics, power, and economy.

[3]Physical structure analyses include the height of the built-up area above sea level, population change status, the number of sub-settlements, the titles of the towns it was included in before the metropolitan law, socio-cultural and economic situation analyses; the most income-generating agricultural activity, cultural identity, immigration and migration history. The information analysis obtained about the planning history includes the level of being affected by zoning activities produced by central decision, the level of being affected by zoning activities produced by local decision, the level of being affected by the new Kandıra road, the level of being affected by the North Marmara highway, the level of being affected by the Anatolian highway, the level of being affected by the presence of industry, the presence of plans and the year of plan making, the status of protected areas in the neighborhoods.

[4]In İzmit rural neighborhoods, 96 interviews were conducted with 52 men and 51 women. A semi-structured questionnaire shaped on the basis of İzmit Municipality Rural Neighborhood booklets was used. In accordance with the subject of Intangible Cultural Heritage, it was paid attention that the interviewees were over the age of 50-55 and had spent a large part of their lives in the rural area where they lived. We would like to thank the Mayor of İzmit Municipality, Mrs. Fatma Kaplan Hürriyet, for making it possible to use the interview recordings of this study.

[5]Unstoppable=spontaneous=means adapting to time, keeping pace with time.

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Article

Examination of the impact of lighting layout on energy efficiency in the case of open plan office

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ABSTRACT

Lighting plays a significant role in the electricity consumption of buildings. It is widely acknowledged that the key factors influencing minimal energy consumption to meet the requirements of lighting design criteria are lamp efficacy, luminaire efficiency, and lighting control systems. However, the impact of the relationship between luminaire arrangement, luminaire's luminous intensity distribution, and furniture arrangement on energy consumption has not been thoroughly examined. The objective of this study is to develop a method that can be utilized to determine luminaire positions while meeting values recommended in the EN 12464-1 for all occupants of an office based on luminaire's luminous intensity distribution and furniture layout. For this purpose, an open-plan office for 24 individuals, 2 different desk layouts, 3 lighting types, and 19 luminaires with different luminous intensity distributions were considered. In the initial stage of the research, luminaire position options that meet the targeted values for each luminaire and workstation layout (a total of 38 configurations) were determined through trial and error. Subsequently, these options were compared in terms of energy consumption, and the most economical option was identified for each configuration. The total luminous flux required for each configuration was considered in the energy comparison. The configuration where visual comfort requirements were met with the least luminous flux was considered the most economical. It was revealed that the quadruple-desk layout was more economical than the dual-desk layout for all luminaires. In the final stage of the study, the energy usage results for 38 configurations were compared and evaluated.

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INTRODUCTION

According to research by the International Energy Agency (IEA), electricity consumption in commercial and public buildings accounts for 21.2% of total consumption (IEA, 2021). Of the total electrical energy consumed in buildings, 20% is used for lighting. Office buildings occupy a large place among commercial and public buildings. Developments in LED technology and its widespread use are also reflected in office lighting. Efficiency in electric lighting is mainly considered in the context of the use of high-efficacy lamps,

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high luminaire efficiency, and lighting control systems. Nowadays, LEDs are widely acknowledged to be more economical than other alternative light sources (IEA, n.d.). Numerous studies have been conducted to highlight the energy consumption superiority of LEDs (Luewarasirikul, 2015; Kim & Yang, 2022; Pallis et al., 2021; Doulos et al., 2017; Principi & Fioretti, 2014). The significant role of high luminaire efficiency, as well as lamps with high luminous efficacy, in reducing consumed lighting energy is undeniable (Manolis et al., 2019). The luminaire efficiency is dependent on factors such as the materials used and optical design (Tsankov et al., 2022). Another crucial factor influencing energy efficiency is the utilization of lighting control systems (International Commission on Illumination, 2017; Simpson, 2003). Indeed, studies aimed at reducing energy consumption in office lighting are fundamentally focused on the implementation of various lighting control systems. In this context, numerous research works evaluate the impact of various lighting control systems such as personal control (de Korte et al., 2015; Kwon et al., 2019), daylight harvesting (Lu et al., 2010; Vathanam et al., 2021), and occupancy sensing (de Bakker et al., 2017; Pandharipande & Caicedo, 2011; Chraibi et al., 2019; Nagy et al., 2015) on energy conservation. Research has also been conducted on the combined implementation of different lighting control systems in office settings (Galasiu et al., 2007; Soori & Vishwas, 2013; Xu et al., 2017).

However, the parameters essential for the effective use of energy extend beyond lamp efficacy, luminaire efficiency, and lighting control systems. The luminous intensity distribution and placement of the luminaire in relation to the interior design also influence energy consumption. There are numerous luminaires suitable for use in offices. The technical and economic diversity of these luminaires complicates the comparison and evaluation of their features, potentially prolonging the lighting design process. In such cases, the selection among luminaires capable of providing the desired illuminances is often based on justifiable economic constraints such as purchase cost and luminaire efficacy. However, luminaires also vary as to luminous intensity distribution, and the arrangement of desks, including the luminous intensity distribution and position of the luminaire, should be considered in luminaire selection. In this context, establishing a relationship between luminaire's luminous intensity distribution and the task area presents a significant energy-saving opportunity that is often overlooked in contemporary practices.

Energy-efficient lighting cannot be considered independently of the requirements for lighting design criteria set by international standards. The goal should always be to meet these requirements with the most economical solutions. Few studies examined conditions where EN 12464-1 European standard criteria are met with minimal energy consumption (European Committee for Standardization, 2011a; Çelik et al., 2015). Çelik et al. (2015) maintained the positions of desks and luminaires constant in each lighting scenario while comparing different luminaires in terms of energy usage. De Bakker et al. (2018) took a different approach to lighting control related to occupancy detection, suggesting adjusting the illuminance in non-user work areas by dimming the light, thereby adapting to the recommended values for immediate surrounding and background area. In this study, the positions of office work desks and luminaires were also kept constant. Zhou et al., (2023) with the aim of improving lighting energy efficiency in offices, explored the results of placing luminaires at elevation angles ranging from 0° to 180° from the downward vertical, with ±10° steps on both sides, unlike the traditional approach of keeping luminaire openings parallel to the work area. In a research study aiming to provide the required illuminance on vertical display surfaces instead of the horizontal plane in offices, luminaire positions, where optimum results were obtained, were examined based on luminaire luminous intensity distribution, display surface position and size, and the results were compared in terms of energy consumption (Kalelioğlu & Dokuzer Öztürk, 2022).

In the literature, there is no study that comprehensively considers luminaire luminous intensity distribution, luminaire position, interior architectural arrangement, and EN 12464-1 standard requirements as a whole to assess the lighting energy efficiency of offices. This study aims to present a method that can be utilized to determine the luminaire type, luminous intensity distribution, and position that meet the requirements of the EN 12464-1 standard (European Committee for Standardization, 2021) for all users in open-plan offices. Two different interior architectural arrangements and nineteen lighting fixtures were considered, and the positions yielding the most economical results for each luminaire were identified.

LIGHTING CRITERIA FOR OFFICES

According to the actual European standard for lighting indoor work places, EN 12464-1, Table 1 provides the recommended lighting criteria based on the activities undertaken in this study (European Committee for Standardization, 2021).

In addition to the values in Table 1, illuminance on the immediate surrounding area and the background area and illuminance uniformities for these areas are recommended as follows (for task $\bar{E}_m$: 500 lx):

Immediate surrounding area: $\bar{E}_m$ (required): 300 lx, U_o: 0.40

Background area: $\bar{E}_m$ (required): 100 lx, U_o: 0.10

Table 1. Visual comfort criteria for offices

Type of task/activity area	$\bar{E}_m$ lx required	$\bar{E}_m$ lx modified	U_o	R_a	R_{UGL}	$\bar{E}_{m,z}$ lx $U_o \geq 0.10$	$\bar{E}_{m,wall}$ lx $U_o \geq 0.10$	$\bar{E}_{m,ceiling}$ lx $U_o \geq 0.10$
Writing, typing, reading, data processing	500	1000	0.60	80	19	150	150	100

$\bar{E}_m$ (required): minimum maintained average illuminance on the reference surface; $\bar{E}_m$ (modified): maintained average illuminance considering common context modifiers on the reference surface; U_o: minimum illuminance uniformity on the reference surface; R_a: minimum colour rendering index; R_{UGL}: Unified Glare Rating limit; $\bar{E}_{m,z}$: maintained cylindrical illuminance at eye height (1.20 m) including task and immediate surrounding area; $\bar{E}_{m,wall}$: maintained average illuminance on walls; $\bar{E}_{m,ceiling}$: maintained average illuminance on ceilings.

METHOD

In open-plan offices, numerous factors determine lighting energy efficiency. For each of these factors, multiple values can be established. However, in order to obtain meaningful and interpretable results, it is necessary to limit the number of variable factors. In this research, the factors have been categorized into constant and variable groups. The methodology of the study involves determining the values to be considered for constant and variable factors as well as analyzing the results of calculations for various combinations of these values. The steps of the research methodology are as follows:

- Assumptions related to constant factors
- Determination of variable factors
- Defining the calculation approach
- Execution of calculations

The following sections elaborate on the examinations conducted and the decisions made within each step.

Assumptions Related to Constant Factors

Within the scope of the study, an open-plan office for 24 occupants was designed. Existing office plans and architectural design guidelines were consulted for the office design (Buxton, 2018; Chiara et al., 1991; Crane & Dixon, 1991; Duffy et al., 1977). Constant factors related to the room and lighting criteria are listed below.

Constant Values Related to the Room

- Number of occupants: 24
- Office space length, width, and height: 27 m, 7.5 m, 3.25 m
- Window location: One long wall of the room
- Joinery width, reflectance, and spacing between mullion axes: 0.1 m, 70%, and 1.35 m
- Location of the joinery within the wall section: In the inner part of the wall section facing the office space
- Reflectance of the window glass: 10%
- Reflectance of walls, ceiling, and floor: 80%, 90%, 60%
- Desk dimensions and reflectance: 0.80 m x 1.60 m x 0.72 m (European Committee for Standardization, CEN 527-1:2011b), 70%
- Distance of the luminaires from the floor (Luminaire height): 2.75 m
- Cabinet dimensions and reflectance: 0.80 m x 0.40 m, 70%

Constant Values Related to the Lighting Criteria

In the context of office lighting alternatives, the objective was to achieve the illumination criteria provided in Table 1, and lighting schemes that meet these criteria were taken into consideration in the evaluation. Daylighting was excluded from the scope of the study. Calculation surfaces were established for each of the 24 occupants in the office in terms of task area, immediate surroundings area, background area, cylindrical illuminance, and direct glare (Figure 1).

- Task area (width, length, height, and position): 60 cm, 60 cm, 72 cm, and centered on the user's side of the desk surface (Figure 1, dark blue) (Figure 7 and 8, pale blue).
- Maintained average illuminance on task areas: 500 lx
- Height, width, and position of the immediate surroundings: Same height as the task area (72 cm), with a 50 cm wide band surrounding this area (Figure 1, light blue)
- Size and location of the background area: The area on the floor surface, 50 cm from the walls and surrounding the projection of the immediate surrounding

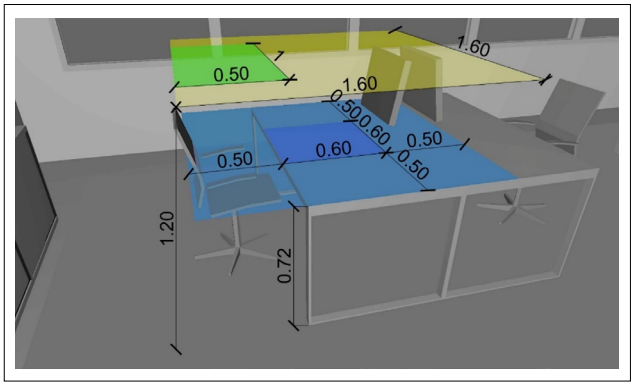

Figure 1. Position of the calculation surfaces.

- Width, length, height, and position of the cylindrical illuminance calculation surface: 160 cm, 160 cm, 120 cm, covering the projections of the task area and the immediate surrounding area (Figure 1, yellow)
- Width, length, height, and position of the calculation surface for Unified Glare Rating: 100 cm, 50 cm, 120 cm, adjacent to the projection of the task area, centered next to the table. The value (RUG) of Unified Glare Rating (UGR) is calculated for the ±90° viewing angle in the main viewing direction (Figure 1, green)

Determination of Variable Factors

Determinations regarding the variable factors of the study have been addressed under the following headings:

- Interior design
- Luminaire type
- Luminaire position

Interior Design

Fundamental architectural design books such as Neufert Yapı Tasarımı,Time-saver Standards, and Metric Handbook, as well as published books on the subject such as Planning Office Space, Architects' Data Sheets: Office Spaces, and architectural plans and furnishings of sample open-plan offices were examined in terms of dimensions, form, and user count (Neufert, 2000; Chiara et al., 1991; Buxton, 2018; Duffy et al., 1977; Crane & Dixon, 1991). In today's open-plan offices, user counts vary widely. Based on the average user count in the examined offices, a standard office for 24 people was designed. In the office room, two different furniture layouts were created, in which work desks were arranged in pairs and quads (Figure 2).

Luminaire Type

A total of 19 LED luminaires, including indirect-direct (3), semi-direct (6), and direct lighting (10) types, which are suitable for office lighting, were considered. Four of the direct lighting luminaires are square-shaped, while the remaining fifteen are rectangular. The characteristics of the luminaires are presented in Figures 3-6. The tables include the luminous intensity distribution, power (W), total luminous flux (lm), color temperature (CCT), and color rendering index (CRI) of the luminaires.

In the tables, luminaires are expressed as the following:

RID: Rectangular-shaped indirect-direct luminaire

RSD: Rectangular-shaped semi-direct luminaire

RD: Rectangular-shaped direct luminaire

SD: Square-shaped direct luminaire

Luminaire Position

The distance of luminaires from the floor has been kept constant at 2.75 m in all lighting configurations. A total of 627 luminaire layout alternatives were studied through three lighting types and nineteen luminaires. In all luminaire layout alternatives, luminaires were positioned parallel to the line of sight. To prevent reflected glare, luminaires were avoided from being placed perpendicular to the line of sight. In line with the objectives of the study, the positioning of luminaires to meet visual comfort requirements with minimum energy consumption has been examined through trial and error, separately for each luminaire and both interior design configurations.

In the initial phase of the study:

a. One luminaire was initially placed on the projection of the geometric center of the task areas (shown in pale blue in Figures 7 and 8, 0.60 m × 0.60 m) for both interior design configurations.

b. For both interior design configurations, two luminaires were initially placed on the projection of the right and left boundary of the task area (a total of 2 luminaires for a table).

c. For the layout of quadruple desks, one luminaire was initially placed on the projection of the junction of two adjacent desks and one luminaire for each on the projection of the right (or left) boundary of the task area of these desks.

Subsequently, for the b and c luminaire configurations, the luminaires were shifted towards the edges of the desk in 5 cm increments. Although it is possible to place square luminaires at different positions than rectangular luminaires, for the sake of ease of comparison, different positions were not considered. Some examples of the studied luminaire positions are shown in Figures 7 and 8. The luminaires are depicted in yellow in the figures, and

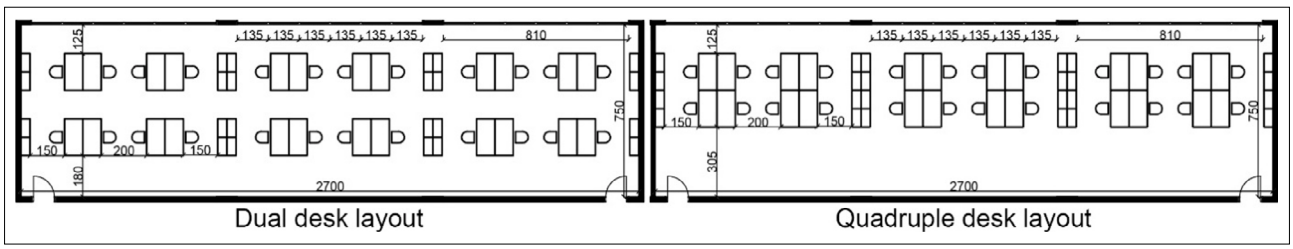

Figure 2. Workstation layouts.

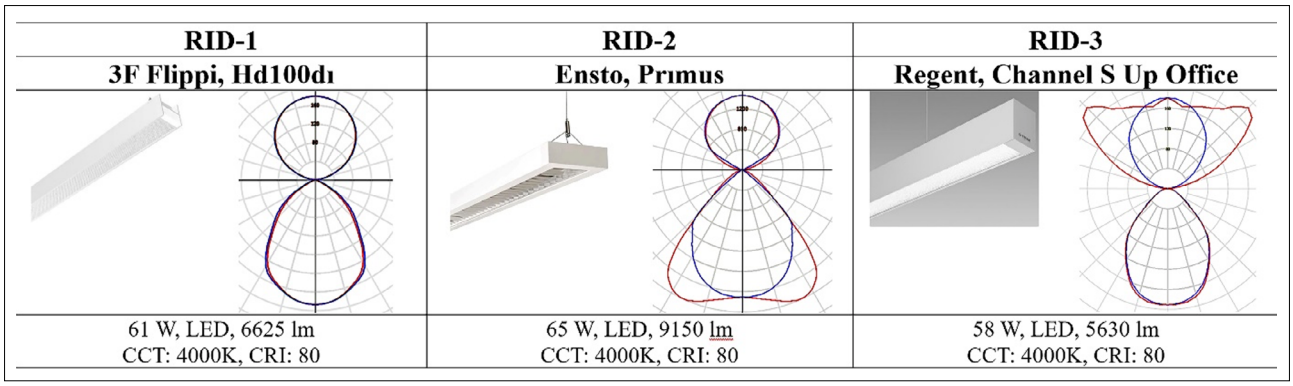

Figure 3. Indirect-direct luminaires.

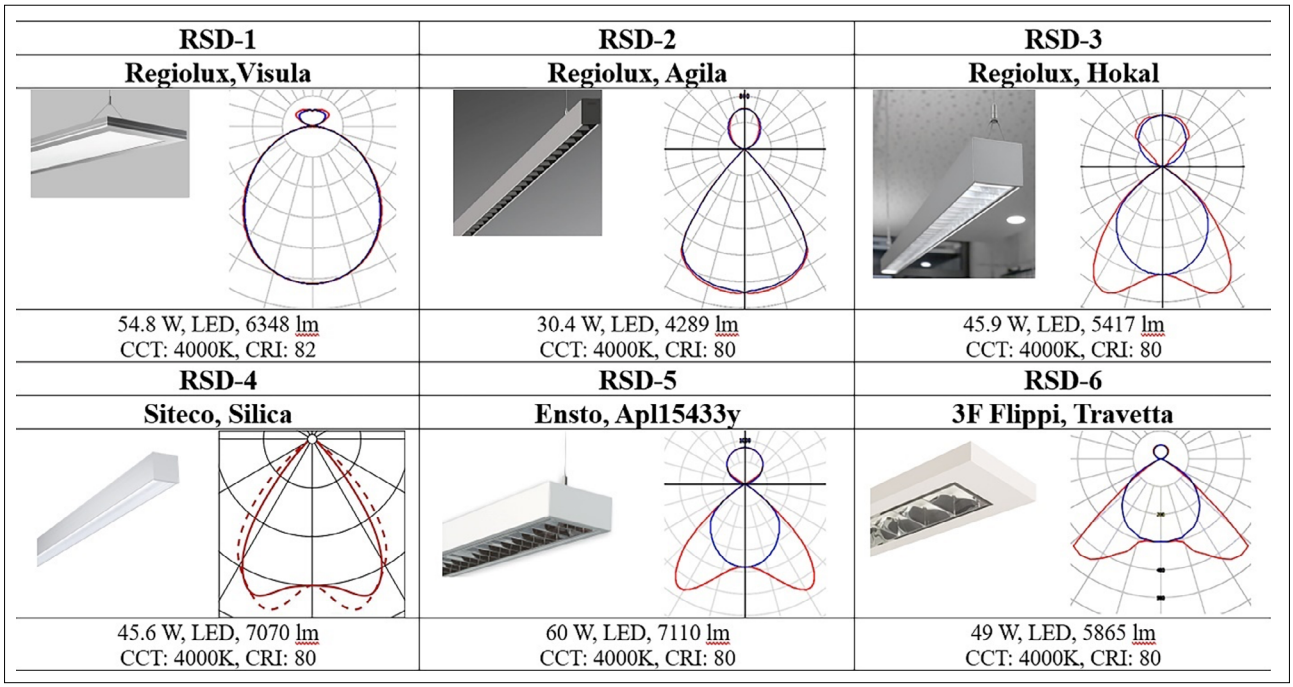

Figure 4. Semi-direct luminaires.

their positions are indicated by specifying the distances from the projection of the task area center shown in pale blue in Figures 7 and 8. This distance is zero for a luminaire located, for example, at the projection of the task area center, and 30 cm for a luminaire located at the projection of the right (or left) boundary of the task area.

In the second stage of the investigation regarding luminaire positioning, for each of the a, b, and c configurations, luminaires were shifted in increments of 2.5 cm in the direction of and opposite to the line of sight while maintaining their positions relative to the task area (Figures 7-8). An example of this shifting is illustrated in Figure 9. The direction of luminaire shifting varied for each desk, and the optimal shifting distance differed based on the desk's position to achieve the most favorable outcome. An example of shifting luminaires in the line of sight and vice versa for achieving the most favorable outcome with the RD-3 luminaire in the dual desk layout is provided in Figure 5. The arrows in the figure indicate the direction of luminaire shifting, and the average illuminance achieved on the task area of each desk is specified.

CALCULATION RESULTS

Within the scope of the study, numerous simulations were conducted using the validated DIALux evo program to examine the optimal luminaire positions for nineteen luminaires and two desk layout configurations, totaling thirty-eight office lighting alternatives (Figures 7-8) (Rizki A. Mangkuto, 2015). Among these, the configurations in which the recommended values in the EN 12464-1 standard (Table 1) were met with minimum energy consumption are presented in this section.

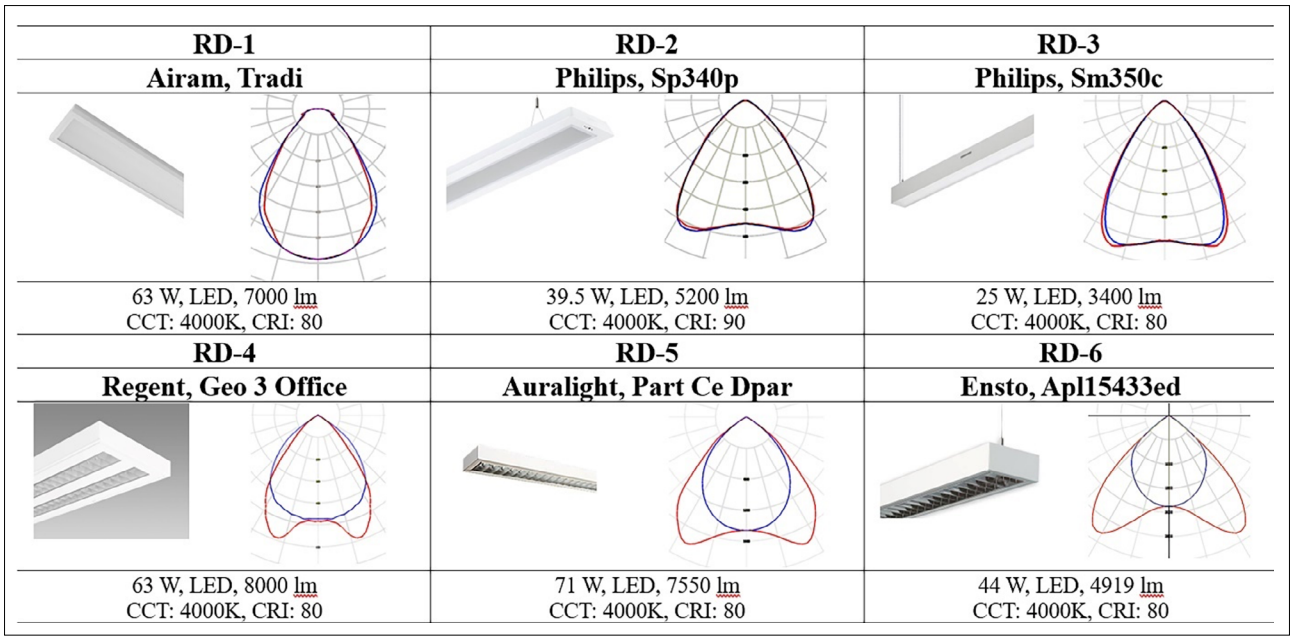

Figure 5. Rectangular shaped direct luminaires.

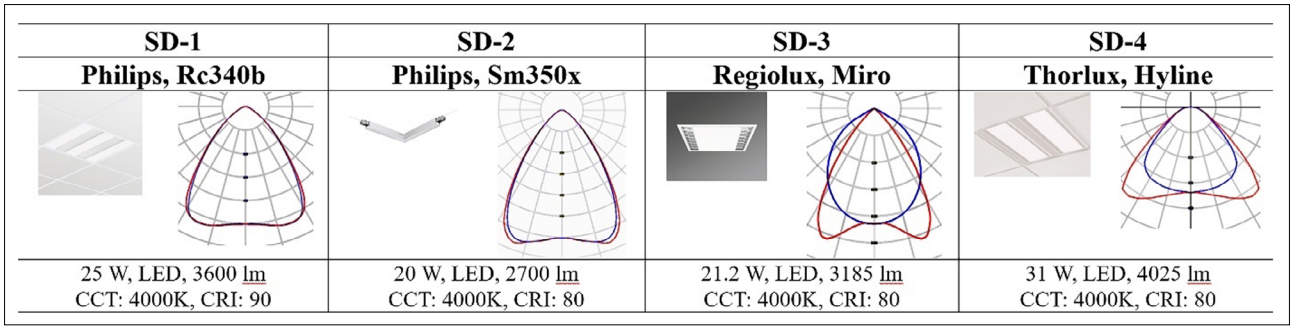

Figure 6. Square shaped direct luminaires.

In the comparison for minimum energy consumption, the quantity of luminous flux emitted from luminaires was taken into consideration. This approach prevented the influence of lamp efficacy and luminaire efficiency in the comparison. Thus, the impact of design decisions regarding luminaire shape (rectangular, square), lighting type (direct, semi-direct, indirect-direct), and luminaire position on lighting energy consumption was evaluated. To make the energy consumption comparison meaningful, the desks with the lowest illuminance in the office were identified, and the luminous flux from the luminaires was adjusted to achieve an average illuminance of 500 lx on the task areas of these desks as much as possible. Following this adjustment, the total luminous flux from all luminaires in the space was used as the basis for the comparison. The range of task area illuminances, range of UGR values for all desks, and the required total luminous flux for dual and quadruple desk layouts, based on lighting type and luminaire position, are presented in Tables 2-4. The luminaire configurations of values given are marked with an asterisk (*) in Tables 2-4.

Regarding the indirect-direct lighting type, the most favorable outcome for both dual and quadruple desk layouts was achieved when a single luminaire was located at the projection of the task area center (configuration a). According to the comparison for meeting visual comfort requirements with minimum energy consumption, the most favorable luminaire for the dual desk layout was RID-1, followed by RID-2 and RID-3, respectively. In this respect, the ranking was RID-2, RID-1, and RID-3 for the quadruple desk layout

Concerning the semi-direct lighting type, the most favorable outcome regarding luminaire positioning varied based on luminaire type and desk layout, as seen in Table 3. The luminaire RSD-1 provided the most favorable result in 'configuration a' for both dual and quadruple desk layouts. However, for other semi-direct lighting luminaires, the most favorable results were mainly yielded in configuration b for the dual desk layout and mainly in configuration c for the quadruple desk layout. Moreover, the distance by which luminaires, placed at the projection of the right

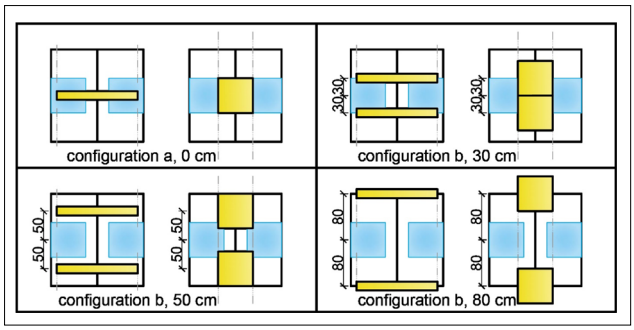

Figure 7. Luminaire configuration examples for dual desk layout.

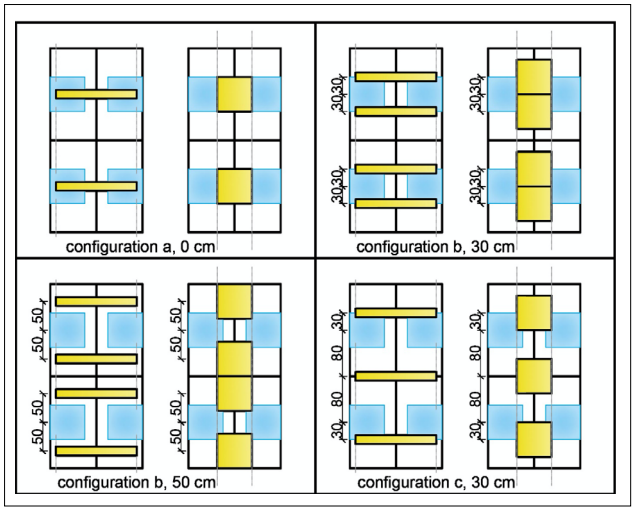

Figure 8. Luminaire configuration examples for quadruple desk layout.

and left boundary of the task area (configuration b), were shifted toward the edges of the desk varied depending on the luminaire type. In the quadruple desk layout, for instance, the distance for shifting the luminaire, placed at the projection of the right (or left) boundary of the task area (configuration c), toward the edge of the desk was 30 cm. For some cases, the distance by which the luminaire was shifted toward the edge of the desk was not a single measure but a range. For example, for the luminaire RSD-3 in the dual desk layout, when shifted toward the edge of the desk in configuration b by, 65 cm, and 70 cm (65 cm-70 cm), the required total luminous flux remained the same. Similar situations were observed in which different luminaire configurations resulted in the same required total luminous flux. In the quadruple desk layout, shifting the luminaire RSD-5 in configuration c by 30 cm and in configuration b by 30 cm-50 cm yielded the same result. In the comparison performed for effective energy use, the luminaire RSD-2 ranked first in the dual desk layout, followed by RSD-4, RSD-6, RSD-3, RSD-1, and RSD-5, respectively. In this context, the ranking for the quadruple desk layout was RSD-2, RSD-4, RSD-6, RSD-3, RSD-5, and RSD-1. For the most economical result, luminaire RSD-2, under the condition of being located in "configuration a, 0 cm", different from the locations stated in Table 3, further reduced the required total luminous flux for both desk layouts. However, in these cases, the RUGL value exceeded 19 for some desks, indicating that visual comfort could not be fully achieved for all desks.

In the direct lighting type, the most advantageous outcome regarding luminaire positioning varied based on luminaire type and desk layout, as seen in Table 4. For both dual and quadruple desk layouts, configuration a for RD-1, and configuration b for RD-5 and RD-6 generated the best results. Generally, for other luminaires, configuration a in the dual desk layout and primarily configurations b and c for the quadruple desk layout resulted in the most convenient outcomes. The distance by which luminaires were shifted toward the edges of the desk at the most beneficial luminaire positions varied depending on the luminaire type. In the dual desk layout, the findings obtained for SD-1, SD-2, and SD-3 were the same in two different configurations. Similarly, in the dual desk layout, the result remains the same for the RD-5 luminaire when shifted toward the edge of the desk within the range of 30 cm to 80 cm. Likewise, in the quadruple desk layout, the result remains unchanged

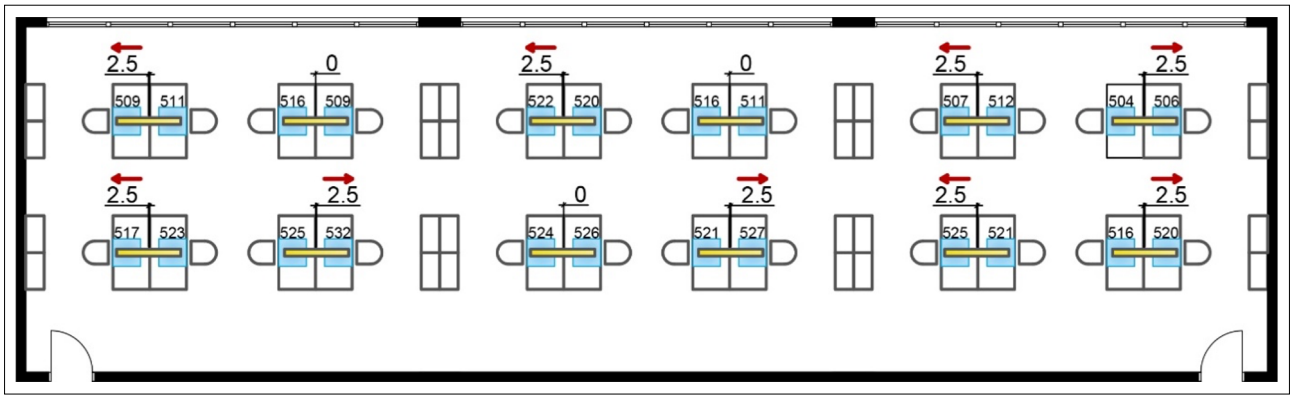

Figure 9. Example of shifting luminaires in the direction of the line of sight and vice-versa in a dual desk layout: RD-3, configuration a, 0 cm.

when shifting the RD-6 luminaire toward the edge of the desk within the range of 30 cm to 50 cm. In the comparison conducted for minimum lighting energy consumption, the ranking from most favorable to least favorable is SD-2, RD-3, SD-1, RD-2, RD-1, SD-3, RD-4, RD-6, RD-5 for the dual desk layout, and SD-2, RD-3, SD-1, SD-3, RD-2, RD-1, RD-4, RD-5, RD-6 for the quadruple desk layout. The RD-6 luminaire, which is at the end of the ranking for the quadruple desk layout, requires less luminous flux when placed in "configuration a, 0 cm", as opposed to the positions stated in Table 4. However, in this arrangement, the RUGL value exceeds 21 for some desks, indicating that visual comfort is not fully enabled for all desks.

EVALUATION AND CONCLUSION

Within the scope of the study, nineteen luminaires suitable for office use and covering three different lighting configurations were considered, along with two distinct desk layouts. For each combination of luminaire and desk layout (a total of 38 configurations), the optimal luminaire placement was examined. Luminaire placement meeting the targeted visual comfort criteria with minimum energy consumption was deemed favorable. The comparison in terms of energy consumption was based on the required luminous flux quantity for each lighting configuration. The configuration where visual comfort requirements were met with the least luminous flux was considered the most economical configuration.

This approach considers only the energy consumption during the use of the lighting system. Factors influencing the total cost of a lighting system are certainly not limited to this. For a comprehensive cost comparison, factors such as the number of luminaires, purchase cost, installation of luminaires, and expenses related to electrical installations must also be considered. Additionally, the amount of luminous flux emitted in relation to the power consumed by luminaires is crucial for effective energy use. On the other hand, numerous luminaires are available for office lighting; hence, factors such as lamp efficacy, luminaire efficiency and appearance, and compatibility with interior design have been excluded when selecting the appropriate luminaires in this study. Thus, the configurations under which the most favorable results are obtained have been explored by investigating the relationship between the luminous intensity distribution of luminaires and desk layout.

The evaluation of the results can be conducted as follows:

- Generally, less energy is consumed in direct lighting compared to the other two types of lighting. This result is parallel to the findings of Çelik et al. (2015). That is, the required luminous flux according to the lighting type was, as expected, the lowest in direct lighting, followed by semi-direct lighting and indirect-direct lighting respectively. In this comparison, the average of the required luminous fluxes was considered on the lighting type scale. For instance, in the indirect-direct lighting type, the average of the required luminous flux for RID-1, RID-2, and RID-3 luminaires was considered (Table 2). In other words, this ranking is not applicable for each luminaire within a lighting type. When comparing on a single luminaire scale, the required luminous flux, for example, was 61608 lm for RD-5 in the direct lighting of the dual desk layout, 49631 lm for RSD-4 in the semi-direct lighting of the quadruple desk layout, and 57096 lm for RID-2 in the indirect-direct lighting of the quadruple desk layout (Tables 3-4).
- In all considered luminaires, the required luminous flux in the quadruple desk layout is lower than in the dual desk layout. On average, 20% less luminous flux is needed in direct lighting, 21% less in semi-direct lighting, and 18% less in indirect-direct lighting in the quadruple desk layout. In other words, the quadruple desk layout is more advantageous in terms of energy consumption.
- Comparison within luminaires providing indirect-direct lighting: Considering all the results obtained for configurations a, b, and c, the most successful outcomes were achieved with the RID-2 luminaire, which emits direct light into the widest angle, in both desk layouts. The RID-3 luminaire, which emits direct light into the narrowest angle, ranked third in the success ranking. The beam angle of downward-emitted light in the indirect-direct lighting type proved to be decisive for the results. Another conclusion drawn from the results is that the most favorable luminaire position in this lighting type is the 'configuration a'.
- Comparison within luminaires providing semi-direct lighting: When considering all the results obtained for configurations a, b, and c, the most favorable outcomes were achieved with the RSD-2 luminaire in both desk layouts. This was followed by RSD-4 and RSD-6. The positive outcome were obtained by positioning the RSD-2 and RSD-4 luminaires 30 cm away from the projection of the center of the task area, as their downward luminous intensity distributions were similar. For the RSD-6 luminaire, whose downward beam angle is the widest, achieving economical results required the luminaires to move away from the center of the task area in the case of the dual desk layout. In the case of the quadruple desk layout, the RSD-6 luminaire needed to be located at the projection of the task area center. The RSD-1 and RSD-5 luminaires shared the last two ranks in the success ranking. Consequently, luminaires with a downward spatial distribution of luminous intensity resembling a sphere (RSD-1) were considered

Table 2. Indirect-Direct Luminaires

Luminaire type	Dual desk layout				Quadruple desk layout			
	Luminaire configuration type	$\bar{E}_m$ (lx)	R_{UGL}	Required total flux (lm)	Luminaire configuration type	$\bar{E}_m$ (lx)	R_{UGL}	Required total flux (lm)
RID-1	config. a, 0 cm	502-533	14.1-14.9	70755	config. a, 0 cm	507-531	14.3-14.7	60420
RID-2	config. a, 0 cm	506-541	15.7-16.7	74664	config. a, 0 cm	501-521	16.6-17.0	57096
RID-3	config. a, 0 cm	502-543	13.6-14.3	76344	config. a, 0 cm	508-534	13.4-13.7	64182

Table 3. Semi-Direct Luminaires

Luminaire type	Dual desk layout				Quadruple desk layout			
	Luminaire configuration type	$\bar{E}_m$ (lx)	R_{UGL}	Required total flux (lm)	Luminaire configuration type	$\bar{E}_m$ (lx)	R_{UGL}	Required total flux (lm)
RSD-1	config. a, 0 cm	500-533	16.0-17.1	70844	config. a, 0 cm	503-525	16.3-17.1	58656
RSD-2	config. b, 30 cm	500-529	17.9-18.4	52510	config. c, 30 cm	505-520	17.8-18.1	43243
RSD-3	config. b, 65 cm-70 cm*	503-527	14.8-15.7	70204	config. c, 30 cm	508-525	15.5-16.1	54603
RSD-4	config. b, 30 cm	506-543	16.1-16.6	62782	config. c, 30 cm	510-527	16.2-16.6	49631
RSD-5	config. b, 80 cm	507-540	15.7-16.5	73375	config. c, 30 cm; config. b, 30 cm-50 cm*	501-518	15.6-16.0	56311
RSD-6	config. b, 90 cm*-100 cm	500-529	15.6-16.8	67565	config. a, 0 cm	500-518	18.2-19.0	50674

Table 4. Direct Luminaires

Luminaire type	Dual desk layout				Quadruple desk layout			
	Luminaire configuration type	$\bar{E}_m$ (lx)	R_{UGL}	Required total flux (lm)	Luminaire configuration type	$\bar{E}_m$ (lx)	R_{UGL}	Required total flux (lm)
RD-1	config. a, 0 cm	507-532	16.0-17.9	50400	config. a, 0 cm	503-517	15.3-17.4	42840
RD-2	config. b, 30 cm	506-530	16.3-16.5	48672	config. c, 30 cm	501-519	15.7-16.0	41184
RD-3	config. a, 0 cm	504-532	18.4-18.8	45696	config. c, 30 cm	500-516	15.6-15.8	37944
RD-4	config. b, 50 cm	501-526	15.5-16.1	57600	config. c, 30 cm	502-526	15.9-16.3	44640
RD-5	config. b, 30 cm*-80 cm	504-532	16.4-16.8	61608	config. b, 50 cm	500-519	16.3-16.6	45300
RD-6	config. b, 90 cm	501-525	18.0-18.9	60221	config. b, 30 cm*-50 cm	501-525	17.7-18.1	47232
SD-1	config. a, 0 cm	501-529	17.9-18.3	49248	config. a, 0 cm*; config. b, 30 cm	501-520	17.2-17.7	40176
SD-2	config. a, 0 cm	503-524	18.6-19.0	41148	config. c, 30 cm; config. b, 50 cm*	500-517	14.6-15.0	34992
SD-3	config. a, 0 cm	502-530	16.2-17.0	52356	config. b, 45 cm	500-514	12.9-13.3	40513
SD-4	config. a, 0 cm	500-529	16.4-17.2	65208	config. a, 0 cm	500-518	15.9-16.7	48300

unsuitable for both desk layouts. The big difference between luminous intensity at the luminaire axis and maximum luminous intensity, along with a little angle between the direction of maximum luminous intensity and the luminaire axis (RSD-5), is also unfavorable for the considered desk layouts. Although the distribution of luminous intensity of the RSD-3 luminaire is similar to that of the RDS-5 luminaire, the difference between luminous intensity along the luminaire axis and maximum luminous intensity is less.

- Comparison within luminaires providing direct lighting: When evaluating all the results obtained for positions a, b, and c, it was observed that, in both desk layouts, the SD-2 square luminaire provided the most favorable results. Following this, the rectangular RD-3 luminaire and the square SD-1 luminaire were in order. The spatial distribution of luminous intensity of these three luminaires was very similar, and they needed to be positioned in the 'configuration a, 0 cm' for the dual desk layout. However, in the case of the quadruple desk layout, the luminaire positions yielding the most favorable results differed (Table 4). The luminaires SD-4, RD-5, and RD-6 ranked at the bottom three in success. It can be noted that these three luminaires share the common characteristic of having a big angle between the direction of maximum luminous intensity and the luminaire axis. Comparing the required luminous flux averages for square luminaires with those for rectangular luminaires, it can be stated that square luminaires are more economical in both desk layouts. On the other hand, among the total of ten luminaires providing direct lighting, the least favorable result was obtained with the SD-4 square luminaire. The conclusion to be drawn from this is that the luminous intensity distribution and the luminaire position are more decisive factors for the results achieved than the luminaire shape. This conclusion is consistent with Kalelioğlu & Dokuzer Öztürk (2022).

The decision regarding the luminous intensity distribution of the luminaire to be used in illuminating an office should be made considering the interior design. This study examined optimal luminaire positions based on the luminous intensity distribution of luminaires and desk layout to achieve the most economical results. The presented data in this research provides valuable insights into lighting design for the considered 19 luminaires and 2 desk layouts. It is evident that the results of this study can be applied to spaces with different functionalities having desk layouts similar to the ones examined in this research. Furthermore, for conditions where the desk layout and/or luminous intensity distribution of luminaires differ from the examples in this article, the most economical decisions can be made following the approach outlined in the study.

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Article

An experimental study on the effects of lighting in the offices

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ABSTRACT

In recent years, the number of studies on light and its effects on human beings has increased significantly. Various studies have shown that light has non-visual as well as visual effects on humans, and that these effects direct physiological, psychological, and behavioral responses such as alertness and circadian rhythms. The relevant literature cites national/international standards, legislation, metric/numerical measurement methods, and some suggested calculation methods (Circadian Stimulus, Equivalent Melanopic Lux, etc.) to quantify these effects. However, the data on the measuring instruments used and the measurement methods followed in indoor/in situ studies are quite limited. In order to contribute to the subject, research has been initiated to determine the visual and non-visual effects of light on indoor working environment users. This research presents and compares the results of an experimental study carried out to compare the photometric and radiometric measurement results of the same parameters (Ev, EML, *T*cp values) by two different devices. To this end, measurements were taken in two different office environments with different daylight proportions to assess whether and under which conditions the devices could be used as substitutes for one another. In order to achieve this, hypothesis tests were applied to the test results to estimate the probability of the two measurements being equal.

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INTRODUCTION

All living things have the instinct to organize their internal cycle according to the characteristics of external stimuli. This instinct, which begins in humans in the womb, is the most fundamental determinant of human-built environment interaction (McKenna & Reiss, 2018). When the subject is considered from this point of view, especially the spaces in which people live/work for a long time, direct the attention, emotions, and behaviors of their users with different features such as function, size, lighting, etc., and play an active role in the change of their existing biological/circadian rhythms.

In the literature, the effects of light on human beings are considered in two groups: visual and non-visual effects. The visual effects of light are evaluated through luminometric parameters (illuminance level, luminous flux, luminous intensity, luminance, color properties of light) related to the lighting conditions in the physical environment. The values given in the standards for these quantities are basically related to the "photosensitivity $V(\lambda)$" properties of cone light receptors, especially M/green cones, in the retina, which operate under "photopic vision" conditions.

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Non-visual effects of light affect human physiological and neurobehavioral brain functions, especially cognitive tasks including basic functions such as perception, attention, memory, language problem solving, reasoning, decision making, psychomotor, and executive functions. Non-visual effects of light are of two types: short-term/instantaneous and long-term effects. Short-term/instantaneous effects in the body can be exemplified by the pupil dilation response and suppression of melatonin hormone secreted by the pineal gland. Long-term effects cause physiological and psychological disturbances such as sleep/wake (circadian rhythm), heart, digestive system disorders, winter depression, etc. (International Commission on Illumination, 2018).

In the evaluation of the non-visual effects of light, parameters related to "melanopic vision" conditions, which also govern the biological/circadian rhythm of humans, are taken into account. These are linked to light exposure duration (minutes), time of day (morning, noon, afternoon, evening, night, etc.), user characteristics (age, gender, education, etc.), and user's light history (living conditions), in addition to luminometric parameters, although these are not yet finalized today (Khademagha et al., 2016).

However, there are numerical models in the literature to explain the relationship between non-visual effects and light measurement parameters. The first example is the "Circadian Action Factor (CAF)" model derived from the experimental studies of Gall (Gall & Bieske, 2004), Brainard (Brainard et al., 2001), and Thapan (Thapan et al., 2001) in the early 2000s. This model correlated the changes in melatonin suppression depending on the wavelengths of light with various luminometric magnitudes. The model suggests different CAF values depending on the time of day; for example, high CAF values during the day and low CAF values at night are more favorable (Oh et al., 2014).

In 2012, at Rensselaer Polytechnic Institute (Lighting Research and Technology, LRC) in the USA, Rea et al., (2012), developed the "Circadian Stimulus (CS)" model. In the Circadian Stimulus model, the "Circadian Light (CLa)" unit is used. In the CS model, a rating is introduced for the rate at which the amount of light entering the eye suppresses melatonin production after 1 hour of exposure to light. In this model, for example, a Circadian Stimulus (CS) of 0 indicates that melatonin is not suppressed, while a CS of 0.7 indicates a theoretical 70% suppression of melatonin. The CS also includes values that should be achieved for at least 1 hour of light exposure. For example, for a typical office environment, CS ≥0.3 during the daytime, CS ≤0.2 in the afternoon, and CS ≤0.1 in the evening and at night (Rea et al., 2010; Rea et al., 2012). With the CS toolbox developed by LRC between 2017 and 2020, CS and CLa values can be calculated for the lighting environment in which users are located (Figueiro et al., 2016; Lighting Research Center, 2020).

In 2014, Lucas et al. (2014) developed a model for the effects of light called "Equivalent Melanopic Lux (EML)." This model assumes that there are five light-sensitive receptors in the retina: S-cone, M-cone, L-cone, rod, and ipRGC (intrinsically photosensitive retinal ganglion cell). The intrinsical photosensitivity of retinal ganglion cells (ipRGC) is mediated by the melanopsin photopigment they contain. It is recommended that the EML value at eye level should be at least 200 EML between 09:00-13:00 during the day and at most 50 EML at night (Lucas et al., 2014).

In 2014, the International Well Building Institute (IWBI) developed a certification system (Well Standard, WS) to assess the minimum requirements for circadian rhythm. This certification system is based on the EML model previously defined in the literature. In the WS, the EML value is obtained by multiplying the illuminance level measured at eye level by a coefficient weighted according to the spectral energy distribution of the light illuminating the environment. Within the scope of WS, an EML rating has been introduced for the spectral distribution of light in indoor workspaces in non-residential building typologies (Lucas et al., 2014; International WELL Building Institute, 2021).

In 2018, the CIE published a standard for non-visual effects of light on humans via intrinsically photosensitive retinal ganglion cells (ipRGCs) that contain melanopsin. The International Standard CIE S 026/E: 2018 specifies a system for measuring optical radiation for ipRGC-influenced responses to light. The standard defines spectral sensitivity functions, quantities, and measurements to identify five types of photoreceptors that may contribute to the retina-mediated non-visual effects of light in humans, and the ability to stimulate each of them (European Committee for Standardization, 2017; International Commission on Illumination, 2018; International Commission on Illumination, 2019). In addition, the CIE has developed a toolbox to enable calculations and conversions of quantities related to ipRGC-influenced responses to light, implementing CIE S026 (International Commission on Illumination, 2020). The α-opic Toolbox calculates the spectral power distribution of the light the person is exposed to in W/m^2 by converting the spectral power distribution of the light into individual α-opic power level values for each of the five receptors in the eye.

In the literature, there are publications stating that the magnitude of the non-visual effects of light is related to the "spectral distribution of light." In these publications, it is stated that there are radiometric and photometric parameters related to the spectral distribution of light (Khademagha et al., 2018). In studies on the non-visual effect by taking into account the spectral distribution of light, in addition to measuring instruments such as lux meter, luminance meter, chroma meter, etc., which are

generally used to determine the visual effects of light, a "spectroradiometer" is also used, which shows the spectral distribution of light in terms of spectral radiance level. These measuring instruments naturally have differences in the way they work. These distinctions can affect the results in terms of measurement accuracy and comparability and are therefore of great importance for design, research, and improvement studies in the field of lighting. There is a limited number of studies in the literature that take into account the differences in the functioning of these measuring instruments.

As can be understood from the above explanations, there are different approaches, different definitions, different measurement parameters, different measurement-evaluation-grading methods for these parameters in the literature on non-visual effects of light. In order to contribute to this issue, the present research was planned and measurements were started to determine the visual and non-visual effects of light on the users of an indoor work environment (office) with integrated lighting (natural and electrical lighting together).

This research presents and compares the results of an experimental study carried out to compare the photometric and radiometric measurement results of the same parameters (Ev, EML, *T*cp values) by two different devices. To this end, measurements were taken in two different office environments with different daylight proportions to assess whether and under which conditions the devices could be used as substitutes for one another. In order to achieve this, hypothesis tests were applied to the test results to estimate the probability of the two measurements being equal. The methodology of the study, the preliminary results of the experiments, and the evaluation of the results are presented in the following sections.

RESEARCH METHODOLOGY

The aim of the research is to measure the non-visual effects of light on office users with different devices having different measurement methods and to evaluate the results. In this context, the steps of the research methodology can be summarized as follows:

- Determination of the characteristics of the office spaces selected as the experimental environment.
- Determination of experimental measurement times.
- Determination of measuring instruments to be used in the experiments.
- Comparative evaluation of measurement results.

Experimental Environment Features

The research was carried out in two separate spaces, which are named as Office 1 and Office 2.

Experiment 1 (E1): The office space (Office 1) where the first experiment was conducted is located on the second floor of a four-story office building in the Kurtköy neighborhood of the Kadıköy district of Istanbul, Turkey (40°55'14"N latitude, 29°19'3"E longitude). The office (width 8.60 m, length 9.90 m, height 3.78 m) has a floor area of 82 m², and windows are oriented southeast. The space is divided into two parts: a manager's room (14 m²) and an open office with 9 desks. The two spaces are separated by glass partitions. The façade of the building has a glass curtain wall system with aluminum joinery and vertical solar control elements. The ratio of window area to window wall area (transparency ratio) is 100%, and there is no external obstruction near the building. Generally, matte materials are used in the space. According to the Munsell Color System, the walls' paint is a high-value, low-saturation yellowish-red (10YR, 9/1), the ceiling's paint is black (N2/0). The floor is covered with gray (N 6/0), matte plastic flooring (PVC) material. Table separators are matte, medium value, and high saturated purple-blue (10B 6/8). There are matte and translucent fabric vertical curtains inside of the windows. The dimension of the curtain parts is 122 mm, and color is yellow with high value and low saturation (2Y 8/4). The reflectance of the interior surfaces of the office was measured with a spectrophotometer (Konica Minolta CM-2600d) as ceiling ρ: 0.1, wall ρ: 0.9, floor ρ: 0.3, desk ρ: 0.8, curtain ρ: 0.7.

The electrical lighting system of the space consists of 14 luminaires. Each luminaire has a linear LED light source (36 W, 6500 K, 80 Ra).

The study was carried out at user location 1, which is located in the viewing direction parallel to the window. The site plan and exterior view of the office building are shown in Figure 1, the experimental floor plan and section in Figure 2, and the interior photographs in Figure 3.

Experiment 2 (E2): The office space where the second experiment was conducted is located on the fourth floor of a fifteen-story office building in the Sahrayıcedid neighborhood (40°98'14"N latitude, 29°19'3"E longitude), Kadıköy district, Istanbul. The space (width 13.25 m, length 13.75 m, height 3.25 m) is divided into two by glass separators. The open plan office (158 m²) has a total of 33 desks, 25 in the first section and 8 in the second section of the room, windows are oriented east, north, and northeast. The façade of the building has an aluminum joinery glass curtain wall system. The transparency ratio of the façade, which uses film on the window glasses, is 53%, and the nearest external obstruction to the building is 20 meters away.

On the interior surfaces of the space, according to the Munsell Color System, the walls' paint is high-value, low-saturated yellowish-red (10YR, 9/1), the ceiling's paint is matte white (N8/0). The floor is covered with medium-dark

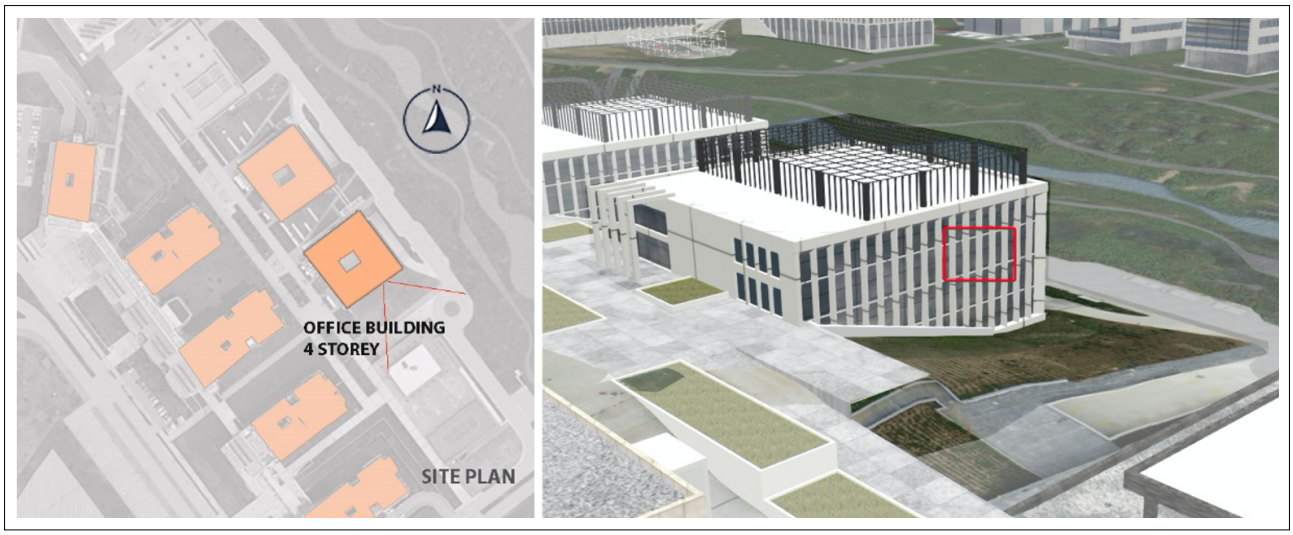

Figure 1. E1office building site plan and building exterior view.

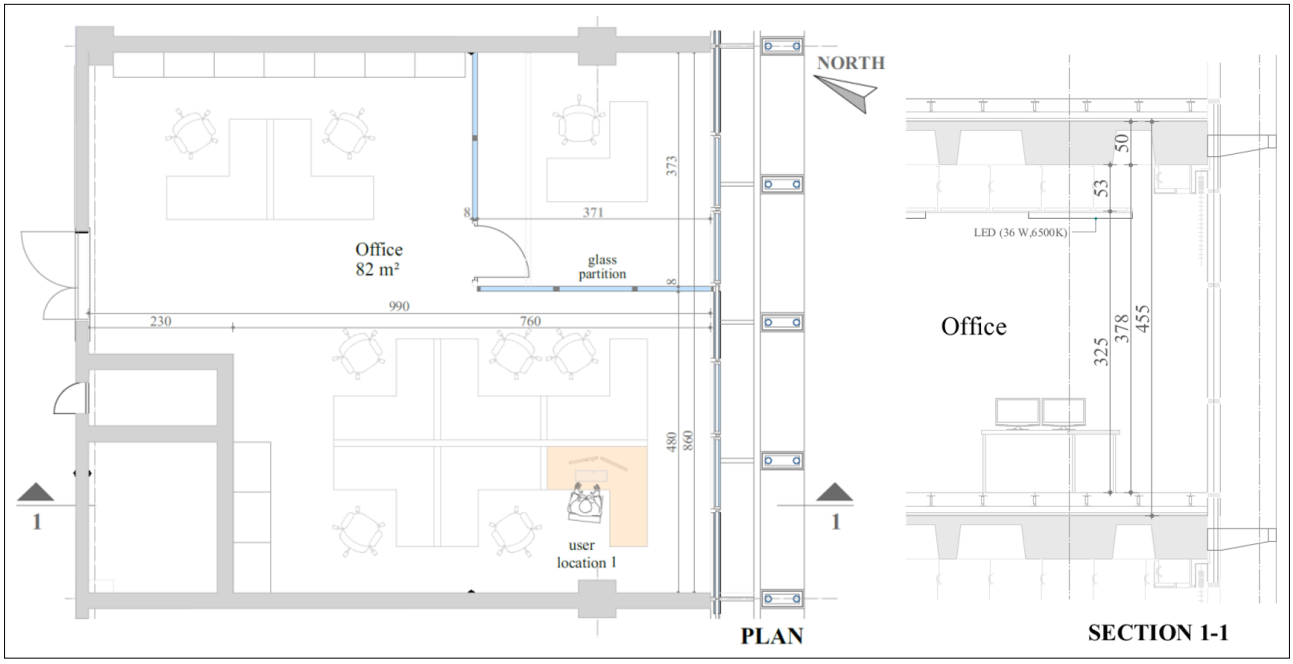

Figure 2. Plan and Section 1-1 of the E1office floor.

and saturated orange (7.5YR 6/6), mixed reflective laminate parquet flooring material. There are light yellow colored, opaque plastic vertical piece curtains (piece width, 90 mm) inside of the windows. The reflectance of the office interior surfaces was measured as ceiling ρ: 0.8, wall ρ: 0.7, floor ρ: 0.2, desk ρ: 0.8, and curtain ρ: 0.7. This study was carried out at user location 1, which is located in a north/northeast facing window.

The electrical lighting system of the space consists of 20 luminaires. Each luminaire is 0.60×0.60 m in size, with a diffuse lighting form. The LED light source (40 W, 3200 K, 80 Ra).

The site plan and exterior view of the office building are shown in Figure 4, the experimental floor plan and section in Figure 5, and the interior photographs in Figure 6.

Measuring Times and Properties of Measuring Instruments

The experiments were designed to investigate the non-visual effects of light on office users in two different situations, during the day and throughout the year. Light effects measurements were carried out:

- Three times during working hours, between 08:00 and 17:00 hours, to investigate the daily (diurnal) variation,

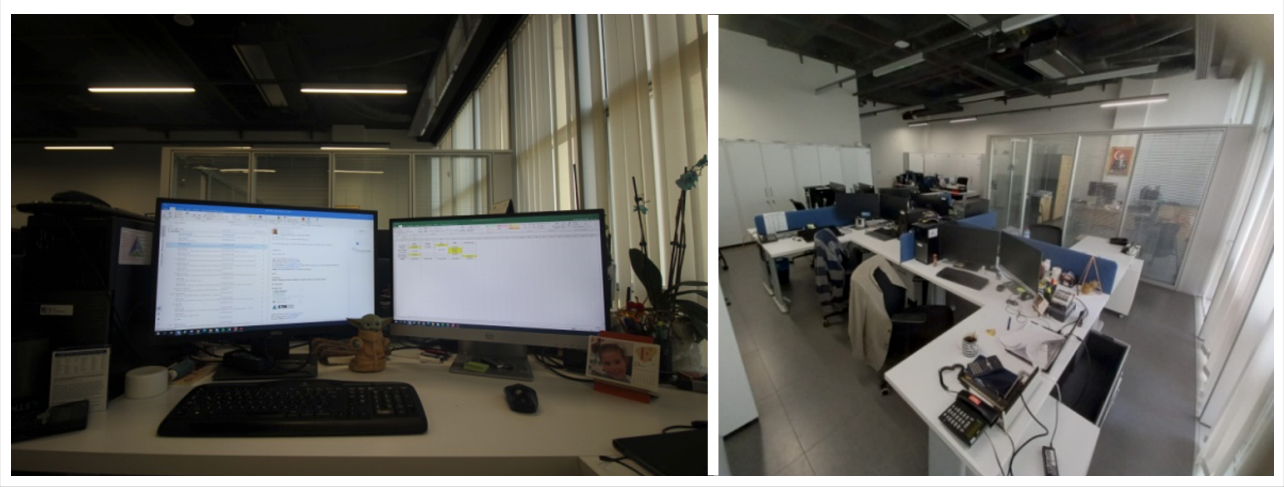

Figure 3. Interior view of E1 office.

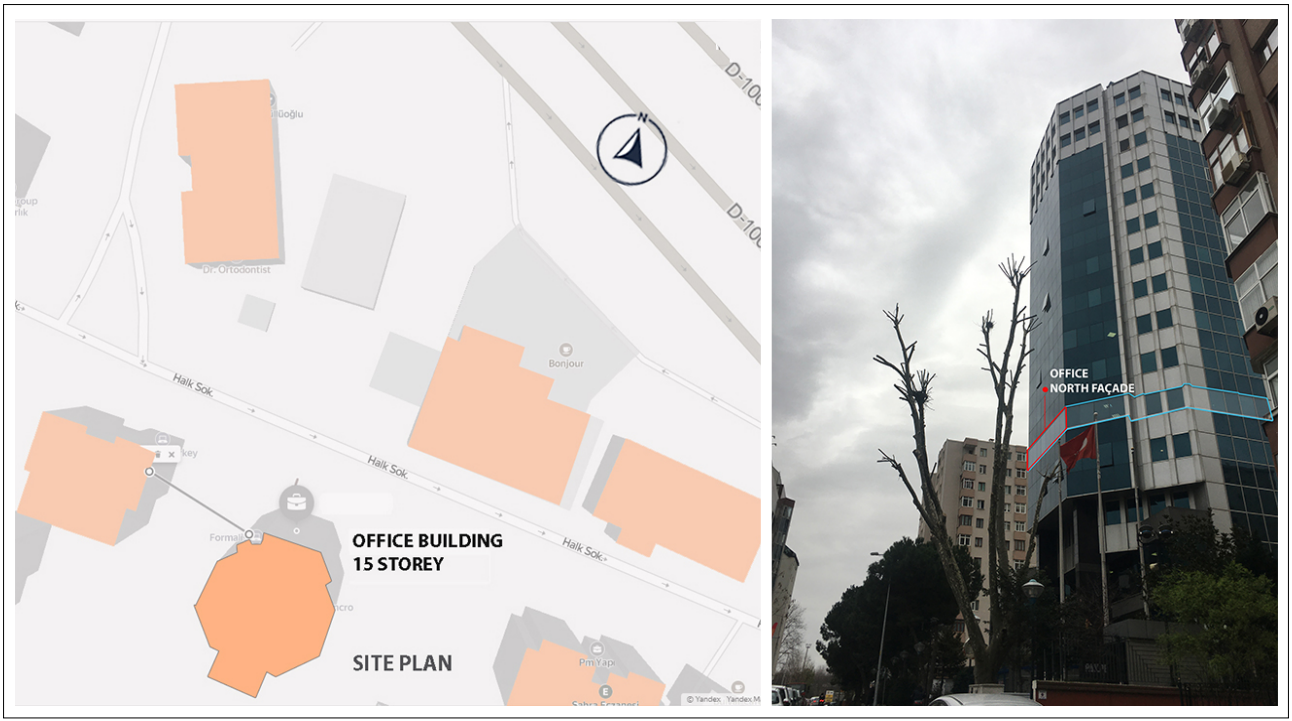

Figure 4. E 2, workplace site plan and building exterior view.

- Five days each in three different seasons (winter, spring, and summer) to determine the annual variation.

Measurements for Experiment 1 were carried out on 20-24 December 2022, 28 March-1 April 2022, and 22-23 June 2022. Measurements for Experiment 2 were carried out on 3-7 January 2022, 4-8 April 2022, and 27 June-1 July 2022. The study was repeated for three seasons (winter, spring, and summer months), five working days a week, for a total of 27 days, and at specific times of the day (09:30, 12:30, 16:00).

The parameters measured in the study and the characteristics of the instruments used to measure them are summarized below (Figure 7):

- **Illuminance** (E, lm/m²; lx):
  - Chroma meter (Konica Minolta Chroma meter CL-200A, Ev_K) that measures incident light according to the sensitivity $V(\lambda)$ of the green (M) cone receptor in the eye.
  - Spectroradiometer (nanoLambda XL-500, Ev_N) that measures the magnitude of the radiant energy of incident light.
- **Equivalent Melanopic Lux** (EML, lm/m²; lx):
  - According to the EML model approach, the EML_K value was obtained by multiplying the Ev_K value by

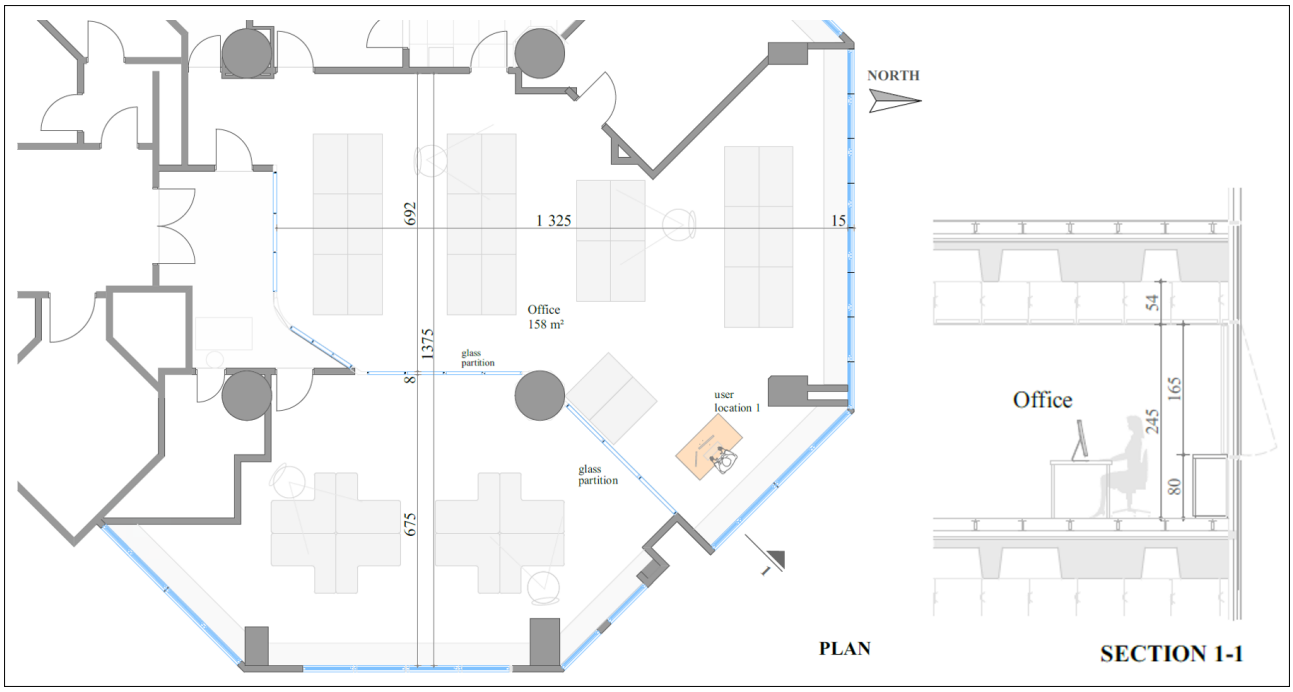

Figure 5. Plan and Section 1-1 of the E2 office floor.

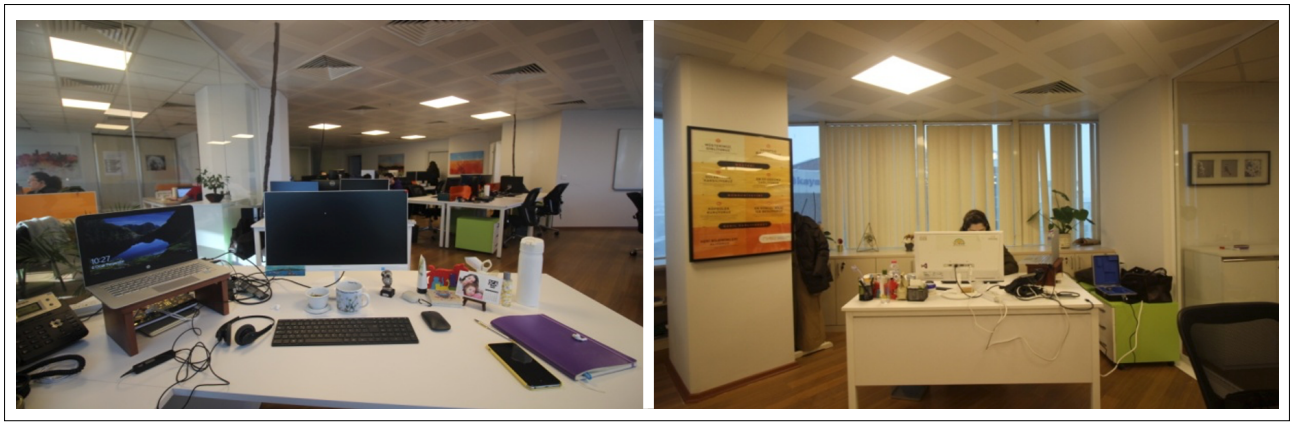

Figure 6. Interior view of E2 office.

the melanopic ratio determined according to the spectral energy distribution of the ambient light used. The melanopic ratio used in the study was taken as 0.76 for LED lamp (4000 K), depending on the ambient light source (International WELL Building Institute, 2021).

- The spectral luminous flux obtained with the spectroradiometer (nanoLambda XL-500), which measures the radiative magnitude of the incident light according to the wavelength, calculates the EML_N value by converting the illuminance values [lx] into α-opic radiations [mW/m²] using the CIE S026 Toolbox, which is included in the software.

- **Color Temperature** (*T*cp, Kelvin):
  - Chroma meter (Konica Minolta CL-200A, Tcp_K) that measures incident light according to the sensitivity $V(\lambda)$ of the green (M) cone receptor in the eye.
  - A spectral radiometer (nanoLambda XL-500, Tcp_N) measures the radiative magnitude of the incident light by wavelength.

The hourly weather information of the region where the experimental sites were located was recorded by following the website of the Istanbul Meteorology Directorate. The daily average weather information of the periods when the measurements were carried out is presented in Table 1.

In the experiment, illuminance and color temperature measurements were performed simultaneously with spectroradiometer measurements. The measurements were taken at eye level in the user position specified in the relevant literature at a height of 1.2 m above the floor

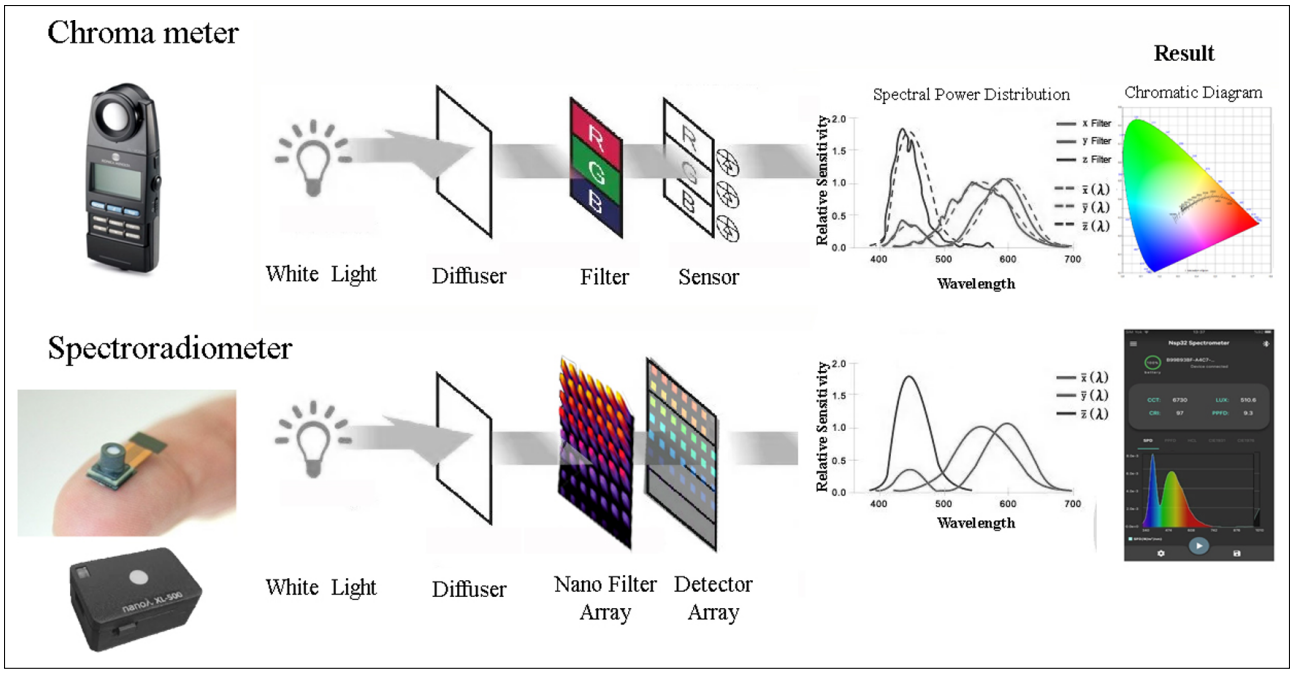

Figure 7. Properties of the chroma meters (photometric measurement) and spectroradiometers (radiometric measurement) used in the study.

Table 1. Daily average weather information of the measurement periods.

E1	Winter Season (20-23 November 2021)	Spring Season (28 March-1 April 2022)	Summer Season (22-23 June 2022)
E2	Winter Season (3-7 January 2022)	Spring Season (4-8 April 2022)	Summer Season (27 June-1 July 2022)

Overcast, Partly Cloudy, Clear/Sunny.

and 0.10 m behind the desk (CIE, 2018; Türk Standartları Enstitüsü, 2021).

Comparison and Evaluation of the Results

In this part of the study, the measurement results obtained by two different photometric and radiometric instruments at different times of the day and across three seasons in two office environments for a total of twenty-seven working days are presented, compared, and evaluated.

The measurement data obtained from the experiments were analyzed using the Wilcoxon signed-rank test and regression analysis in SPSS software. The results of the days (spring and summer periods) when different lighting scenarios (some lights off) were applied during the measurement periods were excluded from the analysis; therefore, a total of twenty-five days of data were analyzed.

In the study, the p-value represents the probability that the simultaneous measurements made with the two different devices are equal. Two different significance levels were used in the analyses for illuminance (E) and Equivalent Melanopic Lux (EML) values ($p < 0.12$) and for color temperature (Tcp) ($p < 0.05$). The recommended illuminance steps (5-7.5-10-15-20...|-5000-7000-10000 lx) to produce a perceptual difference, determined according to the lighting requirements criteria in TS EN 12464-1:2021, were used in the analysis of E and EML values (Walpole et al., 2016).

The mean vertical values of vertical illuminance (Ev_K, Ev_N), the color temperature (Tcp_K, Tcp_N), and the calculated Equivalent Melanopic Lux (EML_K, EML_N), obtained in the experiments at the same times of the day (09:30, 12:30, 16:00) and in the same seasons of the year (Winter, Spring, Summer), and the p-values are presented in Table 2 for Experiment 1 and in Table 3 for Experiment 2 (Pekin & Ünver, 2022).The p-values of the measurements that show statistically significant differences from each other are indicated with asterisk (*).

Table 2. The means and the p-values of the measurements obtained at the same times of the day in the same season with two different devices in Experiment 1 (user position 1).

E1	Winter Season (20-24 December 2021)					
	09:30		12:30		16:00	
	Mean	p	Mean	p	Mean	p
Ev_K(lm/m²)	**243**	**0.043***	445	0.138	221	0.144
Ev_N(lm/m²)	**214**		382		253	
EML_K(lm/m²)	**185**	**0.043***	**338**	**0.080***	168	0.465
EML_N(lm/m²)	**168**		**280**		163	
Tcp_K(K)	4525	0.068	4336	0.080	4553	0.068
Tcp_N(K)	4930		4553		4977	
E1	**Spring Season (28 March-1April 2022)**					
	09:30		**12:30**		**16:00**	
	Mean	**p**	**Mean**	**p**	**Mean**	**p**
Ev_K(lm/m²)	387	0.225	**543**	**0.043***	**262**	0.080*
Ev_N(lm/m²)	294		**429**		**269**	
EML_K(lm/m²)	294	0.225	**412**	**0.043***	200	0.500
EML_N(lm/m²)	197		**323**		198	
Tcp_K(K)	**4366**	**0.043****	**4432**	**0.043****	4780	0.138
Tcp_N(K)	**4674**		**4726**		4887	
E1	**Summer Season (22-23 June 2022)**					
	09:30		**12:30**		**16:00**	
	Mean	**p**	**Mean**	**p**	**Mean**	**p**
Ev_K(lm/m²)	451	0.180	312	0.655	**255**	0.108*
Ev_N(lm/m²)	308		288		**276**	
EML_K(lm/m²)	343	0.180	237	0.655	194	0.180
EML_N(lm/m²)	222		210		203	
Tcp_K(K)	4462	0.180	4538	0.180	4635	0.180
Tcp_N(K)	4663		4778		4918	

* E, EML, Statistically significant (p≤0.12); **Tcp, Statistically significant (p≤0.05).

In general, the Equivalent Melanopic Lux (EML_N) values obtained with the spectroradiometer were lower (EML_N < EML_K) and the color temperature values were higher (Tcp_N > Tcp_K) than those measured with the chromameter, in the experiments. On the other hand, the vertical illuminance level (Ev) values were lower in Experiment 1 (Ev_N < Ev_K) and higher in Experiment 2 (Ev_N > Ev_K) with the spectroradiometer.

In E1 measurements, it was found that

- Ev_K, Ev_N Winter 9:30 am; Spring 12:30, 16:00 pm; Summer 16:00 pm,
- EML_K and EML_N Winter 9:30 am-12:30 pm, 12:30 pm in Spring and 16:00 pm in Summer,
- Tcp_K and Tcp_N Spring at 9:30 am, 12:30 pm, differed significantly.

In the E2 measurements, it was found that

- Only EML_K and EML_N Winter 9:30 a.m. values showed statistically significant differences, while they did not differ in other time intervals and seasons.

As expected, the quite different characteristics of the experimental spaces—the orientations of the buildings, the

Table 3. The means and the p-values of the measurements obtained at the same time of the day in the same season with two different devices in Experiment 2 (user position 1).

E2	Winter Season (3-7 January 2022)					
	09:30		12:30		16:00	
	Mean	p	Mean	p	Mean	p
Ev_K(lm/m²)	370	0.893	362	0.138	342	0.138
Ev_N(lm/m²)	383		414		380	
EML_K(lm/m²)	**282**	**0.043***	**275**	**0.080***	**260**	**0.080***
EML_N(lm/m²)	**194**		**217**		**191**	
Tcp_K(K)	3162	0.080	3335	0.225	3219	0.225
Tcp_N(K)	3336		3406		3319	
E2	**Spring Season (4-8 April 2022)**					
	09:30		12:30		16:00	
	Mean	p	Mean	p	Mean	p
Ev_K(lm/m²)	376	0.465	363	0.273	345	0.144
Ev_N(lm/m²)	393		389		405	
EML_K(lm/m²)	**286**	**0.068***	**276**	**0.068***	262	0.144
EML_N(lm/m²)	**222**		**223**		220	
Tcp_K(K)	3266	0.109	3319	0.068	3329	0.144
Tcp_N(K)	3475		3565		3450	
E2	**Summer Season (27 June-1 July 2022)**					
	09:30		12:30		16:00	
	Mean	p	Mean	p	Mean	p
Ev_K(lm/m²)	**389**	**0.068***	**281**	**0.068***	333	0.273
Ev_N(lm/m²)	**497**		**316**		363	
EML_K(lm/m²)	296	0.465	252	0.690	**253**	**0.068***
EML_N(lm/m²)	319		202		**184**	
Tcp_K(K)	3379	0.068	3206	0.700	3150	0.109
Tcp_N(K)	3942		3511		3326	

* E, EML, Statistically significant (p≤0.12); ** Tcp, Statistically significant (p≤0.05).

different times of the day, and the various seasons of the year—significantly influence the measurements. The differences obtained with two different measuring instruments are higher in E1 compared to E2. It can be said that these differences are related to user location and building orientation. In E1, the user position is in the Southeast orientation where daylight is effective for a longer period of time. Therefore, E1 is exposed to more daylight than E2, which has a Northeast orientation and a user position parallel to the window. The variations of the photometric quantities measured at E1 and E2 according to different times of the day and seasons are presented in Figure 8.

The study also analyzed the effect of weather/sky conditions on the results obtained simultaneously with two different instruments (photometric and radiometric). The mean and the p-values of Ev_K, Ev_N, Tcp_K, Tcp_N, EML_K, and EML_N obtained at the same time of day in the same season are presented in Table 4.

Analysis of the Ev and EML values obtained showed that the photometric (device K) and radiometric (device N) measurements differed at the level of statistical significance ($p \leq 0.12$) when daylight was dominant. It can be seen that the values obtained are significantly different in the partly

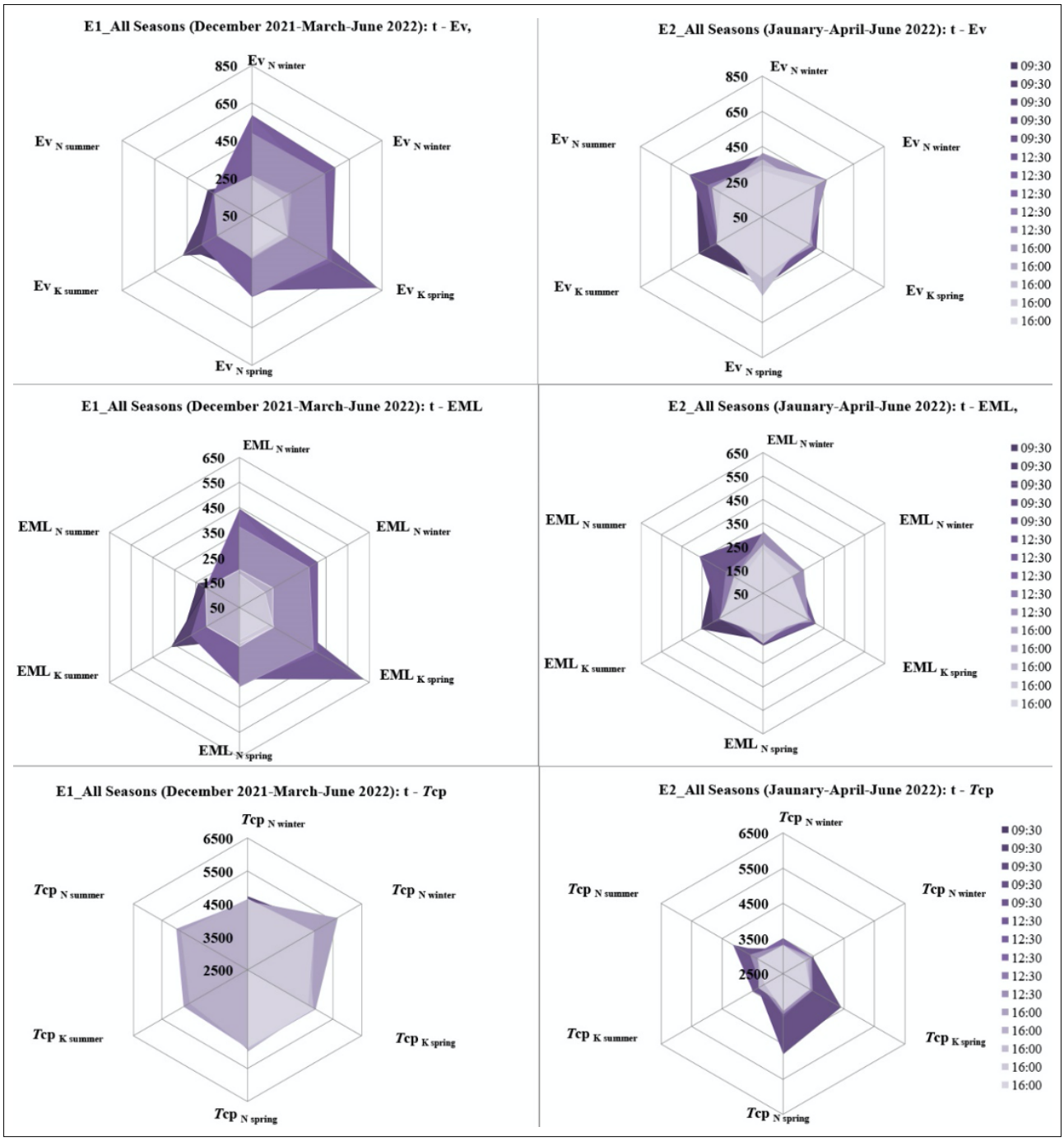

Figure 8. E1 and E2, Ev, EML, and Tcp values for all seasons and measurement times.

Ev_K: Vertical Illuminance Level_Konica CL-200 A; Ev_N: Vertical Illuminance Level, Spectroradiometer_nanoLambda XL-500; EML_K: EvK value converted by a coefficient of 0.76; EML_N: Equivalent Melanopic Lux, calculated bythe Spectroradiometer_nanoLambda XL-500; Tcp_K: Instantaneous Measurement of Vertical Similar Colour Temperature_Konica CL-200A; Tcp_N: Vertical Colour Temperature, Spectroradiometer_nanoLambda XL-500.

cloudy condition, but not in the overcast conditions. This can be interpreted as the fact that in partly cloudy weather, when the clouds are moving, the irradiance can change significantly within a few seconds, and the presence of direct and reflected daylight in the environment affects the measurement results. However, the study shows that the effect of the variation in weather/sky conditions on the measurement results according to the different months of the year (seasons) varies predominantly according to the solar declination. It can be said that the measurement differences are more pronounced

Table 4. Means and calculated p-values of the measurement results obtained with two different measuring devices in the experiments (E1,E2), at the same time of the day, in the same season, according to the weather change.

	Weather Condition																	
	Winter						**Spring**						**Summer**					
	Overcast			**Partly Cloudy**			**Overcast**			**Partly Cloudy**			**Partly Cloudy**			**Clear**		
E1	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**
Ev_K(lm/m²)	233	287	190	**243**	591	238	358	295	241	**491**	**542**	**273**	427	309	-	-	-	-
Ev_N(lm/m²)	204	211	250	**210**	426	233	265	260	246	**319**	**472**	**275**	243	288	-	-	-	-
p	-	0.180	0.180	**0.109***	-	-	-	-	-	**0.109***	**0.068***	**0.109***	0.180	0.655	-	-	-	-
EML_K(lm/m²)	177	218	144	**185**	449	181	272	224	176	**373**	**412**	**207**	324	187	-	-	-	-
EML_N(lm/m²)	162	151	140	**171**	316	167	196	192	179	**202**	**356**	**202**	181	210	-	-	-	-
p	-	0.180	0.655	**0.109***	-	-	-	-	-	**0.109***	**0.068***	**0.068***	0.180	0.655	-	-	-	-
Tcp_K(K)	4653	4609	4451	4476	4139	4657	4442	4551	4854	4255	4402	4761	4462	4538	-	-	-	-
Tcp_N(K)	5418	4644	5122	4881	4580	4829	4589	4855	4868	4492	4694	4892	4721	4778	-	-	-	-
p	-	0.655	0.180	0.109	-	-	-	-	-	0.109	0.068	0.144	0.180	0.180	-	-	-	-
E2	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**	**09:30**	**12:30**	**16:00**
Ev_K(lm/m²)	346	269	340	377	385	343	299	321	201	**389**	**371**	353	**341**	320	224	345	205	353
Ev_N(lm/m²)	366	434	406	367	409	394	229	250	229	**424**	**418**	422	**396**	376	235	530	271	323
p	-	-	-	0.465	0.278	0.273	0.180	0.655	0.180	**0.109***	**0.109***	0.285	**0.109***	-	0.180	-	0.180	-
EML_K(lm/m²)	263	205	258	**286**	**293**	260	227	244	153	**295**	**218**	268	259	243	170	262	132	268
EML_N(lm/m²)	175	223	171	**199**	**215**	215	137	157	197	**246**	**247**	230	256	196	128	364	135	166
p	-	-	-	**0.068***	**0.068***	0.144	0.180	0.655	0.655	**0.109***	**0.109***	0.285	1.0	-	0.180	-	0.655	-
Tcp_K(K)	3283	3136	3145	3132	3385	3238	3734	3625	3385	2242	3409	3380	3628	3166	3401	3493	3412	3107
Tcp_N(K)	3226	3350	3409	3364	3420	3296	4015	4127	3580	3626	3668	3464	4135	3373	376	4145	3902	3348
p	-	-	-	0.068	0.465	0.465	0.180	0.180	0.180	0.109	0.109	0.285	0.109	-	0.180	-	0.180	-

* E, EML, Statistically significant (p≤0.12). ** *T*cp, Statistically significant (p≤0.05).

in the winter and spring seasons when the sun's rays are more tilted, than in the summer period.

It was observed that the Equivalent Melanopic Lux, EML values obtained in both experiments generally met (see Table 2, Table 3) or were close to the 200 EML value recommended for the hours specified in the EML metric (between 09:00-13:00). It is seen that the lowest EML values were obtained in the winter period. In general, it can be said that both instruments can be considered for measuring also the non-visual effect of light with close accuracy.

DISCUSSION AND CONCLUSION

Visual and non-visual effects of light are critical for public health. Improving physical environmental conditions and regulating the amount of light reaching the eye has a positive effect on quality of life, well-being, and aging. In recent years, this effect of light on health has become one of the basic requirements of modern society. Lighting designers need a precise and simple tool or guideline to calculate/estimate the photopic and melanopic illumination at eye level and to determine how this illumination can be improved/supported in each case with respect to the current situation. However, despite various measurement methods and equipment and existing recommendations, it cannot be assessed in a sufficiently accurate/quantitatively scaled manner.

This article, which is limited in scope, presents some findings and evaluations of a study that investigated whether the data obtained by using two different measuring devices with different methods for detecting the non-visual effects of light in closed working environments would affect the accuracy and reliability of the measurements, depending on the measurement time and the characteristics of the measurement environment.

The results of two experiments (E1 and E2) carried out in two different offices as part of the research can be briefly summarized as follows:

- Significant differences were observed between photometric and radiometric measurements for different times of the day (morning, noon, afternoon) and different periods of the year (winter, spring, and summer).
- It is clear that the orientation of the buildings, and hence, the offices E1 and E2, has a clear effect on the measurement results. Differences between the results of photometric and radiometric measurements were found to be higher in E1 than in E2. This situation can be attributed to the fact that daylight is effective for a longer period of time during the day in E1 with a southeast orientation that is related to the visual field of the participant.
- It was found that the weather/sky condition has an effect on the Ev and EML measurement results. Photometric and radiometric measurement results were significantly different in partly cloudy sky conditions compared to the overcast condition. This can be interpreted as the effect of sky conditions/daylight on the measurement results.
- It can be said that the EML values generally meet the 200 EML value recommended for the hours specified in the EML metric (between 09:00-13:00) in all measurement periods, and that both instruments can be considered to measure the non-visual effect of light with close accuracy.

In other words, when the measurement results of the illuminance meter and chroma meter, which evaluate the ambient light according to the sensitivity of the cone receiver in the eye (M), and the measurement data of the spectroradiometer, which measures the radiant magnitude according to wavelength, are compared, it is seen that there are statistically significant differences in the results obtained according to the measurement time (09:00, 12:30, 16:00) and measurement period (December-January, March-April, June). However, most of the other differences between the instruments are not significantly large when compared by season. This phenomenon can be attributed to the differences in the functioning/operation of the two measuring instruments.

Luminance meters are more advantageous than spectral radiation meters in terms of accessibility and cost. For this reason, in studies aiming to quantitatively determine the non-visual effect of light, it can be said that studies with a light source with a known spectral energy distribution and melanopic ratio can be carried out with illuminance meters or colorimeters.

In summary, the values obtained by measurements and calculations in experiments vary with the measuring instrument and method used. However, the levels of statistical significance can reveal very useful information about the selection of measuring instruments and methods to be used in research and the traceability of their calibrations. It reveals that it is necessary to know what the measuring device and the calculation method used in the studies measure, and with what accuracy. It can be said that this will help researchers make more accurate judgments with more meaningful data in experiment design.

In conclusion, the above information shows that the non-visual effects of light also can be analysed with the two different measurement methods, but it also shows that there are differences between them. The research, which was initiated to determine the non-visual effects of light on users of indoor working environments some of which is reported in this article is being continued by extending it to examine the effect of measurement methods on the measurement results.

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Article

Spatio-temporal change of the morphology in west corridor development region of Ankara city and 2022-2039 growth estimation

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ABSTRACT

The land is needed for many activities in cities due to rapid urbanization and population growth taking place on a global scale. In order to meet the demands of the increasing population, cities grow towards extensive rural lands and try to meet the citizens' needs for land spatially used for housing, transportation, industrial facilities, and education facilities. The change in urban morphology is one of the most discussed topics in planning from the past to the present, consisting of uniquely complex phenomena. The traditional method of urban science offers approaches based on Euclidean geometry, based on the assumption of uniform growth. However, urban morphology has a multidimensional fractal structure, and it is insufficient to understand the city as a living organism that evolves, changes, and develops very quickly. Since urban growth and expansion are an inevitable reality intertwined with economic growth, spatial changes in cities as living organisms are inevitable. Population growth worldwide is one of the most critical parameters affecting cities' growth. Unplanned growth in cities causes many environmental problems, such as unplanned urbanization. Monitoring and forecasting land changes in urban growth and expansion processes are significant in producing effective regional and urban planning policies. In this process, the concept of urban morphology comes to the fore. In this context, the fractal dimension analysis emerges as a technique of interest. Decreases and increases in fractal values gain meaning by being associated with processes such as expansion and growth observed in cities. Fractal geometry, on the other hand, provides the opportunity to evaluate this complex structure quantitatively. At the same time, it offers a new mathematical framework for describing urban morphology. The study aimed to investigate the development process of the development zone in the western corridor of Ankara, with a fractal analysis to be made at the urban scale through its morphological change. The temporal changes in urban form and texture between 2005-2022 and the morphological character of Ankara are questioned through fractal analysis. The study was carried out in two stages. In the first stage, the western corridor of Ankara was analyzed on an urban scale, and the morphological change in 2039 was estimated within the scope of two different scenarios. The compact growing scenario (G_C) proposes a growth model within the boundaries of the determined area. The spreading-growing scenario (G_S) assumes a spreading-growth behavior into the land cover, regardless of field boundaries. The G_C scenario defines areas where growth will not occur outside the determined western development zone. On the other hand, the G_S covers the growth areas produced by assuming that the entire urban geography is suitable for settlement without any restrictions. After defining the scenarios, fractal blots from 2005, 2013,

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2022, and 2039 were obtained, and fractal analysis was carried out using the box-counting method. At the same time, it showed that urban spatial richness increased, as the value of 1.63 in 2005 reached 1.85 in G_C and 1.98 in growing by G_S in 2039. As a result of the analysis, it was concluded that the changes in the fractal dimensions obtained at the urban scale, the West development corridor experienced a rapid urbanization process from 2005 to the present, and this process showed urban expansion in the east-west direction.
Increases in fractal dimensions also indicate an increase in the complexity of the urban fabric, in other words, spatial richness. The simulation results of the year 2039 using the Cellular Automata - Markov chain method also support these results. Compact and spreading growth approaches produced within the scope of the research resulted in different growth behaviors of the city. While the growth is more controlled in the model restricted by the research area boundaries, the expansion pressure of the city is quite remarkable in the scenario where there is no restriction. The data obtained by this method for West Ankara, which is determined as the development direction of the city with the plan decisions, has significant potential in evaluating the current situation and future spatial patterns. Therefore, the research offers a new perspective to describe the complexity of the urban system. In addition, it is thought to have a guiding quality in the planning processes. The research offers a current perspective and innovation with a scenario-based model based on fractal geometry to describe the complexity of urban morphology.

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INTRODUCTION

Due to rapid urbanization and population growth, more land is needed in cities for many activities, such as housing, transportation, production, and recreation. Sustainable land use is essential for sustainable development (Fu et al., 2022). In order to meet the demands of the increasing population, cities grow towards large rural lands and try to meet the needs of the citizens for land uses such as housing, transportation, industrial facilities, and education facilities spatially. Urban growth and sprawl are a spatial reflection of rapid urbanization that poses a challenge to sustainable urban development. Rapid urban development challenges spatial planning frameworks and requires holistic approaches to deal with urban development's negative environmental, social, and economic impacts (Artmann et al., 2019).

Along with the change in the use of urban space, the macro form of the city is also changing. The processes of urban growth and change in the urban macro form are of great concern worldwide (Wang & Zheng, 2022; Wang et al., 2022). The most important reason for this situation is that urbanization and population growth will continue with this process, and people will need more livable areas (IPCC, 2021). On the one hand, the increase in the urban population continues. On the other hand, the migration processes from rural areas to urban areas in developing countries increase the need for space. Therefore, urban areas are geographies where processes such as land degradation and social and environmental problems are experienced, and they are areas that offer economic opportunities to improve the quality of life. The spread of urban land to a broader geography has many economic, ecological, and social consequences. Developing planning tools for local governments to produce policies within the sustainable development goal of urban multidimensional dynamics is necessary.

It is effective in constructing and developing cities, depending on the city's history, geographical features, location, climate, land structure, socio-demographic characteristics, and animal and plant resources. In other words, all spatial parameters related to cities shape the urban growth rate and urban morphology (Su et al., 2022). Oliveira (2018) defines urban morphology as the science that studies the physical form of cities and the significant factors and processes that shape them over time. Urban morphology studies change in the physical structure and shape of settlements over time and focuses on growth/change patterns and processes (Carmona et al., 2003). Marshall & Caliskan (2011) describe urban morphology as an abstract shadow of physical reality. Accordingly, urban morphology includes reflecting urban processes on the field with the help of abstract metrics and shapes represented as maps.

The concept of compactness explains urban growth processes in terms of new residential areas being disconnected or coming together intensively and frequently. The compact city approach is a growth model that benefits public health regarding land use and transportation in shortening distances (Stevenson

et al., 2016). However, while the adverse effects of urban sprawl (for example, longer transport times, loss of fertile soils, reduction or loss of ecosystem services (ES), on the one hand, encourage compact urban development, it also has disadvantages. The dilemma of its impact on environmental quality (e.g., absence of green spaces) and reducing social disadvantages are discussed as the "compact city paradox" (Neuman, 2005; Artmann et al., 2019). As another urban growth concept, urban expansion and urban sprawl differ from each other. Urban expansion is defined as a general physical process that includes the reproduction of the material structure of cities in the temporal process (Inostroza, 2018). Urban sprawl, on the other hand, expresses a dispersed urban development behavior (Burchfield et al., 2006). Especially in recent years, the results of urban growth and the future state of urban morphology are essential in the literature. As a result of the technological developments experienced, the methods used in urban growth, morphology, and development are gaining importance. Fractals are geometric constructs that exhibit repeating textures and patterns at all scales, utterly different from new and traditional geometric constructs, and are used from the architectural scale to the urban scale (Çağdaş et al., 2006; Ediz & Gürsakal, 2010). Fractal analysis is one of the remarkable methods in determining the complexity level of urban growth and enabling it to be measured quantitatively. Fractal analysis, an approach considering cities as complex systems, is a numerical method used to evaluate irregular, fragmented, and fractured urban forms (Chen, 2013). Accurate and effective urban morphology estimation and measurement are vital in identifying future urban problems.

In light of the above evaluations, the general purpose of the study is to investigate the development process of the development corridor in Ankara's western corridor with a fractal analysis to be made at the urban scale through its morphological change. In this context, the temporal changes in urban form and texture between 2005 and 2039 and the morphological character of the Western development corridor were questioned through fractal analysis. Thus, while shedding light on local decision mechanisms in terms of planning, it provides an empirical approach to applying the fractal method to urban textures.

MATERIAL AND METHODS

Study Area: Development of the morphology of the city of Ankara in the planning process

In the planning processes that Ankara has experienced from the past to the present, the development of the western part of the city begins with the Jansen plan, and growth is foreseen in this part of the city in the following periods. In this context, this study aimed to reveal the spatial and temporal changes in the morphology of the West Development corridor, a region of Ankara's urbanization effect, between 2005 and 2039 by fractal analysis. According to the 2023 Capital Ankara Master Plan Report, the western corridor development area of the city of Ankara is defined as the "Western Planning area." The city's western corridor was planned to produce a new expansion strategy for the north-south-oriented urban development that had continued until the plan period. The area includes Batıkent, Eryaman, Sincan, and Etimesgut development areas, areas where the rural and natural character is preserved, and Kazan and Ayaş district centers. With these features, the development of the said region, which includes the region, urban, semi-urban, and rural areas together, is also explained in a dual structure (Figure 1).

The city of Ankara, significant throughout history, has initiated various studies to address many problems and establish planned development, especially after becoming the capital city in 1924. In the planning studies, the direction of urban growth and development, which would affect the form of the city, was initially investigated. While one group advocated for the development of the old city, another group argued that the old city had insufficient infrastructure and that a new Ankara should be established. With the development decision for the city of Ankara, the 'Lörcher Plan', thought to organize the old city center and connect it with the new city center, was implemented. This plan adopted a more protective approach to the old city center and proposed a regular settlement pattern for the new development areas. After 30 years, new problems emerged due to rapid population growth and urbanization, necessitating a new city plan. As the Lörcher plan proved inadequate, the Jansen plan was adopted in 1932, proposing a city form surrounding the Ankara castle.

With the increase in the number of immigrants due to urbanization, a new plan was required. In 1957, these problems were addressed with the Yücel-Uybadın plan, and the city macroform was expanded. A compact urban setup integrated with green zones was attempted for the city. During the 1990s, the city of Ankara became a metropolitan city. The most notable feature of the Yücel-Uybadın plan is the absence of the urban form-seeking concern present in the Lörcher and Jansen plans. Instead, existing plans and layouts were developed further. In this context, an axis extending to the west of the city was defined in the Yücel-Uybadın plan, predicting growth in this direction.

Method

This study aimed to reveal the morphology change between 2005 and 2039. In this context, firstly, the temporal-spatial change of the city was estimated according to scenarios produced with different approaches. Then, the

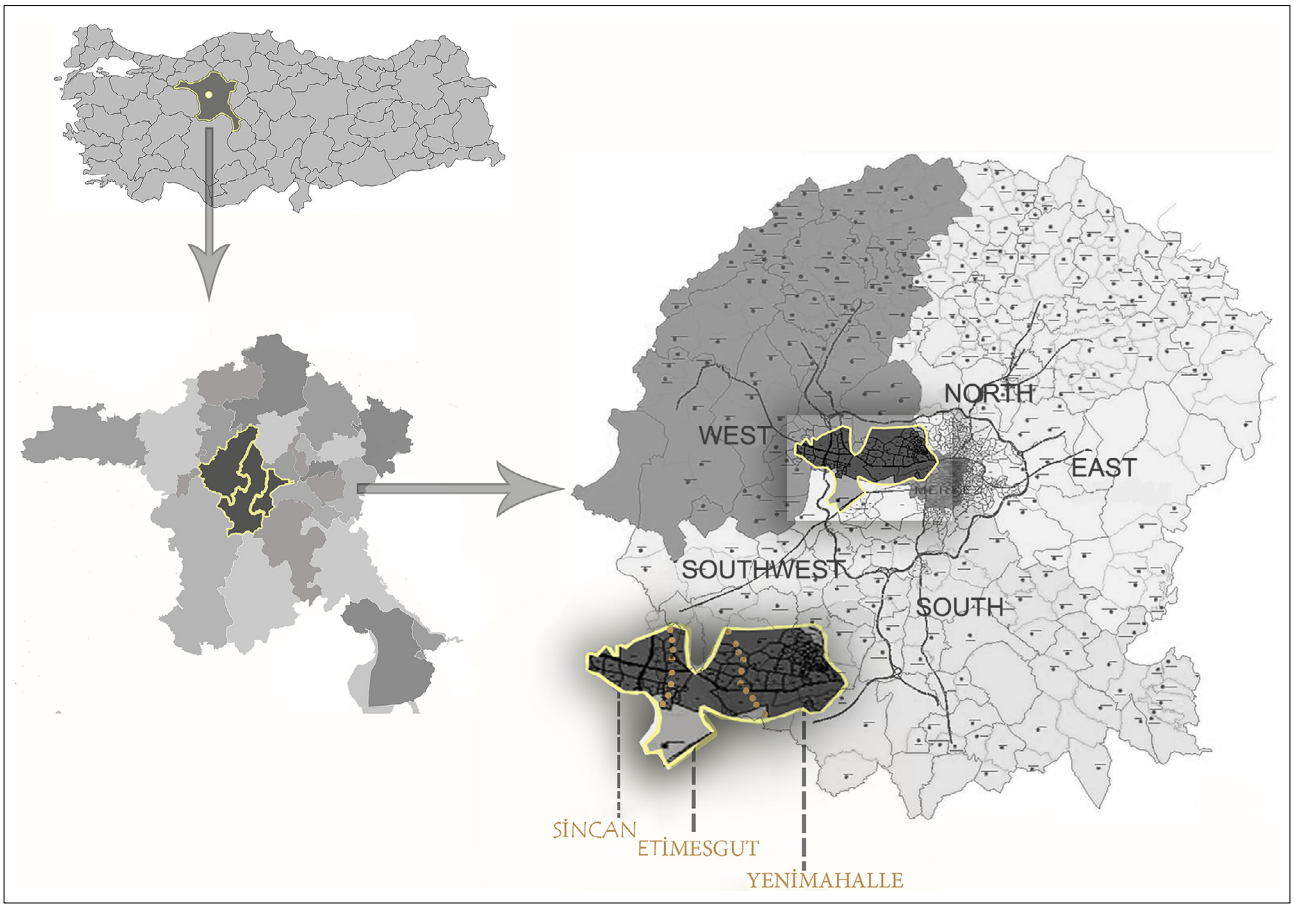

Figure 1. Study area location map.

fractal structure of the settlement spot, created with the city's development, was measured by the box-counting technique. In fractal analysis, this work uses a Box Count estimator, which is based on the simple idea that a single box initially covers the time series graph (Caballero et al., 2022). The box is divided into four quadrants, and the number of cells required to cover the curve is counted, which is advantageous for numerical interpretation.

Urban Growth Forecast: The estimation of urban land use and growth is a central topic of discussion in proactive planning and sustainable development goals. Thanks to temporal-spatial techniques, it is possible to analyze and forecast urban growth on a global and regional scale. These methods also help to determine urban growth dynamics (Lu et al., 2019; Baqa et al., 2021). Various models are used to analyze changes in urban growth (Guan et al., 2011; Azari et al., 2016; Ghosh & Das, 2017; Li et al., 2017; Singh et al., 2018; Shen et al., 2020; Dey et al., 2021). Since the 1990s, many urban growth models have been developed. The SLEUTH urban growth model is one of the most popular and has been used in many projects worldwide (Ayazli, 2019). Among these methods, the cellular automata (CA) model's advantage in modeling spatial variation in complex systems and the long-term prediction advantage of the Markov chain model have been integrated, developing the CA-Markov chain model, which is an effective method for simulating urban growth change and transformation. This method is frequently used to predict and measure urbanization dynamics (Keshtkar & Voigt, 2016; Baqa et al., 2021; Isinkaralar et al., 2023). CA-based models are mostly preferred to mitigate the damage caused by urban sprawl (Terzi & Kaya, 2011; Tong & Feng, 2020; Ayazli et al., 2022; Yılmaz et al., 2022; Isinkaralar & Varol, 2023). These models are significantly influenced by spatial scale, neighborhood configuration, and the choice of probability threshold (Xia et al., 2019). Neighborhood effects are crucial for CA models because these are bottom-up techniques that rely on interactions between nearby cells (Barreira-González & Barros, 2017).

Urbanization spot data for the years 2005, 2013, and 2022 were obtained from the Google Earth program. The obtained data were arranged in the ArcGIS program (in Geotiff format) and made suitable for analysis. Then, the morphology change calibration (kappa values) between 2005 and 2013 was obtained, and the Ankara West Development corridor morphology simulation in 2039 was estimated using the CA-Markov chain method in the IDRISI Selva program. Kappa coefficients evaluate how well

terrain classification or modeling performs beyond chance agreement (van Vliet et al., 2011). Simulation estimation was done using the CA-Markov chain method in the IDRISI Selva program.

The CA-Markov chain method is an analysis that uses the transition probability to predict future states based on the current state and the next state. It models land use change when spatial changes are difficult to define. This analysis indicates the future direction and magnitude of change (Huang et al., 2020). The Markov estimation is applied according to the following formula (Jianping et al., 2005):

$$S(t+1) = P_{ij} \times S(t) \quad (1)$$

Here, S(t) and S(t+1) mean row vectors at time step t and time step t+1; P stands for the transition probability matrix for the previous time interval calculated as follows:

$$||P_{ij}|| = \begin{Vmatrix} P_{11} & P_{12} & P_{1n} \\ P_{21} & P_{22} & P_{2n} \\ P_{n1} & P_{n2} & P_{nn} \end{Vmatrix} \; (0 \le P_{ij} < 1 \text{ and } \sum_{n1} P_{ij} = 1) \quad (2)$$

P_{ij} represents the probability of transitioning from land use type i to j.

Scenario Design: Developing alternative scenarios in urban growth forecasts provides an opportunity to identify possibilities. Two future urban growth scenarios were developed in the study. The compact growing (G_C) scenario proposes a growth model within the boundaries of the determined area. The spreading-growing (G_S) scenario assumes a spreading-growth behavior into the land cover, regardless of field boundaries. The G_C scenario defines areas where growth will not occur outside the determined western development zone. Therefore, urban growth has been limited. On the other hand, the G_S scenario covers the growth areas produced by assuming that the entire urban geography is suitable for settlement without any restrictions.

Fractal Analysis The physical changes of cities cause the formation of simple and regular complex textures. Understanding the growth behavior, one of the essential indicators of physical changes, and especially determining the urban growth trends, is a crucial requirement in urban studies. A practical and comprehensive analysis in this context will guide the determination of a city's current problems and future needs (Öztürk, 2017). Zoned land in an urban area (excluding transportation land and squares) is morphologically similar to Fournier dust (Zhao et al., 2021). Urban land segments are separated from each other by hierarchical streets (axes), whereas the building terrain in a rural area is more random and has an irregular spatial organization. While the urban area is a hierarchical, high-density, and stacked fractal pattern, the rural area shows a random, low-density, and dispersed spatial distribution. In this context, the fractal structure is a current discussion area in urban studies.

Fractals are used to describe the complexity of patterns in terms of the basic order of naturally occurring patterns and artificial phenomena. Batty & Longley (1994) adaptation of fractal theory to urban studies brought a new approach to complex urban growth within the scope of two-dimensional structures such as urban borders, land use, urban form, and growth. The fractal dimension is a ratio that does not have to be an integer but reflects the gap-filling capacity of a pattern at varying scales (Zhao et al., 2021).

After defining the scenarios, fractal spots from 2005, 2013, 2022, and 2039 were obtained, and each image was arranged in Photoshop in 792×500 pixels and 300 dpi format. Fractal analysis was then performed using the box-counting method in the Harfa 5.5 (Harmonic and Fractal Image Analysis 5.5) program. Line segments and box-counting methods are frequently used in fractal dimension (D) calculation methods in fractal analysis by Mandelbrot (1977), Bovill (1996), and Ediz & Ostwald (2012). In urban planning studies, the box-counting method is mainly preferred. D takes a value between 1 and 2. The fact that D is high, a value close to 2, shows that the rate of unused areas in the urban stain is low. High D represents urban spatial richness, spatial efficiency, and compact cities, while low D represents situations where spatial efficiency and spatial richness are low. Fractal analysis is a practical, easy, and accessible method for accurate numerical measurement of urban spaces (Chen, 2018).

The fractal dimension is defined using the below equation:

$$D_{\delta 1-\delta 2} = \frac{\log N(\delta_2) - \log N(\delta_1)}{\log (1/\delta_2) - \log (1/\delta_1)}$$

Where D represents the Fractal dimension by the box-counting method, δ_1 and $\delta 2$ express that elevation is initially filled with a big grid and the edge length of the grid boxes and side length of the smaller box, $N(\delta_1)$ and $N(\delta_2)$ explain the number of grid boxes intersected by the line image and the number of intersected boxes.

RESULTS

Model Verification and Calibration

The morphology stain maps of the West Development corridor for 2005 and 2013, and the simulation results for 2022 were obtained and compared with the existing 2022 morphology stain. The visual comparison shows that the simulated blot has a similar spatial pattern to the reference blot (Figure 2).

The Kappa index, calculated to evaluate the accuracy of the simulation results quantitatively, shows that it is an excellent model for locating the future change of the West development corridor (Table 1).

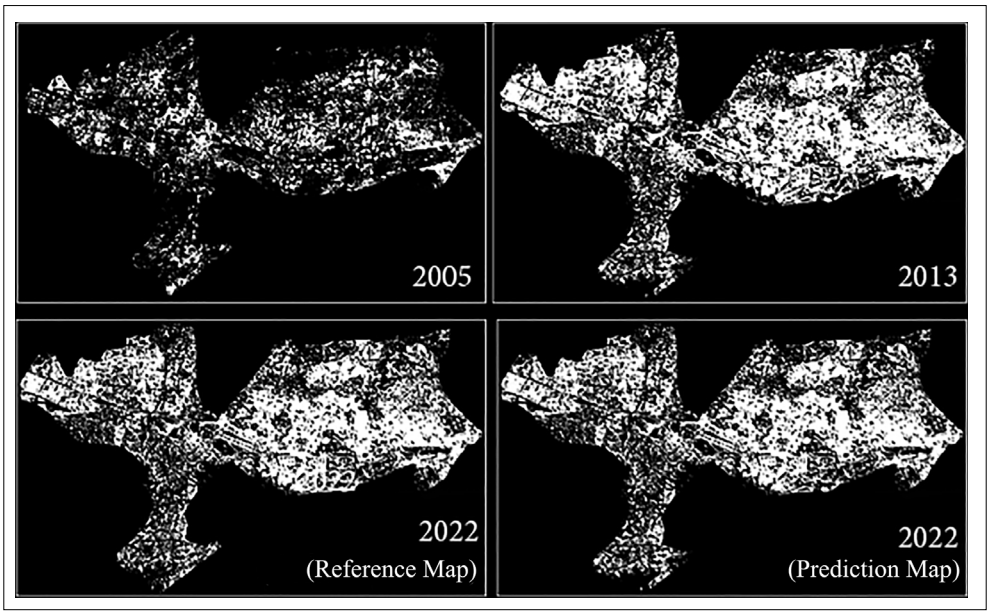

Figure 2. Urbanization spot reference and forecast map for 2022.

Table 1. Kappa values

Kappa statistics	Value
K_{no}	0.9844
$K_{location}$	0.9648
$K_{locationStrata}$	0.9648
$K_{standard}$	0.9333

Values close to 1 indicate the perfection of the model.

Urban Morphology Prediction and Fractal Analysis

The Ankara West Development corridor's morphology has been discussed in four different periods (2005, 2013, 2022, and 2039). Based on the urban morphology data of the years 2005 and 2022, the estimation of the urban growth model of the Ankara West Development corridor for 2039 was calculated using the CA-Markov chain method. It is predicted that urban form development will significantly develop in the east-west directions. Additionally, the development of urban morphology was evaluated as a fractal stain. The fractal size of the urbanization blot was calculated as 1.65 in 2005, 1.70 in 2013, and 1.73 in 2022. On the other hand, the fractal size in 2039, within 34 years from 2005, was calculated as 1.85 according to the KB scenario and 1.98 according to the LW scenario (Figure 3).

A transition area matrix map was created in the Idrisi Selva program to more clearly determine the change in the urbanization spot between 2005 and 2039. According to the map given in Figure 4, it has been determined that urbanization will increase dramatically in the Ankara West Corridor region until 2039. It is predicted that the urban settled area, which had an area of 431.26 hectares in 2005, will increase by 1047.75 hectares according to the G_C scenario, reach 1479.01 hectares in 2039, and reach 3207.67 hectares by increasing by 2776.41 hectares according to the G_S scenario.

DISCUSSION AND CONCLUSION

Since urban growth and expansion are an inevitable reality intertwined with economic growth, the spatial changes in cities as living organisms are inevitable. Population growth worldwide is one of the most decisive parameters affecting cities' growth. Unplanned growth in cities causes many environmental problems, such as unplanned urbanization. Monitoring and forecasting land changes in urban growth and expansion processes are significant in producing effective policies within the scope of regional and urban planning. In this process, the concept of urban morphology comes to the fore. Since urban growth is predicted to cause different environmental and physical problems in the future, determining the scope and boundaries of growth is considered a requirement (Chen et al., 2017; Chen, 2018; Wang & Zheng, 2022; Wang et al., 2022).

The characteristics of the model can be summarized as follows: The fractal analysis method on urban morphology offers a new perspective in evaluating temporal and spatial changes. Within the scope of the study, the fractal analysis method was used to question the changing form of the western development corridor of the city of Ankara in line with urbanization and the temporal and spatial changes in the urban texture. As a result of the analysis, it was concluded that the changes in the fractal dimensions obtained at the urban scale show that the West development corridor experienced a rapid urbanization process from 2005 to the

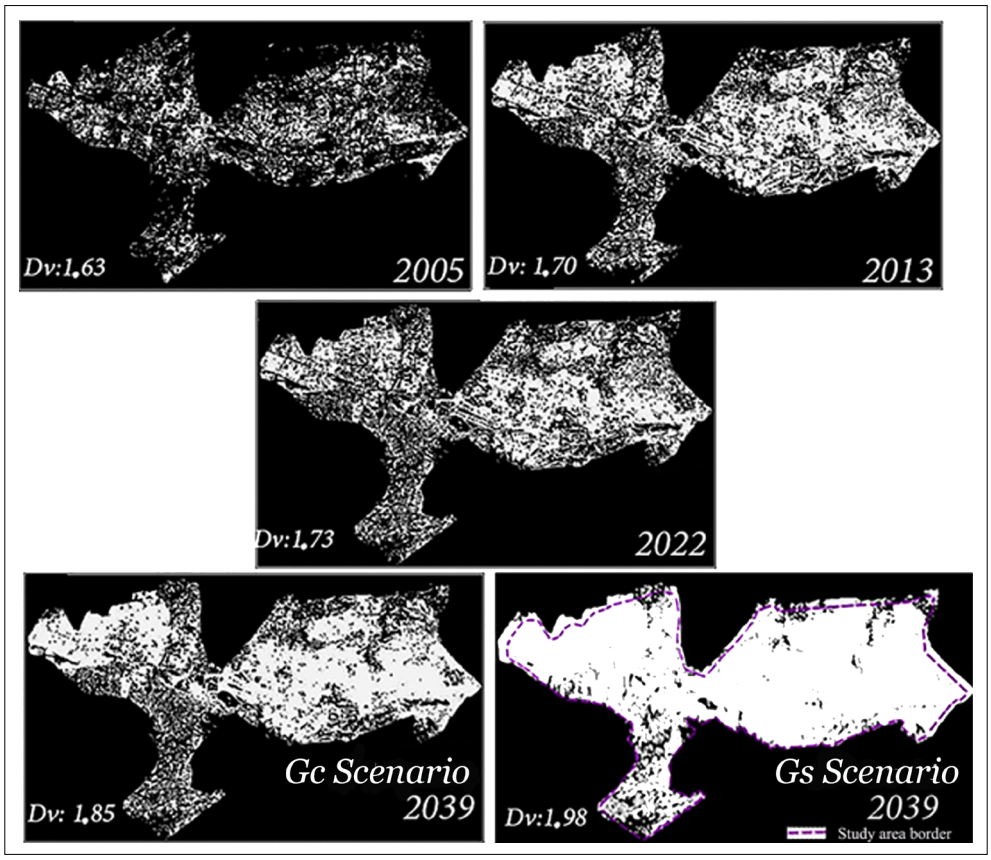

Figure 3. Urbanization spots and fractal dimension of Ankara West Development Corridor between 2005-2039.

present, and this process showed urban expansion in the east-west direction. When the fractal analysis results of 4 different periods are evaluated, increases in numerical values reveal that the urbanization process and urban growth have increased. Increases in fractal dimensions also indicate an increase in the complexity of the urban fabric, in other words, spatial richness. The simulation results of the year 2039 using the CA-Markov chain method also support these results. The urbanization process is predicted to increase, and the urban morphology will expand in this direction.

The main benefit of the model is that its flexible structure provides a comparable approach to the complexity level of the research field. Factors such as the increasingly complex structures of cities, their ever-growing and diversifying parts, and the intense interaction between managers make it difficult to perceive cities as a whole. With new approaches emerging in the 21st century, cities have been defined as dynamic, non-linear, complex systems in constant change and transformation. Evaluating and analyzing this complexity becomes a requirement. Fractals are fundamental to analyzing these complex network relationships (Lionar & Ediz, 2020). Using fractal geometry, especially in cities and systems, provides advantages for illustrating certain specific processes of spatial organization and inventing new articulations, especially for dynamic interpretation (Frankhauser & Pumain, 2022). As a result of the study, it has been determined that fractal analysis is an effective method for evaluating temporal and spatial patterns and their changes to understand urban morphology. Compact and spreading growth approaches produced within the scope of the research resulted in different growth behaviors of the city. While the growth is more controlled in the model, restricted by the research area boundaries, the expansion pressure of the city is quite remarkable in the scenario where there is no restriction.

The data obtained by this method for West Ankara, which is determined as the development direction of the city with the plan decisions, has substantial potential in evaluating the current situation and future spatial patterns. In this study, fractal analysis was used as a tool to emphasize the change process. In today's uncertain world, it is impossible to make definitive forecasts for the future. In today's cities, where planning theory gains new dimensions daily, a one-dimensional deterministic approach to viewing the city weakens decision processes. It is impossible to predict the socio-spatial processes, political aspects, global threats

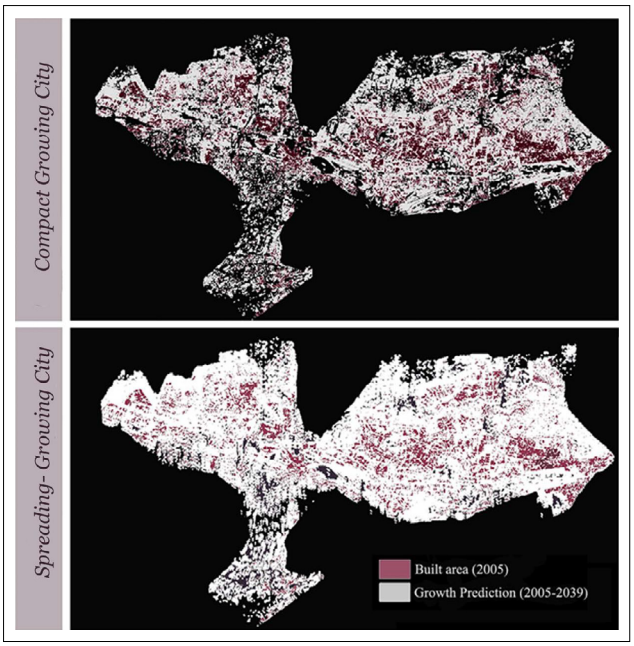

Figure 4. Urbanization spot change between 2005-2039 depending on the scenarios.

and changes, and natural risks that may be experienced in the city. However, growth predictions are required to draw attention to problems such as ecological damages, land losses, socio-spatial problems, and changes in the quality of life brought about by cities' growth and to manage the process. Cities are seen as self-organizing, dynamic, complex systems. From this perspective, the city change in the research is based on the principle of order in disorder in complex systems. The CA-Markov chain method analyzes spatiotemporal probabilities, thus predicting the city's future by participating in the multidimensional network dynamics experienced in the temporal context. The type of growth in the scenario where the forecasts do not constrain the city stands out regarding how decision-makers intervene. In this context, the study is thought to facilitate our perception of urban areas, offer a new perspective that evolves from a deterministic framework to a cause-effect relationship, and have a guiding quality in planning processes.

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Article

The evaluation of the impact of computer classroom wall colors on students' perception in the context of color components

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ABSTRACT

The arrangement of a computer class is as important as a traditional classroom layout. In recent years, as in traditional classrooms, environmental features of these classrooms, such as size, form, color, light, texture, etc., have a direct impact on students' perception, class participation, motivation, and concentration. This study aims to explore how various hues, values, and saturations of wall colors, representing a key environmental feature of a computer classroom, affect students' spatial perception. Saturated, medium, dark, and light colors of red, blue-green, and purple hues, totaling twelve colors, were determined from the Munsell Color System for the wall colors of the classroom. The classroom was visualized using these selected wall colors and presented to the students. Subsequently, they were asked to evaluate the visualizations through a semantic differential scale comprising fifteen bipolar items. The results revealed that students perceived high-value and saturated colors across all hues positively, describing them as pleasant, warm, and cheerful. Medium colors were viewed negatively, characterized by descriptions such as 'lifeless, dull, incomprehensible, unpleasant, ugly.' Dark colors received positive assessments, described as "pleasant, beautiful, clean, and bright" but were also associated with negative descriptions like 'gloomy, boring, passive, and dark.' Additionally, similar perceptions emerged among saturated, medium, light, and dark colors of all hues. This outcome suggests that even when color hues differ, similar values and saturations can evoke similar perceptions in spatial color perception.

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INTRODUCTION

As much as users shape the environment around their own needs, the existing environment is also effective on people's behavior and perception (Sommer, 1969). It has been found in the studies that the physical features of the built environment, such as form, color, texture, and lighting, have many effects on people's attitudes (Read et al., 1999; Hidayetoğlu, 2010; Yıldırım et al., 2007; Altun & Zorlu, 2022; Müezzinoğlu et al., 2020). These physical features influence the behavior of space users, the quality of the functions they perform, and their affective responses, such as satisfaction or dissatisfaction with the

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space. Additionally, these features impact their perception of the space as narrow or wide, spacious or stifling, and the duration of their stay in the space. Therefore, the perceptual and affective effects of spatial design elements on the user should be well known and designed accordingly (Aydınlı, 1986; Altun & Zorlu, 2022).

The physical properties (size, form, texture, color, light) of the classrooms where people spend a significant portion of their lives can positively contribute to education by enhancing students' perceptual, physical, and cognitive development, as well as their motivation, learning performance, experience, exploration, research, critical thinking, creativity, questioning, and socialization (Müezzinoğlu et al., 2020; Altun & Zorlu, 2021). Gifford (2002) stated that students can learn better in a well-designed classroom, while their attention may be distracted in an inappropriate physical environment. Walden (2009) has emphasized that color scheme, lighting, climate, acoustics, smell, and furniture in a classroom are important from the point of view of students' sense of well-being. Studies show that well-designed learning spaces increase the learning motivation, capacity of memorization, and willingness to study of students, and socially contribute positively to friendship relations. Consequently, it is important to organize and design classrooms in a way that supports these activities.

Baker (1986) has discussed interior space properties in three sections as ambient factors (sound, temperature, smell, lighting), design factors (form, color, texture, layout), and social factors (user age, gender, education, perception level, etc.). The differentiation of the three main factors and sub-variables that make up these interior features also causes changes in the perception of the space and the reactions of the users to it. Space color, one of the design factors, is a broad topic that has physiological, psychological (affective), behavioral, and cognitive effects on space users and needs to be researched. Researchers have found that colors have specific behavioral associations and can affect the mental and emotional balance of users when used skillfully and dynamically in the designed environment (Camgöz et al., 2004). In this context, what kind of color design should be applied for which function and user in a space should be planned in line with the effect of the color of the space on the user. In space color research, the effects of various colors on users have been examined. Manav's (2007) study on living space color, blue was found to be cold and associated with calmness. In Kwallek et al.'s (1996) study, it was concluded that participants tend to make more mistakes in office spaces with high in value colors. The sudy by Yıldırım et al. (2012) and colleagues showed that warm colors such as red, yellow, and orange tend to make the space perceived smaller than it is. Similarly, Frieling (1979) has stated that painting all the walls with a warm color would narrow the space because the walls give an effect that unites, surrounds, and directs the space. On the other hand, some studies have found that cool colors such as blue and green and light colors cause the space to be perceived much more spacious and larger, while dark colors cause the space to be perceived smaller (Mahnke et al., 2007; Yıldırım, Hidayetoğlu et al.; 2011). To exemplify, if a low ceiling is painted with a light color, the space will appear higher, while a high ceiling can appear lower with a dark color (Oberfeld et al., 2010). In a study in which users' perceptions of office space color were evaluated using warm (orange), cool (blue), and neutral (gray) color schemes, the office with warm color schemes was generally perceived more positively than offices with neutral and cool colors (Ergün & Yıldırım, 2022). These studies show that it is possible to create the desired effect with the different use of color in a space, and that it is possible to create a difference in the perception of space only with color without changing the dimensions of the surfaces in the space.

In studies which examine the effect of educational space color on students, results have been tested on whether students do not adopt the classrooms they have lessons in and whether they are satisfied with being in these classrooms. In various studies that examine the effects of educational space colors on students, researchers have investigated whether students feel comfortable in the classrooms and whether they are satisfied with the learning environment (Akalın et al., 2009; Hidayetoğlu et al., 2012; Read, 2003; Stone & English, 1998). Engelbrecht and Hathaway stated that the passive mental stimulation provided by the color of the classroom can help students and teachers to focus on their tasks (Engelbrecht, 2003 and Hathaway, 1987). In a study conducted for kindergarten wall colors, users associated a high saturation red class with anger, while a class with low saturation and high value red (pink) class was associated with happiness. In contrast to saturated red, saturated blue was associated with happiness and was the most preferred classroom color (Dalirnaghadeh, 2016). In a study on the behavioral and cognitive effects of primary school classroom wall color, the results showed that in the red environment, students have difficulty focusing on lectures, and students' movements were more intense and disturbing. Conversely, in a blue environment, they exhibited calmer behavior than ever. Wang and Russ' study on computer classroom wall color preference showed that purple, blue, and bluish-purple colors were associated with gender, age, and personality traits, and cool colors were preferred more than warm colors (Wang & Russ, 2008). Liu et al's (2022) study to investigate the effect of classroom wall color on students' performance, five different visualized classroom wall colors (red, blue, yellow, green, and white) were shown to students via virtual reality, and their subjective evaluation was measured with a questionnaire,

and their physiological responses were measured with electroencephalography (EEG) and electrocardiogram (ECG). The results showed that cool colors such as blue and green had the highest level of relaxation and satisfaction, warm-colored walls such as yellow and red had better attention and learning performance, while the white-colored classroom had the lowest subjective evaluation and the worst learning performance (Liu et al., 2022). According to Müezzinoğlu et al.'s (2020) study on classroom wall color, neutral (gray) colored (achromatic) walls were perceptually evaluated more negatively than warm and cold-colored (chromatic) walls by students. Similar results were observed in another study for classroom wall color; white and gray classroom walls were evaluated more negatively than chromatic (red, blue, green, etc.) classroom walls. In a study carried out in primary school classrooms for color, it was concluded that students were not satisfied with the monotonous colors used in their current classrooms and desired colorful surfaces on walls and furniture (Altun & Zorlu, 2022). In another study conducted for wall colors in educational spaces, students found both warm and cool colors more positive than neutral colors (Müezzinoğlu et al., 2020). The results of these studies mentioned above show that users prefer chromatic (colored/non-neutral) colors rather than neutral colors on surfaces.

Trent emphasizes that when determining the colors to be applied in educational buildings and classrooms, the function of the space and the age group of the students should be taken into consideration. In classrooms, warm and saturated colors may be appropriate for younger users, while higher value colors may be appropriate for older ages (Trent, 1995; Faulkner, 1972; Barker, 1982; Altun & Zorlu, 2021). In this context, the age of the students also comes forward as an important parameter in classroom color perception.

In the studies where the effect of space color is considered in the educational dimension, environmental colors that will contribute to students' adoption of the classrooms where they study, their positive affective effects, learning, and concentration have been investigated with various methods (Akalın et al., 2009; Hidayetoğlu et al., 2012; Read, 2003; Stone & English, 1998). Herewith, based on the assumption that different wall colors affect the students differently, the research was designed to evaluate the effects of wall colors of a computer classroom in a Furniture and Interior Design technical high school on the perceptions of the students. The classroom was visualized in a computer, and four sub-colors with different values and saturation of three different color hues (totally twelve colors), selected from the Munsell Color system, were applied to the classroom walls. Since it is not possible to evaluate all the variables that make up the physical properties of the space, only the wall color variable was evaluated and, in the visualizations, only the wall color was emphasized by keeping other confusing variables (colors of furniture, texture, etc.) constant. Each visualized classroom picture with different colors was shown to the students, and they were asked to evaluate it through the semantic differentiation scale. Before delving into the research method, it is essential to clarify the issues related to color and color perception in space. This clarification will enable a better evaluation of the study findings.

COLOR PERCEPTION AND COLOR IN SPACE

Color is a highly influential design element that facilitates in comprehending, distinguishing, and defining the environment. To perceive, define, or use color effectively, it is necessary to understand its various properties. Color is the visual manifestation of the portion of the electromagnetic spectrum known as the visible light gap. Each color corresponds to a specific range of wavelengths within the visible light spectrum.

Visible light runs from a wavelength of about 380 nanometers (nm) at the violet end of the spectrum to around 760 nm at the red end of the spectrum. The human vision organ receives the light from a reflected source, processes it, and color is perceived (Figure 1).

The perception of elements such as color, texture, and form in the environment is realized through visual perception. Color perception is a part of visual perception, and humans determine and perceive the color of objects/surfaces according to the color of the reflected light. Color is an integral part of light and is a subjective sensation caused by physically measurable light. For example, a red surface appears red because it reflects red light more than other light incoming on it. Virtually, color is not an inherent trait of a surface or an object but rather it is perceived depending on the quality of light illuminating the object (Ural, 1995). Therefore, as the color characteristic of the light reflected

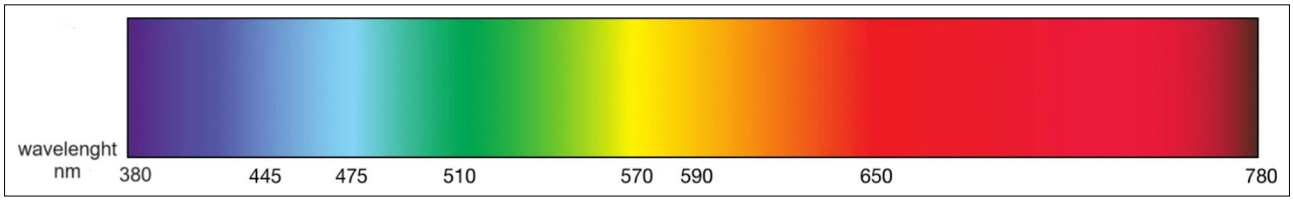


Figure 1. Spectrum of visible radiation.

from the surface changes, the perceived color of the surface also changes. Color perception, as in visual perception, depends on three necessary elements:

- properties of the light source,
- properties of the surface/object,
- the human organ of vision (eye).

As these variables change, color perceiving changes. The human organ of vision can distinguish approximately 2,500,000 colors (Pointer & Attidrige, 1998; Linhares et al., 2008). In this context, it is possible to create numerous distinct color impressions by changing the properties of the light illuminating the surface.

In scientific terms, colors are considered in two aspects: light colors and surface colors. Both light and surface colors have color properties defined by three components known as hue, value, and saturation, which can vary independently of each other. Hue distinguishes one color from another and is described by names such as red, blue, yellow, and purple. Value identifies the lightness and darkness of a color, while saturation expresses the purity of a color; the purer a color, the more saturated it is. With these three properties and different numerical definitions, colors can be expressed through various color systems. Colors are defined by color sorting systems, where similar colors are arranged next to each other, and perceptual steps are sequenced consecutively. Colors, specified in a particular order, are matched with coordinates in space and transformed into a three-dimensional 'color solid' system. Figure 2 illustrates the Munsell Color System, one of these systems.

The Munsell Color System, which is a surface color system, has been developed based on decimal notation with equal perceptual steps. As in other color systems, the Munsell Color System defines colors based on three properties of color: hue, value (lightness), and saturation/chroma, and each hue is represented on a page with different values and chromas.

In color perception, the hue of a color is categorized as warm, cool, or neutral. Colors with shorter wavelengths are classified as 'cool' colors, encompassing purple with the shortest wavelength in the spectrum (360-400 nm), followed by blue (400-480 nm), and extending to green (520-565 nm). Conversely, colors with longer wavelengths are termed 'warm' colors, which include red (625-760 nm), orange (590-625 nm), and yellow (565-590 nm) (Yıldırım, Capanoglu et al.; 2011). Neutral colors, ranging from black to white, lack specific color and are also referred to as 'achromatic' colors. Studies on interior color preferences have predominantly shown a leaning towards colors with shorter wavelengths or cool colors among users. This preference trend suggests a general correlation between wavelength and emotional states in spatial perception (Valdez & Mehrabian, 1994).

The value component is represented on the vertical axis in the color system, with black at the lower end and white at the top. There are several divisions of gray, evenly distributed between black and white. An increase in the saturation of a color means that the color becomes more perceptually effective in terms of hue. Approaching the gray bar, on the other hand, neutralizes the color; in other words, the effect of color is reduced. This implies that the more pure/saturated colors are applied in a space, the greater its impact with respect to hue (Figure 2). According to Küller et al.'s (2009) study, it was found that the saturated red room activated the brain and accelerated the heart rate. However, this result may not be applicable to the high in value colors of red referred to as pink, which may have a completely different effect. In Al-Ayash, et al.'s (2016) study, participants were calmer and more relaxed in the high-value colors of the same hue (red, yellow, and blue), while

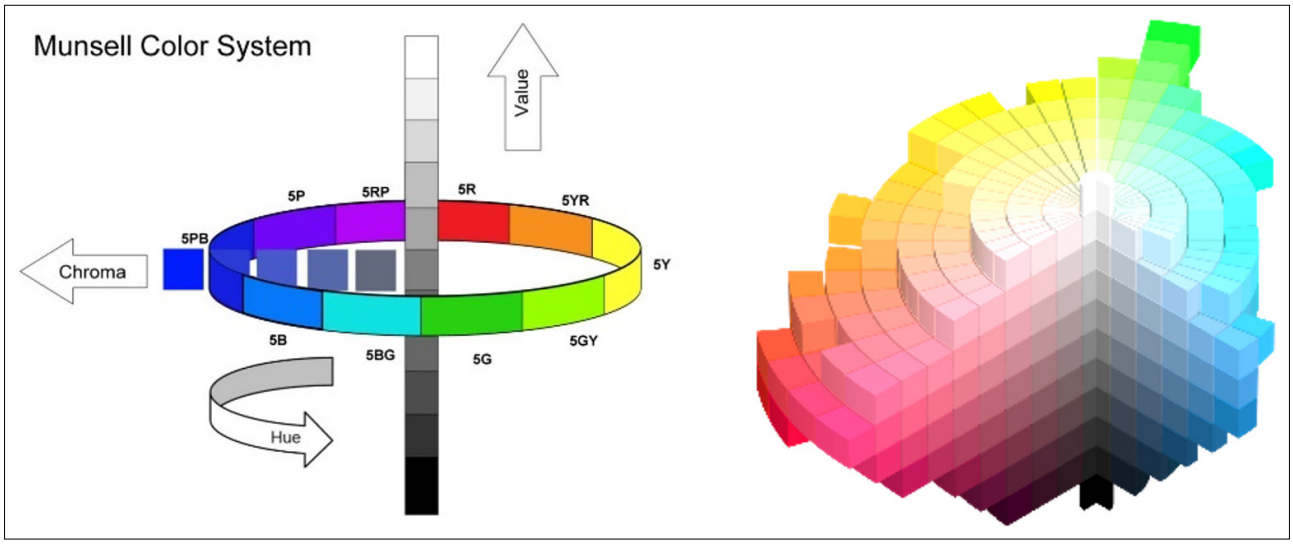


Figure 2. Munsell Color System (Sands, 2017; PNGINDIR, 2024).

their heart rate increased in high saturation. Elliot et al. (2007) have suggested that red impairs performance.

As can be inferred from the explanations provided, the perception of color and its application in a space is a complex topic. Studies on the effects of interior color have delved into various aspects such as the psychological and physiological impacts of colors, user preferences, the sensory and semantic evaluation of space color, and the productivity of the space based on its function. Aligned with these insights, this study explores the impact of color on perception and investigates how the color of classroom walls affects spatial perception.

MATERIALS AND METHODS

This study examined the perceptual effects of computer classroom wall colors on students in a Furniture and Interior Design high school. In this investigation, three hues and four sub-colors of each hue with different values and saturations, 12 colors in total, were utilized. The stages of the study included:

- Determining the colors for the classroom walls
- Visualizing the computer classroom and applying twelve different colors to the walls
- Presenting visuals of the classroom with different wall colors to students
- Evaluating the visuals using the Semantic Differentiation (SD) scale

Participants

The research was conducted with the students of Ümraniye Atatürk Vocational Technical High School in Istanbul. A total of 52 students, comprising 24 (46.2%) girls and 28 (53.8%) boys between the ages of 15-19, randomly recruited from the students who had prior experience with the classroom, participated in the experiment. There were no instances of color vision deficiency among the participants.

Experimental Space

The visualized experiment space is a computer classroom containing 24 computers. It was designed using the SketchUp program, with twelve different colors applied to its walls. These colors consist of three hues, each having four different values and saturations (Figure 3).

Determination of Wall Colors of Computer Classroom

The red hue color family has been extensively used in numerous studies aimed at investigating the impact of color on spatial perception. This color, having the longest wavelength, possesses a stimulating and attention-grabbing effect as observed in previous research, thus rendering it suitable for this study. Within the Munsell Color System utilized in this study, the 7R hue within the red color family is considered a warm color. Another preferred hue is blue-green (7BG), positioned directly opposite the red color on the Munsell hue circle, while the third preferred hue is purple (7P), situated between these two colors (Figure 4).

In most experimental studies on color, only the color hue (such as red, blue, yellow) is considered, being deemed the most prominent characteristic of color. However, in a broader context, acknowledging that each color hue possesses value and saturation, these components also undoubtedly exert effects on the user (Elliot, 2015; Kareklas et al., 2014; Lee et al., 2013).

Hence, in this study, the three preferred hues were further categorized into four sub-colors: saturated, medium, light (with high value), and dark (less saturated and low in value). These variations were visualized by applying them to the walls of the computer classroom using the SketchUp program

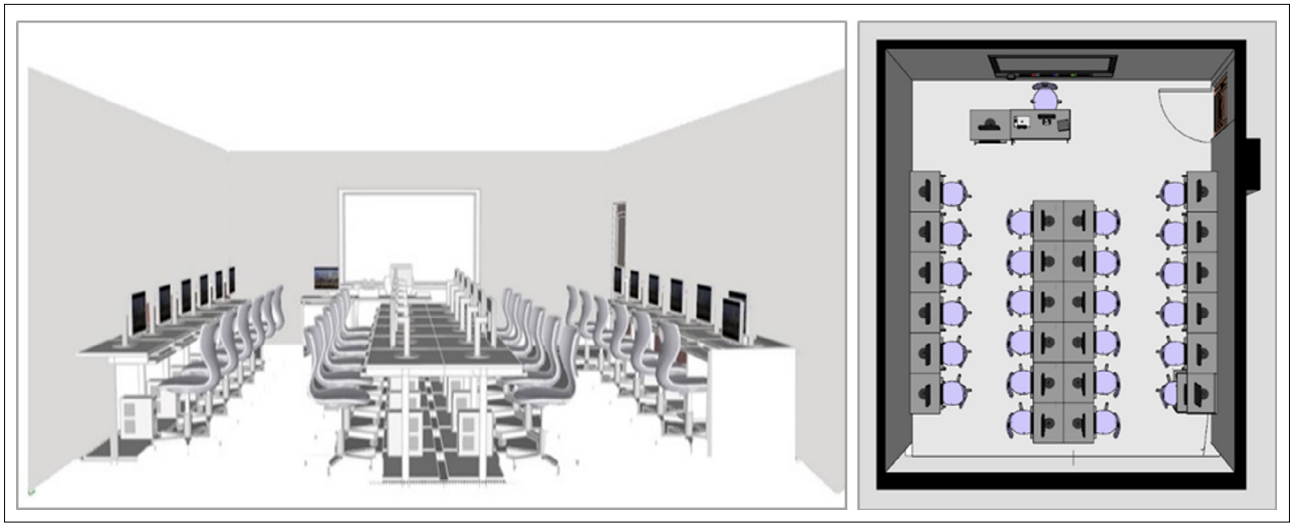


Figure 3. Classroom Plan and model.

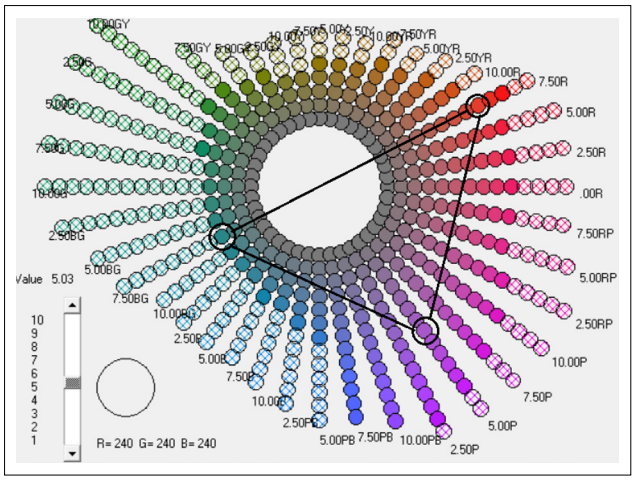


Figure 4. Munsell horizontal section view of red, blue-green and purple colors used in the experiment, Value:5 (WallkillColor, 2023).

(Figure 5a-c). The selected hue pages and sub-colors from the Munsell Color System are illustrated in Figure 6.

Questionnaire Design and Procedure

The questionnaire utilized for the evaluation of classroom wall colors is the Semantic Differential (SD) Scale, which was developed by Osgood, Suci, and Tannenbaum (1957) and has been previously employed in spatial assessment studies (Osgood et al., 1957; Yıldırım et al., 2011b; Imamoglu, 2000; Yıldırım et al., 2007). The questionnaire comprises two parts. The first part collects general information about the participants, including age and gender. The second part consists of the SD Scale, wherein students assessed twelve colors (three hues with varying values and saturations) applied to the computer classroom walls (Figure 7a-c).

The scale entails seven steps and fifteen pairs of adjectives used to evaluate the color characteristics of the classroom. A total of fifteen pairs are: beautiful/ugly, cold/hot, bright/dull, relaxing/incomprehensible, dynamic/static, active/passive, clean/dirty, concentrated/distracting, pleasant/unpleasant, exciting/boring, vivid/lifeless, dark/light. In compiling the list of bipolar items, the emphasis was on selecting adjectives that aptly describe color.

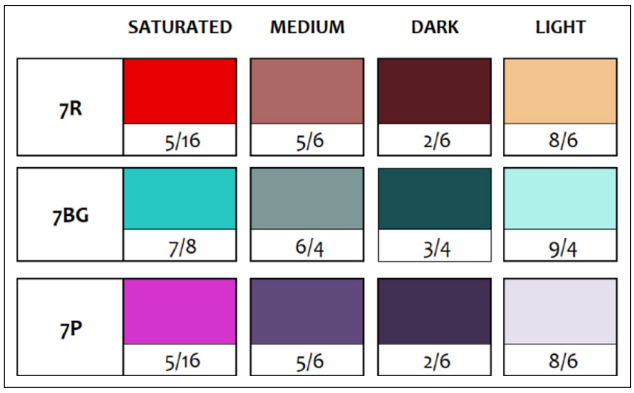


Figure 6. Munsell notations of classroom wall colors.

FINDINGS

The data from the Semantic Differential Scale (SD) were evaluated by the arithmetic mean method across all subjects, ignoring the gender difference. The arithmetic averages' results are given in Table 1, and the graphical outcomes according to the hues of red, blue-green, and purple are given in Figure 8 (7R red), Figure 9 (7BG blue-green), and Figure 10 (7P purple). Each bipolar adjective (items) was rated on a seven-point scale (from -3 to 3) established between the extremes. The "-" (minus) values in the table were evaluated as negative perception and the "+" values as positive. The closer values are to "-3" or "+3" for an adjective, the stronger the perception of the color described by that adjective as negative or positive.

As depicted in the graphics, results above the "0" (zero) line for each adjective pair are considered positive, whereas those below are regarded as negative evaluations. Mostly, all saturated colors were perceived as beautiful, warm, bright, and cheerful. However, this positive perception in saturated colors was reversed for "medium" colors of the

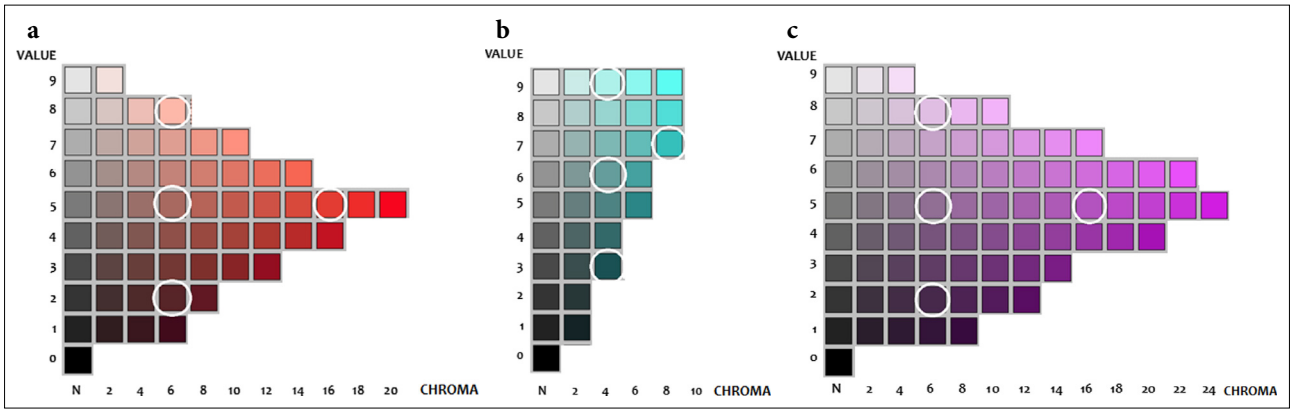


Figure 5. **(a)** Munsell 7R Red hue. **(b)** Munsell 7BG Blue-green hue. **(c)** Munsell 7P Purple hue.

Figure 7 (a). Visuals of the wall colors of red hue.

Figure 7 (b). Visuals of the wall colors of purple hue.

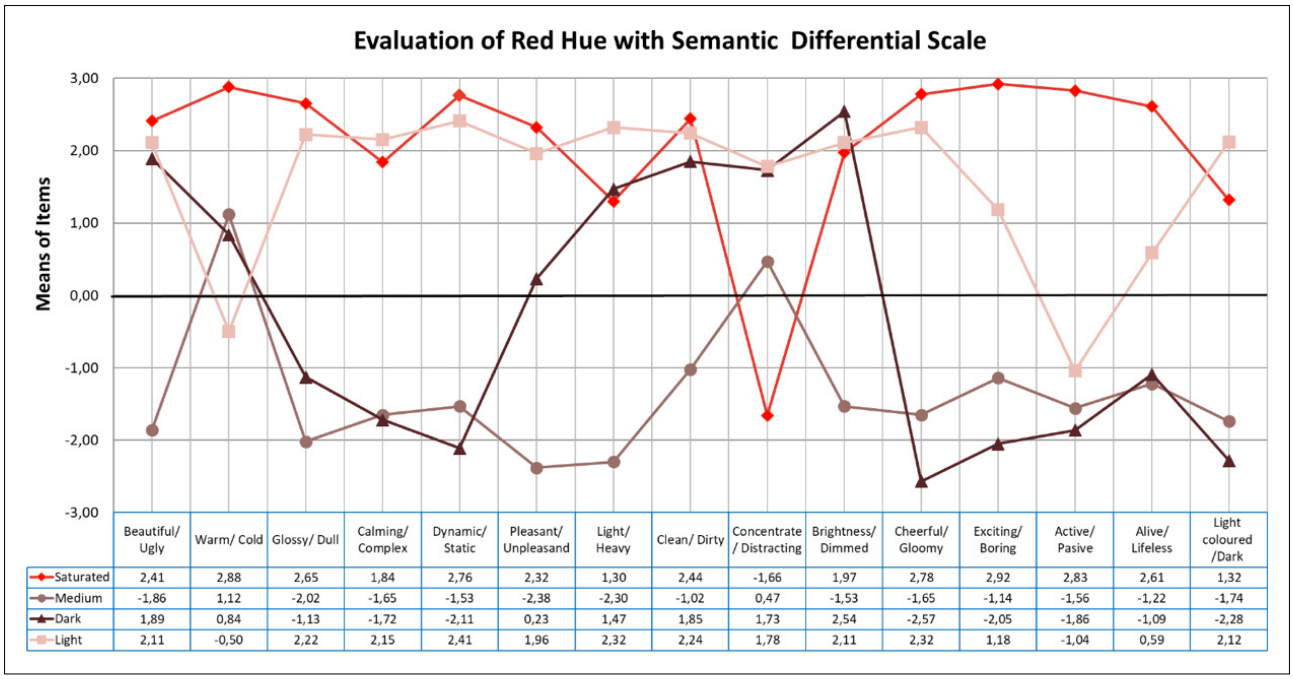
same hues, resulting in a negative impression. While the saturated red color was perceived positively in almost all adjective pairs, intriguingly, it was negatively evaluated as "distracting." This situation resembles findings in the literature, suggesting that red is considered a stimulating color and leads to a distracting effect (Al-Ayash, 2016; Küller et al., 2009). Another notable conclusion regarding saturated red is that students perceive it as highly

Figure 7 (c). Visuals of the wall colors of purple hue.

warm, dynamic, cheerful, and active. These findings are consistent with previous studies evaluating spaces with red color (Kaya & Epps, 2004; Nelson et al., 1984; Whitfield & Wiltshire, 1990; Küller et al., 2009; Nakshian, 1964). In a study centered on hue and saturation, it was deduced that users find saturated colors to be more attention-grabbing, like the outcomes observed in this study (Camgöz et al., 2004).

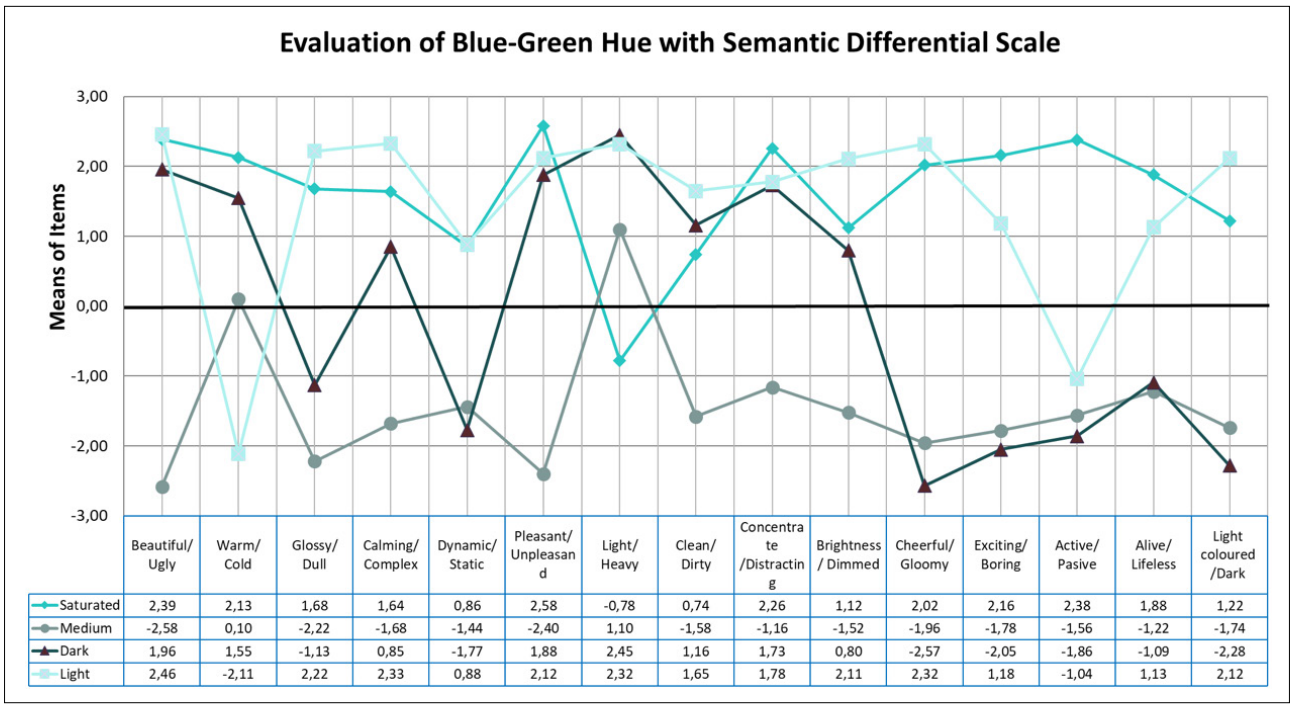
Table 1. Arithmetic mean results of SD scale

Semantic Differantial/	Purple (7P)				Blue-Green (7BG)				Red (7R)			
Bipolar Adjectives	Saturated	Medium	Dark	Light	Saturated	Medium	Dark	Light	Saturated	Medium	Dark	Light
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean
Beautiful/Ugly	2.30	-2.62	2.45	1.43	2.39	-2.58	1.96	2.46	2.41	-1.86	1.89	2.11
Warm/Cold	2.70	-1.85	0.25	-1.79	2.13	0.10	1.55	-2.11	2.88	1.12	0.84	-0.50
Glossy/Dull	2.10	-1.30	-0.50	1.92	1.68	-2.22	-1.13	2.22	2.65	-2.02	-1.13	2.22
Calming/Complex	0.43	0.19	0.19	2.15	1.64	-1.68	0.85	2.33	1.84	-1.65	-1.72	2.15
Dynamic/Static	1.80	-2.60	-2.60	0.12	0.86	-1.44	-1.77	0.88	2.76	-1.53	-2.11	2.41
Pleasant/Unpleasant	2.21	1.94	1.94	1.56	2.58	-2.40	1.88	2.12	2.32	-2.38	0.23	1.96
Light/Heavy	0.90	0.74	0.74	2.65	-0.78	1.10	2.45	2.32	1.30	-2.30	1.47	2.32
Clean/Dirty	2.01	2.84	2.84	2.85	0.74	-1.58	1.16	1.65	2.44	-1.02	1.85	2.24
Concentrate/Distracting	1.75	0.23	0.23	0.79	2.26	-1.16	1.73	1.78	-1.66	0.47	1.73	1.78
Brightness/Dimmed	0.60	2.75	2.75	2.86	1.12	-1.52	0.80	2.11	1.97	-1.53	2.54	2.11
Cheerful/Gloomy	2.30	-2.57	-2.57	2.23	2.02	-1.96	-2.57	2.32	2.78	-1.65	-2.57	2.32
Exciting/Boring	2.86	-2.92	-2.92	1.36	2.16	-1.78	-2.05	1.18	2.92	-1.14	-2.05	1.18
Active/Passive	2.43	-1.25	-1.25	0.58	2.38	-1.56	-1.86	-1.04	2.83	-1.56	-1.86	-1.04
Alive/Lifeless	2.75	0.27	0.27	1.90	1.88	-1.22	-1.09	1.13	2.61	-1.22	-1.09	0.59
Light colored/Dark	-0.65	-2.57	-2.57	2.92	1.22	-1.74	-2.28	2.12	1.32	-1.74	-2.28	2.12



	Beautiful/ Ugly	Warm/ Cold	Glossy/ Dull	Calming/ Complex	Dynamic/ Static	Pleasant/ Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate / Distracting	Brightness/ Dimmed	Cheerful/ Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured /Dark
Saturated	2,41	2,88	2,65	1,84	2,76	2,32	1,30	2,44	-1,66	1,97	2,78	2,92	2,83	2,61	1,32
Medium	-1,86	1,12	-2,02	-1,65	-1,53	-2,38	-2,30	-1,02	0,47	-1,53	-1,65	-1,14	-1,56	-1,22	-1,74
Dark	1,89	0,84	-1,13	-1,72	-2,11	0,23	1,47	1,85	1,73	2,54	-2,57	-2,05	-1,86	-1,09	-2,28
Light	2,11	-0,50	2,22	2,15	2,41	1,96	2,32	2,24	1,78	2,11	2,32	1,18	-1,04	0,59	2,12

Figure 8. SD Scale results of 7R (Red) Hue.

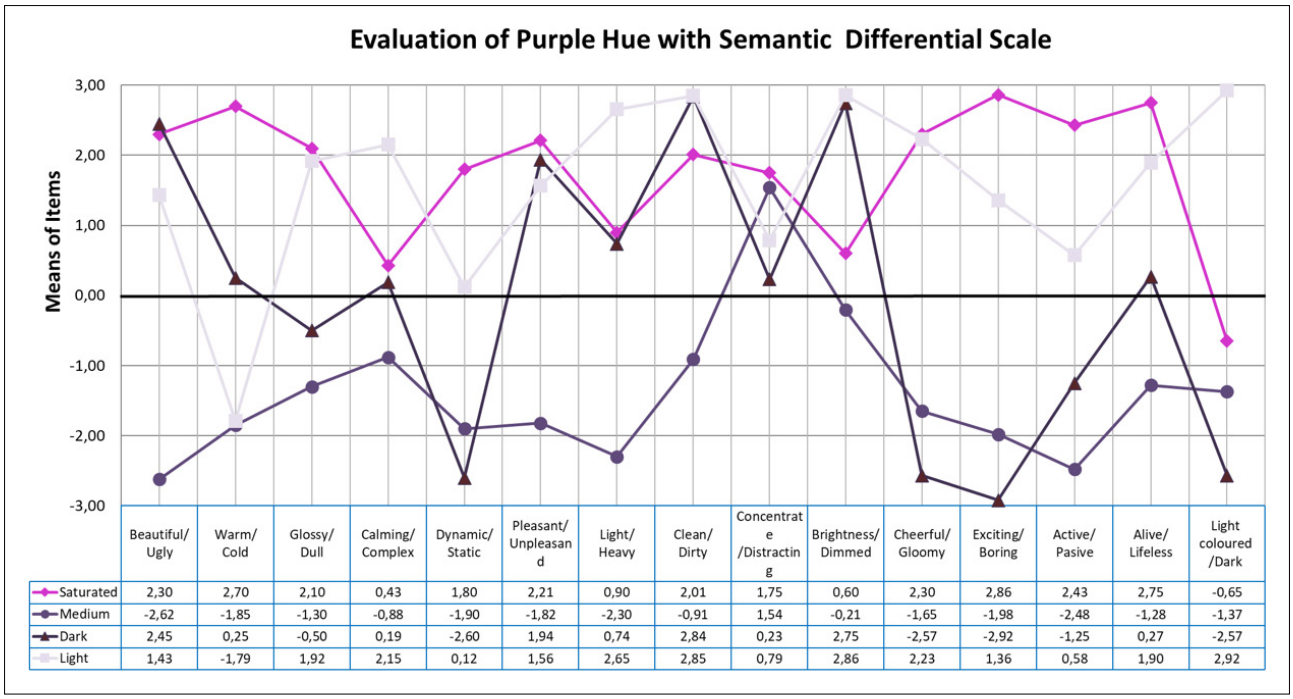


	Beautiful/ Ugly	Warm/ Cold	Glossy/ Dull	Calming/ Complex	Dynamic/ Static	Pleasant/ Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate /Distracting	Brightness / Dimmed	Cheerful/ Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured /Dark
Saturated	2,39	2,13	1,68	1,64	0,86	2,58	-0,78	0,74	2,26	1,12	2,02	2,16	2,38	1,88	1,22
Medium	-2,58	0,10	-2,22	-1,68	-1,44	-2,40	1,10	-1,58	-1,16	-1,52	-1,96	-1,78	-1,56	-1,22	-1,74
Dark	1,96	1,55	-1,13	0,85	-1,77	1,88	2,45	1,16	1,73	0,80	-2,57	-2,05	-1,86	-1,09	-2,28
Light	2,46	-2,11	2,22	2,33	0,88	2,12	2,32	1,65	1,78	2,11	2,32	1,18	-1,04	1,13	2,12

Figure 9. SD Scale results of 7BG (Blue-green) Hue.

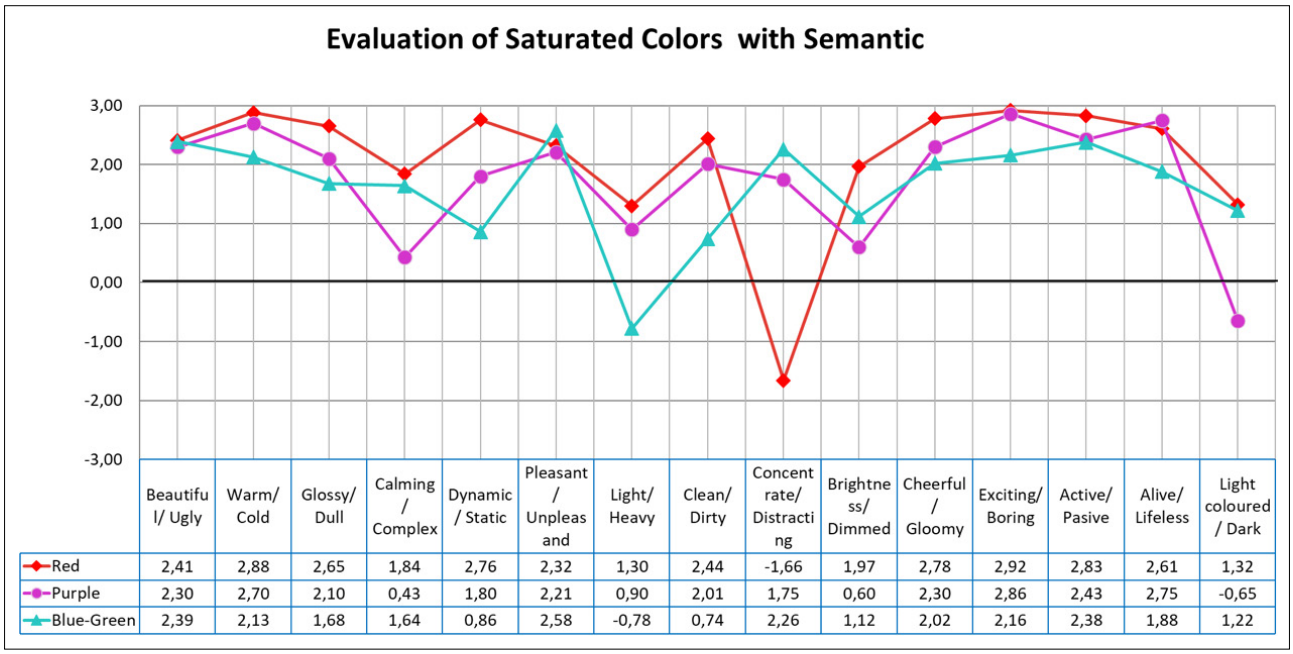
The SD scale results were evaluated in terms of saturated, medium, light, and dark colors of the three hues; the relationship between them can be discerned from the graphs in Figures 11a-d.

According to these results, most of the semantic responses to the saturated colors are on the positive side of the graph and show similar results with each other. Only the saturated red color was found slightly distracting, and the blue-green color was perceived as somewhat heavy (Figure 11a). The "medium" colors of each hue, on the other hand, mostly reside in the negative zone of the graph. These parallel evaluations in the medium colors of all hues indicate that these colors are generally not perceived positively (Figure 11b).



	Beautiful/ Ugly	Warm/ Cold	Glossy/ Dull	Calming/ Complex	Dynamic/ Static	Pleasant/ Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate /Distracting	Brightness/ Dimmed	Cheerful/ Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured /Dark
Saturated	2,30	2,70	2,10	0,43	1,80	2,21	0,90	2,01	1,75	0,60	2,30	2,86	2,43	2,75	-0,65
Medium	-2,62	-1,85	-1,30	-0,88	-1,90	-1,82	-2,30	-0,91	1,54	-0,21	-1,65	-1,98	-2,48	-1,28	-1,37
Dark	2,45	0,25	-0,50	0,19	-2,60	1,94	0,74	2,84	0,23	2,75	-2,57	-2,92	-1,25	0,27	-2,57
Light	1,43	-1,79	1,92	2,15	0,12	1,56	2,65	2,85	0,79	2,86	2,23	1,36	0,58	1,90	2,92

Figure 10. SD Scale results of 7P (Purple) Hue.

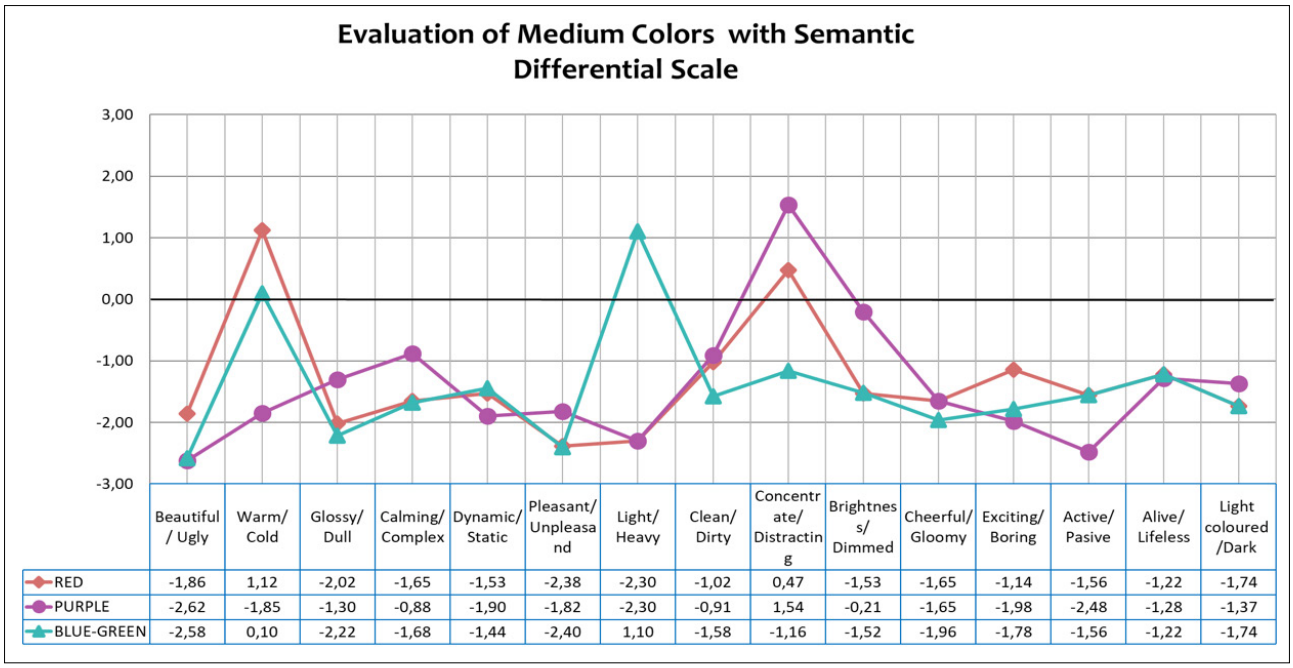


	Beautiful/ Ugly	Warm/ Cold	Glossy/ Dull	Calming / Complex	Dynamic / Static	Pleasant / Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate/ Distracting	Brightness/ Dimmed	Cheerful / Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured / Dark
Red	2,41	2,88	2,65	1,84	2,76	2,32	1,30	2,44	-1,66	1,97	2,78	2,92	2,83	2,61	1,32
Purple	2,30	2,70	2,10	0,43	1,80	2,21	0,90	2,01	1,75	0,60	2,30	2,86	2,43	2,75	-0,65
Blue-Green	2,39	2,13	1,68	1,64	0,86	2,58	-0,78	0,74	2,26	1,12	2,02	2,16	2,38	1,88	1,22

Figure 11 (a). Evaluation of Saturated Colors with Semantic Differential Scale.

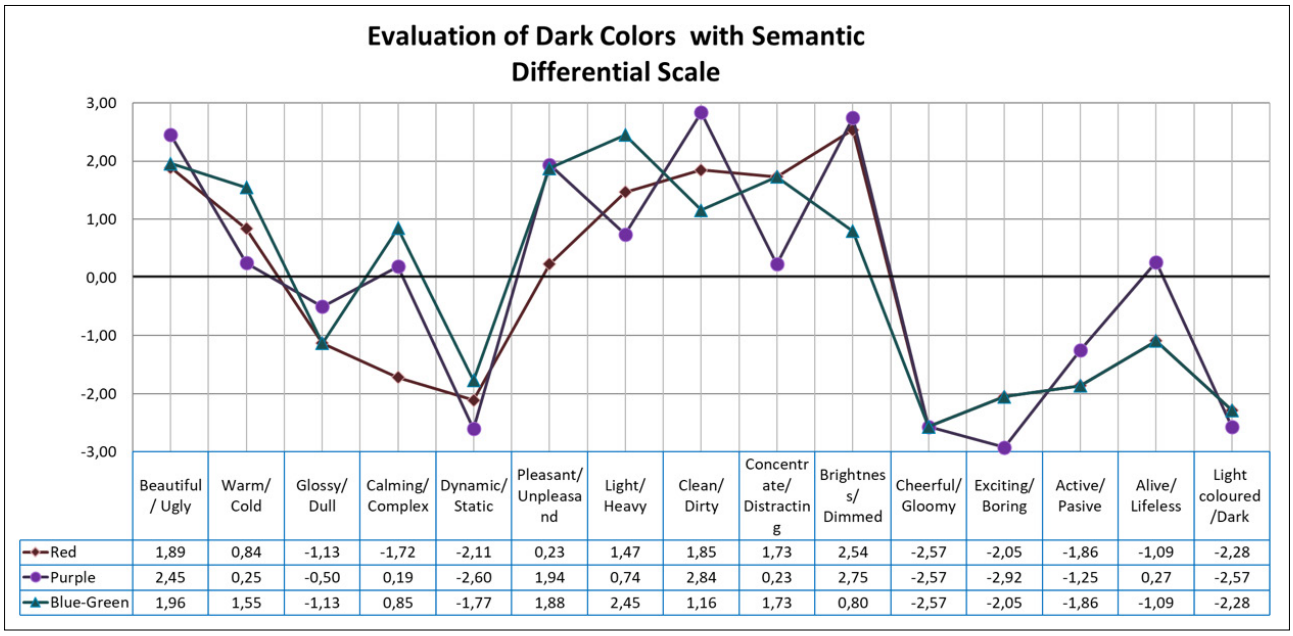
As depicted in Figure 11c, "light" (high value) colors are positioned on the positive side of the graph, and this indicates nearly parallel and similar perceptual evaluations for all light colors of different hues. Students characterize light colors with positive adjectives such as "pleasant, beautiful, warm, cheerful, relaxing, exciting, and active," while considering them "cold and passive" across all three hues. Despite red being predominantly associated with warmth in prior studies, the light red (pink) color was described as cold in this study by participants. This result implies that, regardless of whether a color is warm or cool, if it has a high value, the color of space will be perceived as cool.

The semantic evaluations given for dark colors exhibit parallelism for almost all adjectives, as shown in Figure 11d. Dark colors are found to be positive with descriptors such as "pleasant, beautiful, and light," but they also carry negative connotations like "stationary, gloomy, 'boring,' passive, and dark." Additionally, it can be inferred that these



	Beautiful / Ugly	Warm/ Cold	Glossy/ Dull	Calming/ Complex	Dynamic/ Static	Pleasant/ Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate/ Distracting	Brightness/ Dimmed	Cheerful/ Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured /Dark
RED	-1,86	1,12	-2,02	-1,65	-1,53	-2,38	-2,30	-1,02	0,47	-1,53	-1,65	-1,14	-1,56	-1,22	-1,74
PURPLE	-2,62	-1,85	-1,30	-0,88	-1,90	-1,82	-2,30	-0,91	1,54	-0,21	-1,65	-1,98	-2,48	-1,28	-1,37
BLUE-GREEN	-2,58	0,10	-2,22	-1,68	-1,44	-2,40	1,10	-1,58	-1,16	-1,52	-1,96	-1,78	-1,56	-1,22	-1,74

Figure 11 (b). Evaluation of Medium Colors with Semantic Differential Scale.



	Beautiful / Ugly	Warm/ Cold	Glossy/ Dull	Calming/ Complex	Dynamic/ Static	Pleasant/ Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate/ Distracting	Brightness/ Dimmed	Cheerful/ Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured /Dark
Red	1,89	0,84	-1,13	-1,72	-2,11	0,23	1,47	1,85	1,73	2,54	-2,57	-2,05	-1,86	-1,09	-2,28
Purple	2,45	0,25	-0,50	0,19	-2,60	1,94	0,74	2,84	0,23	2,75	-2,57	-2,92	-1,25	0,27	-2,57
Blue-Green	1,96	1,55	-1,13	0,85	-1,77	1,88	2,45	1,16	1,73	0,80	-2,57	-2,05	-1,86	-1,09	-2,28

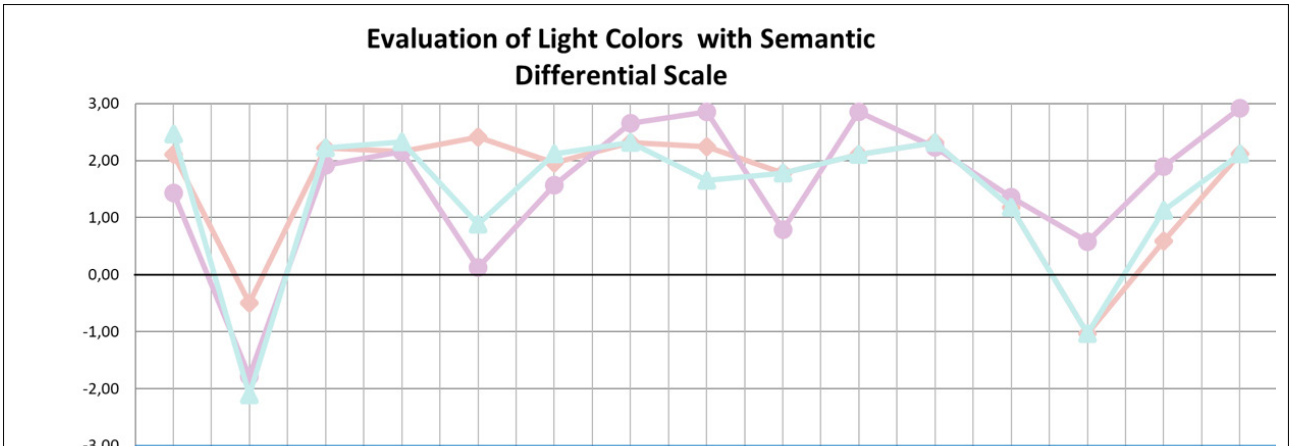
Figure 11 (c). Evaluation of Dark Colors with Semantic Differential Scale.

colors are perceived as 'concentrated' by the students.

In the classification of saturated, medium, light, and dark colors within their respective categories, it is observed that there are similar perceptual evaluations in the graphs. This inference leads to the conclusion that, even when different hues (such as red, blue etc.) are applied to the walls of a space, similar values and saturations in each hue can result in resembling perceptions.

CONCLUSION AND DISCUSSION

The colors in our environment not only facilitate our perception and understanding of the spaces we inhabit but also have physiological, cognitive, affective, and behavioral effects on users. Spaces may require dynamic environments for activities such as dining, conversation, dancing, etc., as well as serene settings for activities like relaxation, sleep, and study. In this context, space colors should be organized accordingly. This study focuses on wall colors of a computer



	Beautiful / Ugly	Warm/ Cold	Glossy/ Dull	Calming/ Complex	Dynamic / Static	Pleasant/ Unpleasand	Light/ Heavy	Clean/ Dirty	Concentrate/ Distracting	Brightness/ Dimmed	Cheerful/ Gloomy	Exciting/ Boring	Active/ Pasive	Alive/ Lifeless	Light coloured /Dark
Red	2,11	-0,50	2,22	2,15	2,41	1,96	2,32	2,24	1,78	2,11	2,32	1,18	-1,04	0,59	2,12
Purple	1,43	-1,79	1,92	2,15	0,12	1,56	2,65	2,85	0,79	2,86	2,23	1,36	0,58	1,90	2,92
Blue-Green	2,46	-2,11	2,22	2,33	0,88	2,12	2,32	1,65	1,78	2,11	2,32	1,18	-1,04	1,13	2,12

Figure 11 (d). Evaluation of Light Colors with Semantic Differential Scale.

classroom environment designed for learning purposes, investigating the effects of three different color hues with various values and saturations on the spatial perceptions of users. The results derived from the data are discussed below.

Commonly, high value (light) and saturated colors of all hues of wall colors were perceived positively, with light colors being evaluated as "cool and passive." This result indicates that, even if a color (hue) belongs to the warm category, lighter colors of the respective hue can be perceived as cooler, highlighting the role of value and saturation in the perception of warm/cold colors.

Largely, it is observed that blue is the most preferred color in the literature (Brill, 1984-1985; Camgöz, 2000). In this study, the positive perception of only light, saturated, and partially dark colors of blue shows that the role of value and saturation is also very important in the preference of color. In this context, when defining colors in similar studies, not only the hue of the color such as blue or red but also the contribution of its other two components as value and saturation should be specified.

Medium colors, on the other hand, were perceived negatively with definitions such as "static, boring, dark". While dark colors were perceived positively as "pleasant, beautiful, clean, and bright" but negatively as "gloomy, boring, passive, lifeless, and dark," they were perceived negatively with the definition “static, boring, and dark”. Dark red and dark blue-green colors and all colors of the purple hue were perceived as concentrating colors.

Consistent with findings in the literature, this study revealed that saturated red is perceived as “exciting, dynamic, and active,” while also creating a “distracting” effect (Kaya & Epps, 2004; Küller et al., 2009; Elliout, 2015; Wilson, 1966; Xia et al., 2016; Coutinho & Akbay, 2023). It conveys the idea that the association between red and failure found in many studies might be attributed to the challenging impact it has on focus (Mehta & Zhu, 2009; Moller et al., 2009; Kwallek et al., 1988). Similarly, in the study conducted by Elliot and colleagues, it was concluded that being in a red environment or seeing the red color in the context of success can undermine performance in challenging tasks (Elliot et al., 2007; Elliot, 2015).

In the comparisons for the saturated, medium, light, and dark colors of each of the three hues, it is generally observed that responses to the SD scale yield similar results within their respective categories. This indicator suggests that in spatial color assessments, colors of different types but with similar values and saturations may elicit similar perceptions.

When learning spaces are consciously designed with consideration of the effects of colors, they can contribute to students' active learning, exploration, socialization, research, thinking, and creativity, providing an enjoyable environment. In this context, the objective of this study, which explores high school students' perceptions of classroom wall colors, is to help establish an environment that enhances students' enthusiasm and motivation for learning through environmental colors. In the next stage, evaluating classroom wall colors using different colors or methods will contribute to the literature within the framework of education. Eventually, conducting more comprehensive studies with a variety of colors for educational spaces, where people spend a significant part of their lives, will be beneficial in creating efficient and more enjoyable environments for students.

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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

The holistic view of urban space method: Examination of public spaces around Kadıköy Marmaray stations

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ABSTRACT

This study focuses on the development of a 7-criteria examination method for understanding, analyzing, mapping, and interpreting urban space, and the testing of the method in the area around Marmaray Kadıköy stations. Within the framework of the study, based on the need for a method that enables the understanding and analysis of urban space, 7 research criteria were created that include the holistic data of the city. These criteria aim to obtain holistic data by combining the plan level and urban form data of the urban space, the three-dimensional perceived (experienced) data of the space, the relationship of the historical process with economic, political, social, and spatial dynamics, and mapping techniques. This method, called the "holistic view of urban space," allows data to be brought together, mapped, and multiple readings and inferences to be made while experiencing and researching urban space. In the study, carried out with the qualitative research method, theoretical information is brought together with the thematic analysis method and associated on the matrix. By associating the concepts on the matrix, the "holistic view of urban space" method is obtained. The data obtained after the field examination are analyzed with 7 examination criteria, and a mapping study is carried out. The analysis criteria make it possible to collect data at eye level and at plan level and to interpret them by associating them in the analysis of the urban space. The criteria allow deepening the information by elaborating the collected data, as well as providing holistic information from a higher scale through induction.

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INTRODUCTION

The city is a complex structure, and the perception of the city is a complex, interrupted, and fragmented process (Harvey, 2009; Lynch, 2011). Public space can be defined as the natural and built environment in which the public can move freely. In its broadest definition, it includes all parts of the city between the dichotomy of built and natural-structured, public-private, internal-external, urban-rural (Carmona et al., 2008). In studies of urban life and urban form, researchers have created concepts and scales to improve the quality of urban life. While some definitions, such as the 15-minute city, the sustainable city, the smart city, the slow city, and the resilient city, contradict each other, others may overlap. For example, compact urban

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This article is based on ongoing phD dissertation which aims to propose a methodology for the study of public spaces and to test it around Marmaray stations by Özgün Özbudak under supervision of Prof. Dr. Ömür Barkul at Yıldız Technical University, Department of Architecture.

design emphasizes pedestrian life, while sprawling cities may encourage the use of vehicles as settlements that are far from each other (Jaroszewicz et al., 2023). With advances in technology, the growth of cities, and the invasion of vehicles into cities, the emphasis on public spaces and what their 'good' qualities should and can be is becoming increasingly important (Aydınsoy & Ötküng, 2021). In order to create and maintain good urban public spaces, it is important to act with a holistic view by identifying the current situation, past traces, problems, and positive features. What is meant by a holistic view is that in the process of analyzing urban space, the ruptures created by economic, political, and social dynamics in the historical process, the pattern of urban space on the plan level, and the three-dimensional urban life should be treated together.

As a result of the lack of holistic management of spatial data transformed by economic, political, and social dynamics (Harvey, 2009), urban spaces are transformed into spaces that are incompatible with natural environmental features, incapable of creating their own identity, unrecognizable, lacking identity features, and copies of each other. Therefore, good urban spaces can be created by determining the analysis techniques in urban spaces before the decisions to be taken inside or outside the urban texture and by revealing the unique values of urban spaces (Çolpan & Akın, 2015). The open or hidden traces of historical process ruptures in space, the relationship between current life and the future, the impact of urban space on life are important elements that enable the understanding of the relationship between human and urban space.

Within the scope of the study, based on the need for a method that enables the analysis of the urban space in its entirety, 7 examination criteria including the holistic data of the city have been created. This method, called "holistic view of urban space," enables data to be brought together, mapped, multiple readings, and inferences to be made while experiencing urban space and conducting research on space. The method aims to reveal the historical ruptures in urban life and the data in layers in contemporary urban life, and to make them analyzable and holistic. The method is tested in the station environments of the rail transport system, which is one of the important transformers of urban space, namely around the Marmaray (Kadıköy) stations. Rail transport systems contribute to the creation and enrichment of urban space, bringing it to life with their dynamism. While railway transport creates urban spaces with the dynamism it generates, at the same time, the addition of different transport systems to the station points makes the nodes both stronger and more complex.

The research derives a new method from the theoretical knowledge through the method of thematic analysis, which is one of the sub-headings of the qualitative research method. The mixed method proposed in the study is a social and spatial analysis method created to study the form, quality, and social structure of the urban public space through mapping techniques, taking into account the historical ruptures (economic, political, social dynamics). This method is called "the method of the holistic view of urban space." It is aimed to analyze the social and spatial analysis of urban space with a mixed method created with Corner's (2011) mapping techniques by bringing together Jan Gehl's (2020) good city qualities for lively, safe, sustainable, and healthy cities, Oscar Newman's (1996) urban public space hierarchy, Kevin Lynch's (2011) legible city criteria, David Harvey's (2009) emphasis on the necessity of examining both concepts together.

Aims of the study;

- To create a mixed method that proposes to deal with the quality of space, the representation of space, the social structure of space, the perceptual characteristics of space,
- To make the urban public life, which is the result of human interaction with the space, visible through the method and to make it available as design data,
- To provide an overview of the problems and possible solutions in the use of urban public spaces that are intensively used in daily urban life through mapping,
- To create a holistic view between the upper scale (urban macroform) and the human scale and to create a cycle from the upper scale to the human scale.

It is believed that with the "method of holistic view of urban space" created in the study, the following contributions can be obtained in the studies of public space:

- The holistic data of the urban space can be obtained and the urban space with all its data can be easily analyzed,
- To be able to relate apparently unrelated features through a holistic view and to make multiple readings,
- To reveal the data hidden in the layers of urban life.

In this context, by analyzing the urban spaces around the stations, both the old stations and the newly designed urban spaces around the stations, an attempt is made to create a perspective for the existing and future urban spaces, which are assumed to be of great importance in the daily lives of the city's people.

Theoretical Background

This section of the study presents a literature review that constitutes the method of a holistic view of urban space. The chapter consists of the concept and characteristics of public space, economic, political, and social dynamics, the nature of urban public space, and the representation of urban public space.

The Concept and Characteristics of Public Space

Public spaces are urban spaces, a common ground

that brings people together for purposes such as daily activities or collective ceremonies (Erdönmez & Akı, 2005). Madanipour (2003) defines the most fundamental distinction between private and public as the distinction between a person's inner world and the outer world. While the mind is a space that can be opened or hidden from other people at will, it is also shaped by the influence of the outside world. Therefore, the private sphere of the body and the public sphere of the external world intertwine and shape each other (Madanipour, 2003).

Newman (1973) defines urban space from public to private:

- Public space,
- Semi-public space,
- Semi-private space,
- Private space.

The idea is that these spaces should be designed in a hierarchy (Figure 1). He argues that these spaces are not separated by sharp boundaries and that they influence each other in terms of their use and life.

Trancik (1986), on the basis of the evolution of modern space and historical examples, explained urban design theories with three different interrelated theories. These are: Figure-ground theory, linkage theory, and place theory (Figure 2). When these theories come together, potential urban design strategies emerge.

Quality of Urban Public Space

Gehl (2020), summarizes the characteristics of a "good city" as dense urban fabric, short walking distances, pleasant routes, high levels of mixed-use, active ground floors, distinguished architecture, and meticulous detailing. He elaborates these qualities under four main headings:

- **Lively:** Places where more people walk, bike, and spend time in the city.
- **Safe:** Where people spend more time in the city because they can see and be seen by other people.
- **Sustainable:** Where pedestrian use, cycling, and public transportation are prioritized.
- **Healthy:** Where people's more active participation in urban life can be ensured through movement.

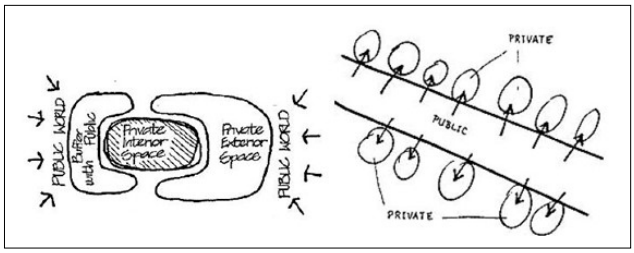

Figure 1. Diagram showing the sequence between private and public space in urban space (Newman, 1996).

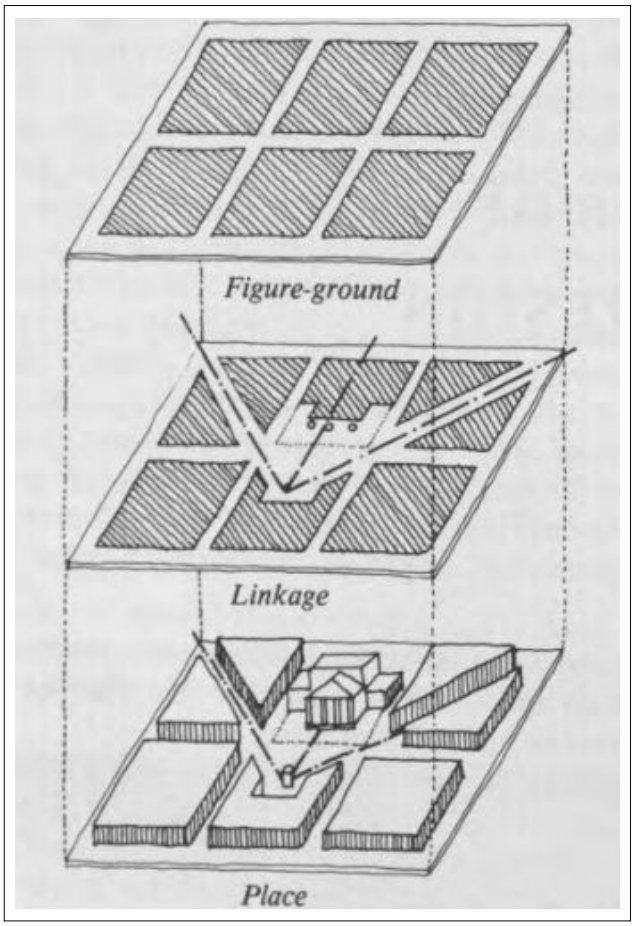

Figure 2. Urban design theories of Trancik (Trancik, 1986).

A city that has a simple form, a continuity of building types and use, a city that is unique in the city, a city with precisely defined boundaries, a city that is clearly merged with neighboring regions, a visually concave region with easily identifiable features is an imaginable city (Lynch, 2011).

The concepts of proximity, ecology, solidarity, and participation emerge with the proposal of 15-minute cities with an approach that emphasizes pedestrian and bicycle use by centering on the idea that the rhythm of cities should follow people, not vehicles, and that every square meter should be usable (Moreno et al., 2021). The prominence of vehicles instead of pedestrians, whereas humans have been prone to walking and walking speed for centuries (Jacobs, 2017; Gehl, 2020), the ability to make discoveries by walking, and the efficiency gained while conducting research (Wiley, 2010) are important components that can be addressed when examining urban problems.

Economic, Political, Social Dynamics

Until the 18th century, the dichotomous urban structure, such as center-periphery, urban-rural, started to unravel due to the increasing population and changing modes of production. Parallel to the change in the mode of

production, the cultural atmosphere has changed with the effect of modernism, and the meaning of place and space for people has changed (Salah, 2013).

In the early 20th century, the development of technology and increased production led to an increase in the scale of cities. The distances between buildings have increased, and instead of looking at the city as a texture formed by the coming together of buildings, it has begun to be viewed as separated buildings and the gaps between them (Jacobs, 2017; Gehl, 2020).

Tekeli (2009) divides the urbanization process in Türkiye into five periods: Ottoman Modernization before the Republic, the search for a planned economy in the Republican period, the populist modernity process between 1950-1960, the rapid urbanization of the 1980s, and the globalization period afterward. The traces of these processes can be seen in urban spaces, on buildings, and can help in the analysis of urban spaces by creating background knowledge.

The traces of these dynamics can be read in space during the urban experience. An urban fabric from the Ottoman period can be replaced by boulevards and squares that represent the modern cultural image of the Republic (Çalışkan, 2004; Çetin, 2012). Buildings and urban textures from different periods can coexist and intertwine with each other. The coexistence of differences strengthens urban memory and enriches urban life. For this reason, historical process breaks that affect social life emerge as important dynamics that transform spaces and show their traces in the urban space.

Representation of Urban Public Space

The quest to create 'good' urban space is a constant concern for designers. They have used mapping to reveal and simplify the complexity of the city through visual representation with graphical tools to understand its characteristics (Amoroso, 2010). Instead of a static representation, mapping refers to a practice in which the maker, the mapped place, and the product are produced, redefining and repositioning each other in the process (Şenel, 2014). In this context, maps always and inevitably include the behavioral and ideological orientations of the mapmaker, and studies on maps must take these orientations and their effects into account (Aral, 2018).

Corner (2011) presents mapping as an approach that shows the world in new ways by revealing possibilities and creating unexpected solutions and effects, and defines mapping practices in four groups (Figure 3).

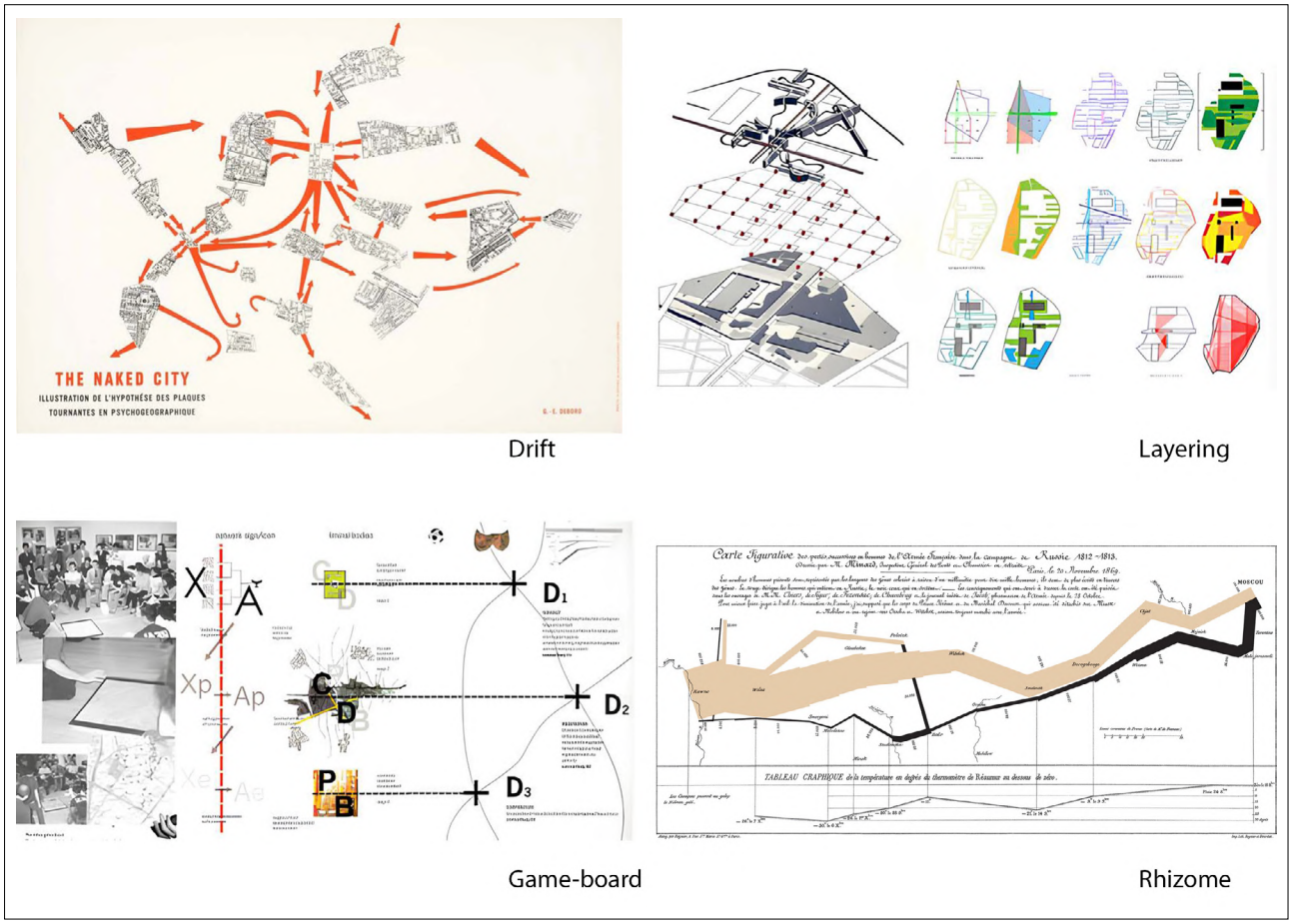

Figure 3. Mapping techniques (Aral, 2018).

Drift: It covers the expression of perceptual sub-areas on a route experienced in the city. Guy Debord, in his work "The Naked City," in which he maps his aimless wanderings in Paris, reveals that the map of the city formed in the mind is fragmented (Corner, 2011; Aral, 2018). As a critique of the modernist and holistic concept of the city of the period, these maps demonstrated that a fragmented map of the city was also possible for the expression of individual perceptions, momentary preferences, and experiences (Aral, 2018).

Layering: The superposition of independent layers to create heterogeneous life. It aims to produce multiple combinations of use and life for the future in an open-ended spatial construct proposed by the combination of different layers (Aral, 2018).

Game Board: The city is constructed as a game board, and the actors in the city take part in the formation process of the space as active players (Corner, 2011; Aral, 2018).

Rhizome: Mapping as a rhizomatic activity allows for new and open-ended relationships to be established through both inclusive and pluralistic, and flexible techniques (Corner, 2011; Aral, 2018).

Within the scope of the study, "Drifting" is used to represent drifting between stations, "Layering" is used to overlap the traces of the historical process in space, and "Rhizomatics" is used to bring these elements together.

A METHOD SUGGESTION FOR ANALYZING PUBLIC SPACES: A HOLISTIC VIEW OF URBAN SPACE

As a result of the literature review, the theoretical knowledge on the concept of public space, the quality of public space, and the representation of public space was summarized, and the research results were obtained. In the sources, data summarizing how a good city should be and what to look for to understand the city are listed in a matrix system. The first matrix was completed by placing dots in the boxes for views that are parallel and related to each other from the theoretical information (Figure 4). In the matrix study, there is a similarity between Lynch's (2011) and Harvey's (2009) emphasis on the interrupted perception of urban space and the concept of 'drift' theorized by Corner (2011), based on Guy Debord's work. Gehl's (2020) criteria for the quality of urban life are in parallel with other views, except for the view that urban perception is fragmented. Newman's (1973) urban public space hierarchy is related

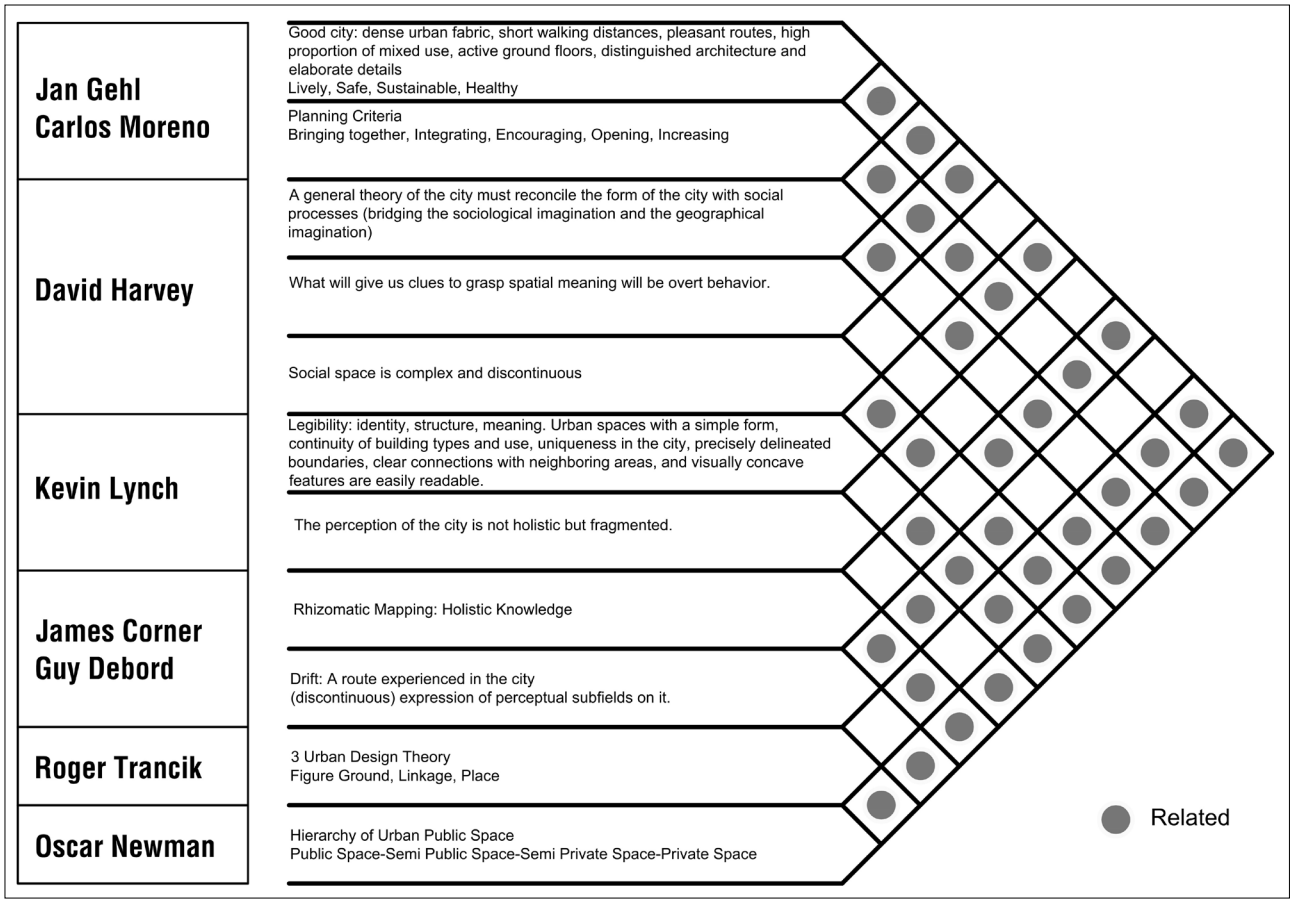

Figure 4. Associating the theoretical knowledge with the matrix study.

to all views and provides a general framework for urban public space design.

After determining the related or not related status on the upper scale, the concepts indicated by the dots were separated from each other by coloring. As a result of the colored markings, a keyword was given to the concept represented by each color. The keywords constitute the criteria for a holistic view of urban space. Each criterion represents important components of urban space.

Through the matrix study, the theoretical data are divided into parts, and their relationship with each other is revealed; the relationships obtained are brought together to reach the whole, in other words, induction is made.

The points marked with green color represent the image of the city, its permanence in mind, easy comprehensibility. The dark blue dots represent the meaningful relationship of squares and streets with each other in urban space, articulating with each other and encouraging the user to explore. Light blue dots indicate the relation between social life and urban space. The current data of public spaces and urban textures, as well as the reflections of the traces of the past in the space, are represented by yellow dots. The dots marked with red color represent that the urban space allows meeting compulsory needs such as going to work, school, shopping, etc., as well as non-mandatory needs such as spending time in the space, gathering together. Pink dots represent the relation between the space and natural environmental data such as topography, coast, river. The orange-colored dots represent the possibility of generating new ideas in the mind during and after the experience of the space (Figure 5).

With the matrix study, 7 criteria were obtained. These criteria are:

- Legibility
- Spine Formation
- Social Integration
- Having a Place in the City's Memory
- Responding to User Needs
- Harmony with the Natural Environment
- Allowing Creativity

Legibility: Easy to Understand, Persistence in Mind

In order for the public life of cities to be meaningful and legible, it is necessary to create short routes; these routes should be connected to each other by creating a meaningful hierarchy with stopping areas suitable for human scale (Gehl & Svarre, 2013; Gehl, 2020). The urban environment can become a definable and real place when it is clearly defined, and when urbanites connect with it meaningfully (Lynch, 2011).

For urban space to be legible, it should be easy to reach the desired destination; it should be free from complexity, the urban elements should form a meaningful sequence while coming together and enable the experiencer to move easily in the city; the space should be easily remembered after it is experienced, and a clear image should be formed.

Spine Formation: Drifting, Spatial Hierarchy

Lynch (2011) states that the perception of the city is not holistic but fragmented, Harvey (2009) states that social space is complex and discontinuous, and urban spaces are functionally separated from each other, with some users avoiding some spaces. These views align with Corner's

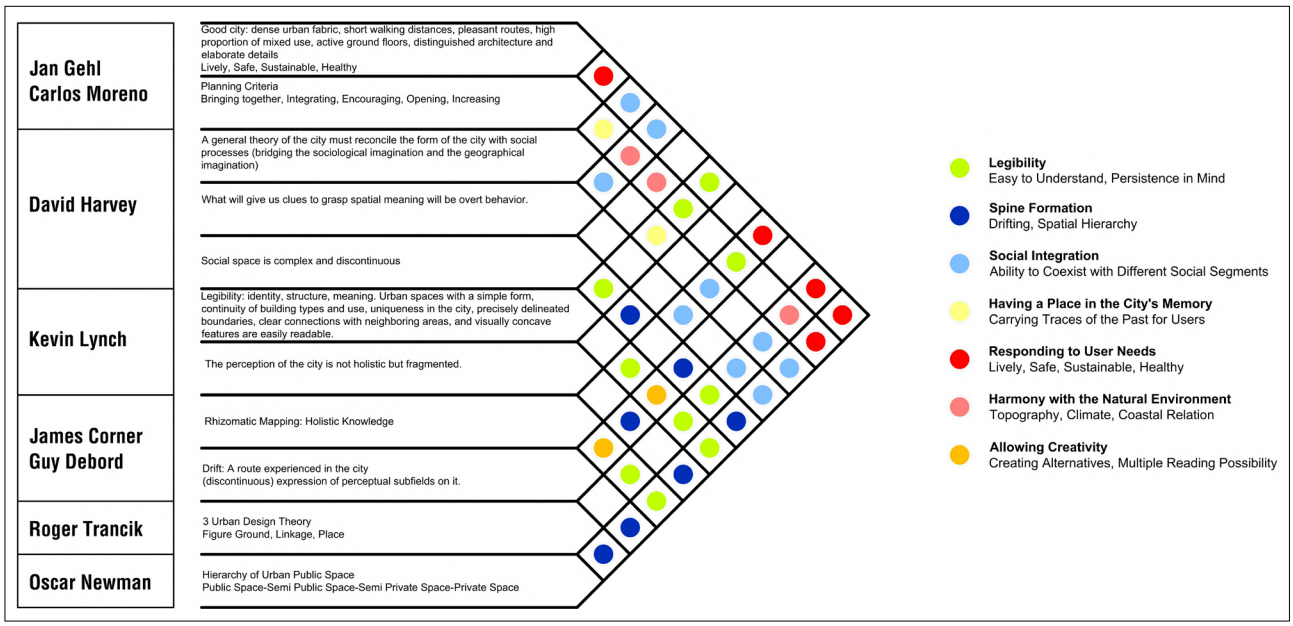

Figure 5. Criteria for the holistic view of urban space with matrix study.

(2011) concept of 'drift' derived from Guy Debord's work. Spine formation can be defined as urban space drawing the user between its spaces in a "good" way. During the movement from one point to another in the urban space, the spaces should be arranged in a qualified manner, articulating with each other to form a meaningful whole. While experiencing urban space, or drifting in the city, the harmonization of different parts with each other and the smooth transition from one to another can create a strong urban spine.

Social Integration: Ability to Coexist with Different Social Segments

In urban strategies, spatial decisions transform the social structure, and changes in the social structure shape the space. While making these decisions, the social welfare function—who will be affected, who will be harmed—should be taken into consideration (Harvey, 2009). It can be defined as the ability of different segments to coexist and form a non-exclusionary heterogeneous structure. It is the capacity of the urban space to accommodate individuals with different social characteristics without excluding them, not to appeal to a certain segment of society, and for individuals to feel that they belong to that place.

Having a Place in the City's Memory: Carrying Traces of the Past for Users

While historical urban textures reflect the social and spatial characteristics of their period, they can achieve this in an uninterrupted manner from the human scale to the upper scale. When the human-environment relationship is analyzed, a continuity in the process of renewal and adaptation can be seen (Arabacioğlu & Aydemir, 2007). The human being adapts to its environment and, on the other hand, creates a cycle by changing and reconsidering it. Şentürer (1995) states that people want to be in environments and spaces where past and present elements coexist and are reinterpreted. Urban space should contain layers of the historical process, and the features related to the process should be readable. The economic, political, and social dynamics and the ruptures in the historical process leave traces in the space.

Responding to User Needs: Lively, Safe, Sustainable, Healthy

According to Gehl's (2020) criteria for a lively, safe, sustainable, and healthy city, space should facilitate the essential needs of the city's daily life, such as going to work, shopping, and transferring from one place to another, while at the same time allowing for spending time, gathering, and resting. The ground floors in the area should accommodate many different functions within a 100-metre route, and the distances should be short and easily accessible. The height of the pavement, adequate lighting, and easy perception of pedestrian and vehicle separation make the space safe. With night use, it allows people to feel safe when they are in this place at night. Encouraging people to walk, cycle, and use public transport makes the space sustainable and healthy.

Harmony with the Natural Environment: Topography, Climate, Coastal Relation

Architecture and the city are in interaction with nature. A structure forms in nature; other structures are added to this structure, and a city forms. Then, this city transforms with the natural conditions (Özer, 2011). Urban texture should be in harmony with the components of urban geography such as coast, river, and topography, which constitute the natural environment data. In the process of articulating streets and forming squares, it is important how the relationship with natural environmental data is established. Urban textures in harmony with natural environmental data are easy to read and offer rich public life opportunities.

Allowing Creativity: Creating Alternatives, Multiple Reading Possibility

Among Henri Lefebvre's concepts of "spatial practice/perceived," "representations of space/designed," and "representational spaces/lived," the representational space, which is the lived space, contains the hidden images, meanings, and memories of life (Lefebvre, 2014; Aral, 2018). It enables the discovery of spatial features of the city that are hidden and pushed to the background, and the perception of different qualities when experienced at different times. The fact that urban space allows for multiple readings by offering fictions and relationships that will enrich the experiencer, and that it offers different options and routes by offering alternatives is important in terms of enabling the city to foster creativity.

Figure 6 shows the process of creating and testing the method in the study. The image shows the methodological perspective of the study from left to right.

The concept of public space, the quality of public space, and the representation of public space constitute the theoretical framework, with the researchers shown on the left. On the right, the stages of creating and testing the method of holistic view of urban space from theoretical knowledge are shown.

A HOLISTIC VIEW OF URBAN SPACE: ANALYZING PUBLIC SPACES AROUND MARMARAY KADIKÖY STATIONS

Cities have been changing with economic, political, and social dynamics since their existence. Although the main sources of these changes are technological inventions and innovations, administration, religion, finance, industry, and disasters are the main variables (Türkantoz, 2011;

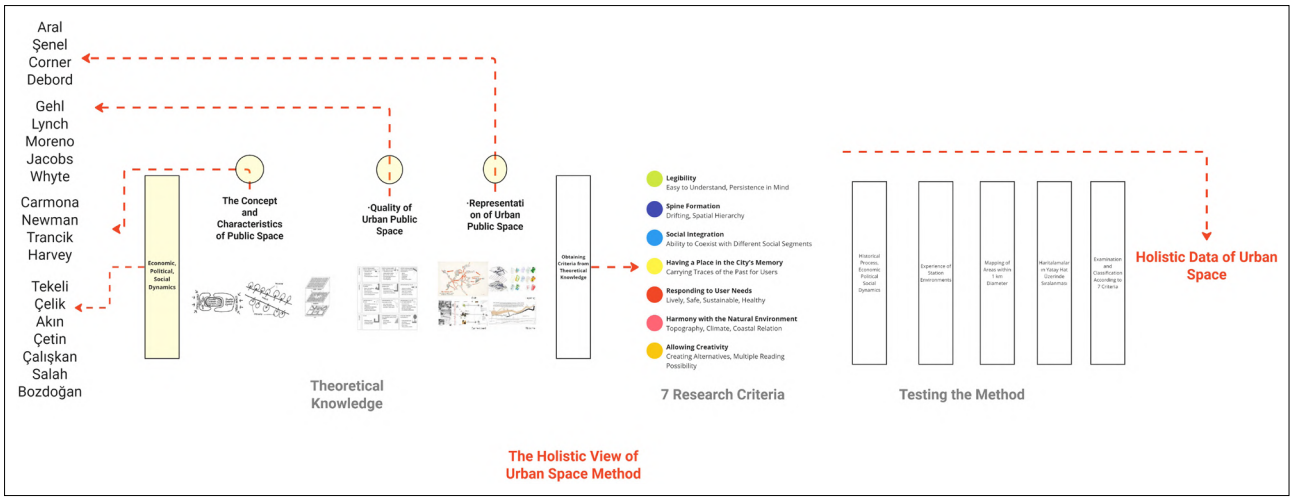

Figure 6. A holistic view of urban space.

Akın, 2012). The city of Istanbul has also been affected by the dynamics that shape urban spaces throughout the Byzantine-Eastern Roman Empire-Ottoman-Ottoman Republic of Türkiye process. The first urban fabrics, consisting of the Historic Peninsula, Üsküdar, and Kadıköy settlements facing the Historic Peninsula, have expanded by spreading first along the coastline and then toward the north in the historical process with economic, political, and social dynamics (Akın, 2012).

The settlement of Kadıköy dates back to 1000 BC. Until the advent of railway transport, Kadıköy comprised vineyard gardens and mansions of the courtiers along the coast, while to the north were the residences of agricultural families, with these areas connected by road networks. Before the railway was introduced, Kadıköy exhibited rural characteristics (Salah, 2013). One of the most significant developments of the 19th century was the migration of people outside the city walls and the establishment of sayfiye (summer resort) life in these areas (Çelik, 1996). With railway transportation, sayfiye life transitioned to suburban life with permanent residences. Historically, Kadıköy has evolved from rural-sayfiye-suburban to metropolis.

Kadıköy's main character derives from the road networks leading to the peninsula and the residential neighborhoods around it. In this system, between the northern Ziverbey road and the southern Marmara coast, urban textures with grid systems of irregular sizes are observed. While Bagdat Street forms the main axis of this system, the railway line integrates into this system according to the topography (Say & Özer, 2003).

There are nine railway stations in Kadıköy (Figure 7). The B2 suburban line was closed in 2013 and resumed service as Marmaray in 2019. Among these stations, Haydarpaşa and Kızıltoprak are not in use, Ayrılık Çeşmesi station has been newly added, and Göztepe station has been relocated. There are seven stations currently serving as Marmaray stations.

Within the scope of the study, the criteria are tested within a 1km diameter boundary circle around the Kadıköy stations. This distance was chosen because it can be easily walked in 15 minutes. After a 15-minute walk and site inspection around a station, the process was repeated for the remaining stations. The areas were mapped within a 1 km diameter and aligned horizontally. In Figure 8, the nine stations are listed horizontally, and the seven examination criteria are listed vertically. Stations in use are marked in blue, closed stations in gray, and stations added later in yellow. Green marks indicate the presence of an inspection criterion in the area; black marks indicate its absence. Notes taken during field inspections are displayed in the lower area. This rhizomatic mapping facilitates the correlation of information about the areas, allowing for a holistic reading.

Figure 7. Kadikoy mapping study and station points.

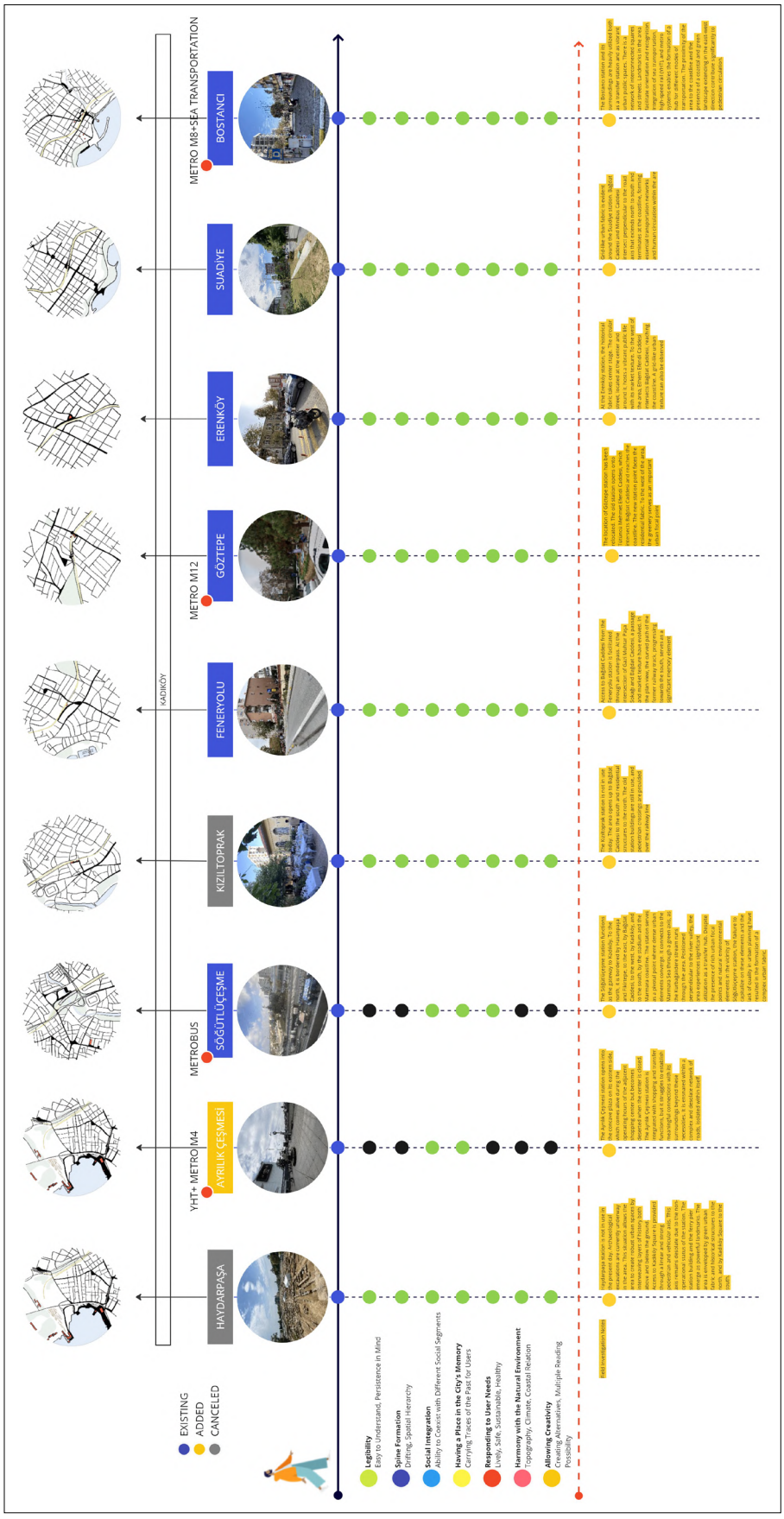

Figure 8. Marmaray Kadıköy stations rhizomatic mapping study.

After completing the mapping in Figure 8, the study was summarized with a holistic mapping study. Figure 9 shows that the green spots are concentrated around the old stations and their vicinities. Negative qualities (Ayrılık Çeşmesi, Söğütlüçeşme) emerge in the urban fabric, which is newly added and complicated by the intertwining of different transport systems, particularly around Ayrılık Çeşmesi and Söğütlüçeşme. This suggests that the quality of the urban fabric and public life around the old stations remains positive.

After the holistic analysis of the line, the station environments were categorized according to their characteristics. Each station environment exhibits a distinct urban structure and social life. Some have become transfer stations with the convergence of different transportation systems, others are primarily residential, some are characterized by urban spaces surrounded by buildings with square-like features conducive to public use, others open onto industrial areas, and some are oriented around shopping centers.

The seven examination criteria are elaborated through mapping studies within a 1 km radius of the stations. Stations where the qualities according to these criteria are prominent are analyzed. In the mapping study, road networks are drawn in black, and building blocks appear as gaps created by these networks. Where the black lines thicken, the street texture transitions into squares, enhancing public life. The train line is depicted with a yellow dotted line, coastlines and rivers in blue, and green spaces in green. Old railway station buildings and historical city landmarks are marked in red.

Legibility: Although Haydarpaşa station is closed to use, when its surroundings are analyzed in terms of legibility, it creates a strong image (Figure 10). Haydarpaşa station is bordered by the station building to the east, the green texture to the north, the urban texture of Kadıköy to the south, the Marmara Sea to the west, and the silhouette of the Historical Peninsula. The station point is situated at the center of strong urban nodes. Moving towards Kadıköy Square along the linear axis from the station, the green texture transitions into the urban texture. During the pedestrian experience around the station, which is enveloped by diverse urban textures, one texture gradually transitions into another. This facilitates the perception of the parts of the image formed in different time periods and enhances memorability.

Ayrılık Çeşmesi station, located to the northeast, contrasts with Haydarpaşa in terms of legibility (Figure 10). It is challenging for pedestrians to perceive the surroundings while reaching the central points along a weak and complex axis. Departing from the square defined by the shopping center renders the area desolate, and the continuity of public life is disrupted.

Although Söğütlüçeşme station and its environs possess prominent landmarks, they exhibit negative characteristics in terms of legibility (Figure 11). The area constitutes an urban texture where transportation systems converge and become entangled, with the railway line and Kurbagalıdere acting as boundary elements. As the railway line extends overhead, it generates unused spaces beneath it. Kurbagalıdere flows underneath the site, remaining unnoticed. Consequently, the components of the image cannot be perceived and assessed.

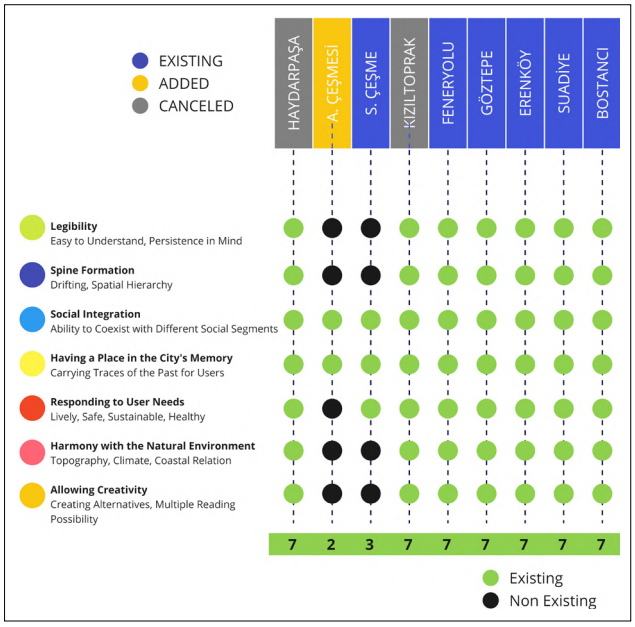

Figure 9. Marmaray Kadıköy Stations holistic mapping.

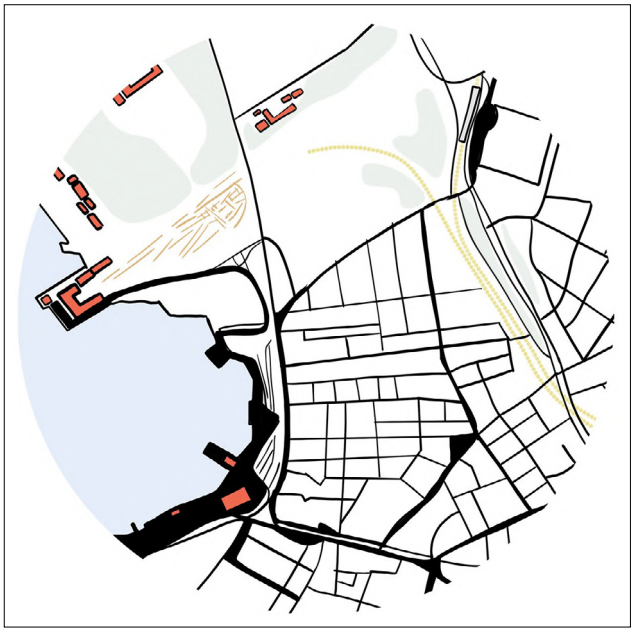

Figure 10. Haydarpaşa-Ayrılık Çeşmesi 1 km in diameter area mapping.

Figure 11. Söğütlüçeşme 1 km in diameter area mapping.

Spine Formation: Among the stations evaluated, Bostancı demonstrates robust spine formation (Figure 12). The arrangement of public spaces around the station guides individuals from one location to another, navigating them through the interstitial spaces. In Bostancı, urban spaces interconnect from north to south. Spaces broaden to form plazas, contract into streets, and then widen once more, delineating another plaza. This spinal configuration persists from the marketplace texture in the north down to the coastal line in the south.

From the north, the market is replaced by the square and the transport node, and then by sea transport and coastal use. The squares define strong rectangular public spaces surrounded by buildings.

Linear spine formation is observed in and around Suadiye station (Figure 13). The spine axis is formed in the north-south direction, between the Marmara coast in the south and Şemsettin Günaltay Street in the north. On this axis, buildings retreat and define small-scale squares and connect to each other.

The spine system formed in Suadiye is also strengthened by vertically intersecting important urban centers such as Bağdat Street and the coastline. Squares are formed at these vertical intersection points.

Figure 14 drift map shows the holistic spine formation of Kadıköy. There is a strong spine formation at Haydarpaşa and Kadıköy Square in the west direction, and this spine formation is interrupted towards the east where Söğütlüçeşme and stadium buildings are located. Kızıltoprak and Feneryolu station areas are connected to Bağdat Street by establishing a direct relationship with this street. Göztepe and Erenköy station neighborhoods form nodes in the north close to Fahrettin Kerim Gökay Street and vertical axes towards Bağdat Street and the coast. Around Bostancı and Suadiye stations, Fahrettin Kerim Gökay Street, Bağdat Street, and the coast are closest to each other, and a strong spine formation emerges.

Social Integration: Söğütlüçeşme station and its surroundings allow different age groups, genders, ethnic identities, and social lives to come together due to its proximity to Kadıköy. The fact that it is a transit center

Figure 12. Bostanci 1 km diameter area mapping.

Figure 13. Suadiye 1 km diameter area mapping.

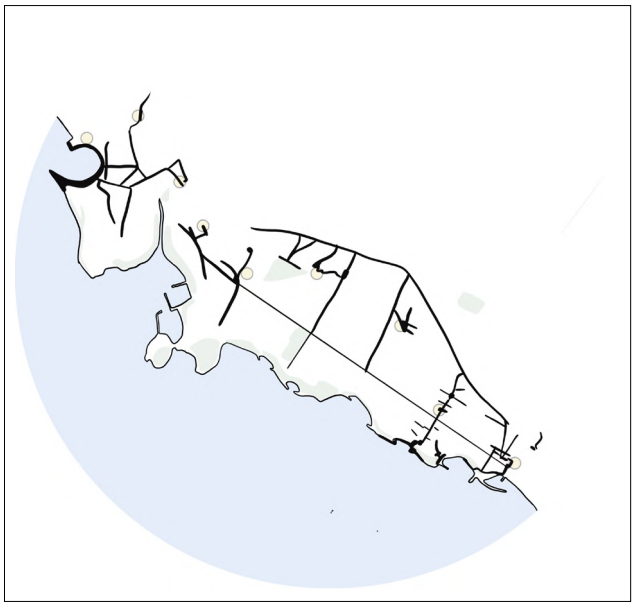

Figure 14. Kadıköy holistic spine formation and drift mapping.

and Kadıköy is a center of attraction allows people with different backgrounds to see and contact each other. Since this point is also the center of sports, arts, and activities, it brings together different functions. The coexistence of different functions enables the area to be socially enriched.

Having a Place in the City's Memory

Areas where historical environmental features are legible in urban spaces make users prefer these areas and want to be more present in the area. Haydarpaşa preserves its importance in the urban memory even though it is not currently used. Being the entrance threshold to the city in the past increases the importance of the area in the historical process. The fact that the station structure is one of the important urban images, as well as important points such as its integration with maritime transport, archaeological site, Kadıköy transportation axis, ensures that this area maintains its actuality. The spatial traces of Türkiye's economic, political, and social dynamics and transformation can be easily read in the area.

Responding to User Needs

When Kızıltoprak, Feneryolu, Göztepe, and Erenköy station areas are analyzed, it is seen that they are predominantly residential areas. These areas form neighborhood scale textures that meet the daily needs of people.

Kızıltoprak (Figure 15) and Feneryolu (Figure 16) stations have a close relationship with Bağdat Street with direct access, while Göztepe (Figure 17) and Erenköy (Figure 18) stations provide access via avenues extending in the north-south direction. In all four areas, there are facilities that allow both mandatory and optional needs to be met, making these areas full of life. At a distance

Figure 15. Kızıltoprak 1 km diameter area mapping.

Figure 16. Feneryolu 1 km diameter area mapping.

of 100 m, the coexistence of many different functions, active ground floors, and a lively bazaar life provide the criteria of fullness of life. Since business and residential buildings are located together, the spaces living day and night create safe environments. The urban texture that is appropriate for human scale and encourages pedestrian life strengthens the potential of these points to be healthy and sustainable. By observing people in urban spaces in these areas, it is seen that daily life movements such as going to work, spending time in urban furniture, shopping continue vividly.

Figure 17. Göztepe 1 km diameter area mapping.

Figure 18. Erenköy 1 km diameter area mapping.

Harmony with the Natural Environment

Traces of the natural environment can be read in current urban life. When the area is analyzed in a holistic manner (Figure 14), it is seen that the urban spaces developing parallel to the train line along the coast are shaped by establishing a relationship with the topography, coast, and green texture. Stations close to the coastal line (Haydarpaşa, Söğütlüçeşme, Bostancı) are shaped by river environments and coastal recreation areas. In the station distances away from the coast (Göztepe, Erenköy), it is seen that the altitude rises and access to the coast is provided by gridal urban textures. Bostancı station (Figure 12) and its surroundings are located in the centre of the river valley reaching the sea in the north-south direction. Söğütlüçeşme station (Figure11) is also located in the centre of the river valley in the north-south direction. These two stations are located in areas with similar geographical characteristics.

Allowing Creativity

The quality and quantity of urban elements in the public spaces around the stations make users want to visit these areas again. Qualified spatial formations also enable the formation of a strong urban image and allow the urban experience to be reconstructed over and over again in the mind. In this way, new relationship patterns regarding the urban space can emerge. Positive criteria in Bostancı station and its surroundings can create strong urban spaces. The formed spine allows different routes to be created so that the experience of the space can be differentiated each time.

CONCLUSION

With the method of a holistic view of the urban space created in the study, the areas were examined and mapping work was carried out. On-site examination, mapping, and evaluation of 9 station areas in Kadıköy were carried out according to the criteria. It is aimed to examine large-sized areas under equal conditions with systematic boundaries. These limits are to determine an area size of 1 km in diameter, to limit the inspection time to 15 minutes, and to repeat this for all station perimeters. Although stations such as Söğütlüçeşme and Bostancı are similar in terms of transfer function, it is seen that Bostancı station, which preserves the human scale and forms a strong backbone, is differentiated with this feature. Ayrılık Çeşmesi station cannot establish a relationship with the city except for shopping and transport functions. Since Haydarpaşa station is closed for use, it remains outside the urban life with its high potential. Feneryolu and Kızıltoprak stations enliven the daily life of the city due to their proximity to Bağdat Street and the coastline. Although the location of Göztepe station has changed, the old station area and the bazaar axis create spaces that easily meet user needs. Erenköy station opens to the bazaar area and creates an attraction area at a strong focal point, while spreading from this area to the surrounding area. Suadiye and Bostancı stations also create strong urban spaces at the nodes where the coastal and east-west transport systems converge. When the data obtained are evaluated, the following conclusions are reached for the method:

- The method enables understanding the holistic fiction of an urban area. It is possible to analyze the construction and social life of a dimensioned urban area at eye level and on the plan plane.

- The method of a holistic view of urban space enables the formation of urban public spaces and urban textures to be analyzed with background data.
- Holistic data is reached by induction. Partial data are brought together, and information about the whole is obtained.
- It can reveal the common or differentiating features of places that are distant from each other in terms of distance.
- It is possible to reproduce spaces through investigation and mapping. Through investigation and mapping, the hidden relationships between spaces, the prominent qualities of the space, or the qualities that are common with different spaces can be realized and revealed.

The study proposes a method to understand and analyze urban space in a holistic way. Through this method, which is called a holistic view of urban space, new studies can be carried out for purposes such as data collection in urban spaces and revealing the relationship between different urban spaces. In future studies where the method will be tried in different urban spaces, it is thought that different readings can be provided for urban spaces by changing the limitations such as the area diameter and the time spent in the area.

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