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Article

Illuminating fuzziness about Istanbul's urban growth dynamics through the lens of climate change impact with fuzzy modelling

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ABSTRACT

The fact that taking an action about controlling urban growth to minimize risks and adopt climate change is considerably significant in this century. This study explores the influence of urban growth dynamics on climate change indicators in İstanbul, Türkiye's largest metropolitan area. Unlike many other studies that primarily focus on individual indicators, this research comprehensively examines the association between urban growth indicators (UGIs) and climate change impacts (CCIs) by defining direct and indirect relations, contributing valuable insights to the literature by considering the main components of urban growth in the context of urban areas. Primarily, the literature was reviewed to release CCIs originated from urban growth and to highlight UGIs. After the study area was chosen as an İstanbul, population rate, economic structure and quality of life (QoL) as three main indicators of urban growth one by one were examined and some values/indexes about UGIs was compared with the İstanbul's value. Fuzzy Decision Making Technique (FDMT) in MATLAB programme was chosen as a methodology to be applied through main indicators which affect CCI in İstanbul. What the urban growth dynamics have effects on climate change was concluded by FDMT graphs that had been interpreted through five scenarios (the worst, bad, medium, good, the best). The study's results reveal a significant correlation between population, economy, QoL, and CCIs. Specifically, it is proof that a high population rate, low economic wealth, and low QoL are associated with heightened CCIs in İstanbul.

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INTRODUCTION

In the early 1990s, 15% of the global population lived in urban areas. By 2010, this figure reached 50.5%, and projections indicate it could reach 68% by 2050 (Ritchie, 2018). Urbanization, driven by anthropogenic factors, significantly impacts natural resources such as land, water, soil, and the atmosphere, triggering climate change and global warming (Neumann et al., 2015). Converting undeveloped land into urban areas disrupts ecosystems and generates climate change. This unrestricted urban growth paradigm leads to adverse environmental effects for both cities and nature (McEvoy and Wilder, 2012; Cooley et al.,

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2006; Johnson, 2001), exacerbating negative CCIs linked to greenhouse gas emissions (GHGs), the urban heat island (UHI) effect, extreme weather events, floods, and social challenges resulting from rapid urbanization.

The main aim of the research is to evaluate how urban growth patterns relate to CCIs through the utilization of the FDMT. This methodology allows for the evaluation of which urban growth indicators (UGIs) influence climate change and to what extent each indicator contributes, achieved through IF-THEN predictions implemented in the MATLAB program. In essence, uncontrolled and rapid urban growth stands as a principal driver of climate change, which is one of today's most critical global challenges (Ren et al., 2020; Zhang et al., 2020; Bektaş and Sakarya, 2023). This research focuses on understanding the extent of climate impact resulting from population growth, changes in economic structure, and alterations in quality of Life (QoL), all considered key components of urban growth. These selected UGIs offer the advantage of easier data access compared to other indicators, making them more representative and suitable for analysis.

This study distinguishes itself by considering selected UGIs collectively and making comprehensive inferences through an assessment of these indicators in urban areas in Türkiye. Initially, a literature review on urban growth and climate change was conducted. Subsequently, İstanbul was chosen as the case study area based on justifications. The inputs (UGIs) and output (CCIs) in İstanbul were evaluated using the FDMT. The methodology, conducted literature review, and the study's outcomes can provide guidance for future studies and policymakers.

LITERATURE REVIEW

The literature review encompasses two primary components, namely, the ramifications of urban growth on climate change and the assessment of UGIs on the climate change effects. First, this review delves into the consideration of GHGs, which are both a significant contributor and a consequence of climate change, attributed to urban growth. Subsequently, it evaluates various CCIs stemming from urban growth in leading countries engaged in climate change research. In the second section, a review of the relevant literature elucidates UGIs within the framework of all these climate change effects. Some of these indicators are more readily quantifiable due to their accessibility to data, whereas others necessitate local situational assessments and analyses, resulting in prolonged data acquisition processes. As part of this research, the forthcoming section will concentrate on relevant UGIs in İstanbul, Türkiye's largest metropolitan city, based on accessible data for evaluation.

GHGs not only constitute the principal driver of climate change but are also a fundamental component within the spectrum of CCIs (Worrell et al., 2001). Although the recent studies especially show that there are many indicators of climate change as annual mean temperature, maximum temperature, maximum precipitation, extreme weather events, UHI, sea level rise, and drought (Seneviratne et al., 2021; EPA, 2023), GHG is taken as the main indicator of climate change (WMO, 2017; EPA, 2023) due to their pivotal role in influencing Earth's temperature and climate system. GHGs, including carbon dioxide (CO_2), methane (CH4), and nitrous oxide, are responsible for the GHG effect. These gases trap heat from the Sun, preventing it from escaping back into space. This process, known as radiative forcing, is well-established in climate science. IPCC reports, such as the Fifth Assessment Report, extensively discuss the radiative forcing of GHGs and their impact on global temperatures (IPCC, 2013). Moreover, GHGs are a clear driver of changes in other climate indicators. For instance, rising CO_2 levels are closely correlated with rising temperatures (Hansen et al., 2005). By monitoring GHGs, scientists can better understand the primary drivers of various climate changes. Therefore, many international climate agreements, like Kyoto Protocol, are based on controlling GHG emissions. Monitoring GHGs is crucial for tracking progress toward emissions reduction goals and assessing the effectiveness of climate policies (Rosenqvist et al., 2000).

Anthropogenic factors, primarily driven by factors such as increasing population and economic policies, significantly contribute to the escalation of GHG emissions. The emission rates of GHGs vary among nations, leading to the formulation of distinct GHG emission scenarios for each country in compliance with international agreements addressing climate change, such as the Kyoto Protocol and the Paris Agreement (Figure 1).

As shown in Figure 1, MLT means mid-level transition, and the representation of CO_2 emissions is based on the classification of countries into Annex I and Non-Annex (Annex II) groups. In the context of the United Nations Framework Convention on Climate Change and the Kyoto

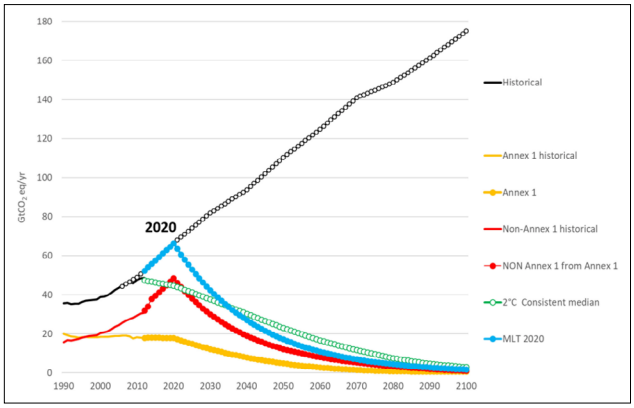


Figure 1. Yearly CO_2 emissions 1970–2100 and global scenario in the world (Perissi et al., 2018).

Protocol categorize countries based on their responsibilities and commitments regarding GHG emissions as "Annex I" and "Annex II" countries. Annex I countries are industrialized and developed nations that were historically responsible for the majority of GHG emissions. These countries include most of Western Europe, the United States (USA), Canada, Japan, Australia, and the United Kingdom (UK) among others. Since their emissions over the industrialization period have significantly contributed to the agglomeration of GHGs in the atmosphere, Annex I countries are considered to have historical responsibility for climate change. Therefore, Annex I countries committed to providing technological and financial assistance to Annex II for their efforts in addressing and adapting to climate change. Conversely, Annex II countries are a subset of Annex I countries. They include the most developed countries within Annex I. Annex II nations are anticipated to offer increased technological and financial aid to developing countries. Moreover, according to the Kyoto Protocol, Annex II countries are under a specific obligation to enhance financial support to developing nations for their climate change mitigation efforts (Rosenqvist et al., 2000).

However, as illustrated in Figure 1, immediately following the signing of the Kyoto Protocol, it is evident that the emission rates in countries falling within the Annex II category, such as China and India, significantly exceeded those in developed nations (Annex I). Furthermore, empirical studies have indicated that, according to projected trends, emissions from Annex II countries are anticipated to surpass those of other nations well into the 2070s. This phenomenon may be elucidated by the propensity of developed countries to engage in GHG-emitting investments within Annex II nations or by the pursuit of GHG-intensive investments by countries already situated within the Annex II group, as they endeavor to achieve economic development (Perissi et al., 2018).

It is important to note that these categories have evolved in international climate negotiations, and the obligations of countries under newer agreements such as the Paris Agreement are more diverse and flexible. Under the Paris Agreement, all countries, both developed and developing, are expected to contribute to global climate action based on their capabilities and responsibilities. The concept of historical responsibility remains relevant in discussions about climate justice and equity, but it is not the sole basis for determining emissions reduction targets and commitments in modern climate agreements (UN, 2015). Given that climate change manifests varying impacts/indicators across different geographic regions, encompassing a spectrum of factors such as GHGs, meteorological and climatic patterns, marine environments, snow and glacial dynamics, public health and societal dynamics, and ecological systems, it is imperative to comprehend the distinct political responses associated with climate change in diverse nations. Consequently, this study focuses on the Netherlands, the UK, and the USA as exemplars of countries at the forefront of formulating climate change policies in response to CCIs. In addition, China positioned among the primary contributors to GHG, and Türkiye representing a notable case study within the context of this research, are also included. Within this framework, a comparative analysis is conducted to elucidate the climate change effects stemming from urban growth among these selected five nations.

Urban growth associated with climate change is a complex interplay that encompasses various critical indicators. Sea-level rise, while pivotal for countries with coastal areas such as the Netherlands (Amsterdam and Rotterdam) and the UK (London and Cardiff), may not directly correlate with urban growth. To grasp the complete picture, it's essential to connect sea-level rise data with urban development trends (Roggema, 2014). UHI effect, conversely, is a localized temperature rise within cities compared to the outskirts of rural areas affected by human actions and urban infrastructure. While it might not encapsulate the full spectrum of climate impacts, especially in diverse metropolitan areas, it remains a significant indicator, notably in rapidly urbanizing regions such as the Netherlands, the USA, and Türkiye. Rapid urbanization exacerbates the UHI effect, intensifying heat waves in cities and linking it directly to urban growth (Oke, 1982; Stone and Norman, 2006). Furthermore, urbanization can alter drainage systems, increasing vulnerability to flooding, especially in low-lying areas, as seen in the Netherlands and Türkiye. In Turkish cities like İstanbul, rapid urbanization heightens the risk of urban flooding events, demonstrating the adverse impact of urban growth on flood risk (Gedikli and Balaban, 2018).

Urban expansion and land-use changes are significant climate change indicators, closely associated with urban growth. Monitoring land-use transitions, such as converting green spaces to urban infrastructure or agricultural zones into urban areas, helps understand urban sprawl. This is especially relevant in the UK and China, where urban expansion contributes to climate change by increasing energy consumption and GHG emissions, as observed in the USA (Scheraga and Furlow, 2001). Conversely, urbanization can lead to increased air pollution, notably in the UK and China (e.g., Beijing and Shanghai). Monitoring air quality parameters like PM2.5, NO_2, and O_3 highlights the influence of urban growth on the quality of the air and its impact on public health. It is not only attributed to urban growth but also industrial activities resulting from rapid urbanization (Song et al., 2017), as seen in Türkiye's industrial cities such as İstanbul, Kocaeli, and Bursa. Finally, water stress is a multifaceted issue shaped by the mixed impacts of urban growth and climate change. Chinese municipalities, experiencing escalating urbanization, face increased water stress due to rising demand. Türkiye

also witnesses urban water demand contributing to water stress, influenced by factors such as agricultural practices and regional climate patterns. Monitoring variables such as drought frequency and severity aids in understanding climate-related impacts on urban water resources (Gedikli and Balaban, 2018).

In conclusion, while contemporary times witness the presence of virtually every climate indicator in every country, Table 1 presents the predominant CCI specifically within the case countries (Table 1).

Among the five examined countries, UHI, urban expansion/sprawl, and air quality issues emerge as the most frequently encountered CCIs stemming from urban growth as shown in Table 1. Furthermore, numerous urban growth effects exhibit a direct relationship. It is essential to recognize that each indicator possesses inherent strengths and limitations. Hence, a comprehensive comprehension of the interplay between urban growth and climate change within a specific region necessitates the utilization of a multifaceted indicator approach. Nevertheless, it is noteworthy that Türkiye stands out as the province experiencing the most pronounced CCIs in comparison to its counterparts. Hence, there is an urgent requirement for an expansion in research efforts pertaining to this subject matter within the Turkish case.

UGIs pertaining to the climate change effects are addressed in the second part of the literature review. These indicators encompass quantifiable variables that signify the growth and progression of urban regions and elucidate their ramifications on the local and regional climatic conditions. First, land-use changes, involving the conversion of green spaces or forests into urban areas, are discernible through land cover data and satellite imagery (Lambin et al., 2001; Zhang et al., 2020). These alterations can impact surface properties, affecting temperature, precipitation, and local climate patterns. Human-induced alterations in land use and land cover influence climate through two pathways: the biogeophysical pathway, which involves altering physical land surface characteristics such as albedo, soil moisture, and roughness, and the biogeochemical pathway, which considers changes in GHG concentrations (e.g., CO_2, CH4, N_2O) resulting from shifts in land-atmosphere fluxes of these gases (Kennedy et al., 2009). Furthermore, the density, design, and layout of urban infrastructure and the built environment affect local climates. Compact urban forms with mixed land uses can reduce energy use and transportation emissions (Newman and Kenworthy, 1999).

As urban populations continue to expand, cities will exert an increasingly pronounced influence on climate change. This heightened urban impact makes urban areas more vulnerable to various climatic events, including floods, rising water levels, heat waves, droughts, and storms. The relationship between expanding urban development and its impact on local climates is especially significant when considered at a provincial scale that encompasses both urban and rural areas (Bektaş and Sakarya, 2023). Land uses paramount influence on climatic conditions becomes particularly evident within urbanized territories. The expansion of urban centers, combined with higher population density, leads to significant shifts in land use patterns, increased energy consumption, and modifications in surface characteristics, resulting in UHI phenomenon, where urban areas experience localized temperature elevations compared to rural surroundings (Stone, 2009). Thirdly, indicators related to transportation patterns, such as the vehicle numbers on the road, mode shares (e.g., walking, cycling, and public transit), and congestion levels, are crucial for understanding emissions and air quality (Sallis et al., 2016).

Conversely, the population is a pivotal UGI linked to CCIs. It signifies urban residents and significantly shapes cities' environmental footprint and vulnerabilities in the climate change context (Chen et al., 2014; Yi et al., 2016; Ren et al., 2020). Growing urban populations demand expanded infrastructure, causing notable changes in land use patterns that impact climate dynamics (Black et al., 2008; Bektaş and Sakarya, 2023). Urban population encompasses size, density, demographics, migration, and social dynamics. High densities increase energy usage for heating, cooling, transport, and infrastructure, affecting GHG emissions (Seto et al., 2016). The number of urban residents influences

Table 1. Climate change indicators due to urban growth

	Countries				
Climate change indicators/impacts	**The Netherlands**	**United States (USA)**	**United Kingdom (UK)**	**Türkiye**	**China**
Sea level rise	*		*		
UHI	*	*		*	
Flooding	*			*	
Urban expansion and urban sprawl		*	*		*
Air quality			*	*	*
Water stress				*	*

GHG emissions from transportation, heating, industry, and waste (Kennedy et al., 2009). Urban population growth rates and distribution affect land use, transportation, land cover, local climate, air quality, and ecosystems (Wu, 2014).

Figure 2 illustrates the United Nations' country categorizations based primarily on economic factors but also incorporating human development and other criteria. More developed countries, such as the USA and Western European nations, exhibit advanced industrialization, technology, and high per capita income, leading to a high living standard and Human Development Index scores. Less developed countries, including parts of Latin America and Asia, are in transition from low to high income, typically with lower industrialization and technology levels. Least developed countries represent the poorest nations with low income, limited industrialization, and basic infrastructure, categorized using UN criteria such as income, human assets, and economic vulnerability (UN, 2011).

In light of these, it is predicted that less developed regions reached high population rate while the population rate of developed countries is stable. The high population in less developed or developing countries highly concentrates GHG emissions. They classified the population into three groups according to CCIs as 2–4 million has low impact, 10 million has medium impact and approximately 15 million has high impact on climate change (Jiang and Hardee, 2011; UN, 2011).

Urban economy/economic structure can be considered another significant UGI related to CCIs the urban economy encompasses financial activities and their role in climate change (Commission on Growth and Development, 2009; Kahn et al., 2019). Limited research explores how the economy triggers CCIs (Commission on Growth and Development, 2009; Stern, 2008). It involves factors such as GDP, industry composition, employment, income distribution, and economic resilience within urban boundaries (Yi et al., 2016; Ren et al., 2020). Urban economic composition, including sectors such as manufacturing

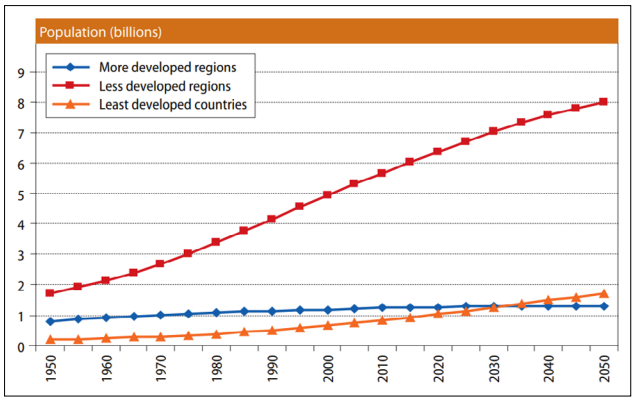


Figure 2. Projected population by development regions (1950–2050) (UN, 2011).

and services, affects energy use, resource consumption, and emissions. High-emission industries contribute to climate change, while green sectors mitigate it (Stern, 2008; Lu, 2018). The economy can increase or decrease a city's climate change vulnerability. Energy-intensive industries, transportation, and buildings are key GHG emission sources. Sustainable urban development aims to separate economic expansion from emissions (Bowen et al., 2012). The urban economy also provides jobs and income. Economic disparities affect the vulnerability and adaptive capacity of urban populations to climate change (Zografos et al., 2016).

On the other hand, the economic situation of the developed countries is more resilient due to transforming their economies from carbon dependent to clean and green economy than less developed and developing countries; therefore, there are no negative impacts of climate change (Raddatz, 2009; Dell et al., 2008). However, for instance, Türkiye is among the developing nations globally can affect the climate change due to its economic growth policies. The growth policies mostly depend on carbon-based sectors (industry and agriculture) (OECD, 2020), which leads to increase sensitivity to climate change. Moreover, economic structure has unique variables for each city in a country. According to the OECD Better Life Index, it is assumed that the average household net disposable income per capita is 30.563 USD (227.331 TL) in a year while it reaches 69.477 USD (516.778 TL) in a year for highly developed countries. In addition to this, household income in undeveloped countries has on an estimated 11.026 USD (82.012 TL) a year (OECD, 2020). It is obviously that there exists a substantial disparity between countries' economic situation originating from development status, which is an important dynamics for taking action against climate change.

QoL is a multifaceted indicator of urban growth (Rahman et al., 2011). Some studies suggest that urban growth negatively affects QoL, attributing this to population growth and environmental issues (El Din et al., 2013). However, others argue that as the economic structure, a key UGIs, improves labor skills, QoL can also improve. High living standards often lead to the expansion of living environments, positively impacting QoL. Urban growth's macroform, encompassing city spatial layout, and structure, significantly influences residents' QoL. Factors such as urban sprawl, density, access to amenities, and green spaces play vital roles in well-being. For instance, higher-density, transit-oriented development can reduce vehicle use, improve air quality, and enhance QoL indicators such as reduced traffic congestion and lower healthcare costs (Ewing and Cervero, 2010). However, the relationship between QoL and urban growth is complex. Effective, sustainable urban planning can enhance QoL by improving access to services, economic opportunities, and cultural amenities, reducing spatial inequalities, and promoting social inclusion (Stratigea et al., 2019).

Conversely, uncontrolled urban growth with issues such as congestion, pollution, inadequate infrastructure, and reduced green spaces can harm QoL, leading to stress and health problems (Gehl, 2013). Mitigating negative impacts and enhancing positive aspects of urban growth on QoL requires effective land use planning, sustainable transportation, green infrastructure, and social services.

In general, in contrast with the population growth, improving QoL has a positive impact to adapt climate change. According to OECD Better Life Quality Index, the environment which consists of air quality and water quality is one of the indicators of QoL and it affects climate change. Environmental index values of developed countries such as Norway, Sweden, Finland, and Australia are very high in there (approximately 10) (the values from 1 to 10). However, the QoL in terms of environmental conditions value equal to 3 in Türkiye as one of the developing countries, which demonstrates that the vulnerability of climate change partially high in contrast to developed countries. Similarly, NUMBEO index which is online data to calculate the QoL in the world cities demonstrates that İstanbul in Türkiye is ranked approximately 112 score (Values from 40 to 200), while developed cities are ranked approximately 200 score. It takes into account various factors that impact one's QoL, including purchasing power, pollution levels, housing affordability, cost of living, safety, healthcare quality, commute times, and climate conditions in NUMBEO. The index is designed to provide a comparative measure, where a higher index value indicates a better QoL.

Finally, the Climate Change Performance Index for the year 2019 was scrutinized. This index incorporates GHG emissions (weighted at 40%), renewable energy (weighted at 20%), energy use (weighted at 40%), and climate policy (weighted at 20%) as its key components. Accordingly, Sweden holds the top position with a score of 76.28, followed by Australia, Norway, and Finland in succession. Türkiye, on the other hand, ranks 50th with a score of 40.22 (Burck et al., 2018). In light of these findings, the assessment of the literature regarding the relationship between UGIs and CCIs is presented in Table 2.

As observed in Table 2, CCIs are associated with UGI in both direct (indicated in red as "D") and indirect (indicated as "I") manners. It is demonstrated that GHG emissions can be directly influenced by all UGI. Furthermore, for instance, when there is any alteration in land use, GHG emissions, UHI effect, flooding, and urban expansion are directly affected, whereas sea-level rise, air quality, and water stress are indirectly impacted. Alternatively, if the economic structure transitions towards greater sustainability and eco-friendliness, there can be a direct interaction since GHG emissions and UHI may decrease while air quality improves. Additionally, increased budget allocations for investments in urban systems can lead to measures being taken to mitigate flooding. QoL is indirectly related to nearly all CCIs among UGI. This suggests that the QoL indicator is contingent upon population and economic structure and falls within their purview. Population exacerbates the effects of climate change, whereas economic structure can either mitigate or exacerbate these effects. However, a high QoL mitigates the impacts of climate change.

Consequently, the indicators highlighted within the delineated area marked by the dashed red line (population, economic structure, and QoL) have been designated as three criteria for evaluation. The choice is made considering the greater ease of data accessibility and measurability in İstanbul in comparison to other UGIs (Figure 3).

CASE STUDY: ISTANBUL IN TÜRKİYE

Research endeavors aiming to assess the interplay between UGIs and the ramifications of climate variability reveal that population size, economic structure, and the QoL serve as the primary determinants of urban growth, which subsequently exert considerable influence on climate change dynamics (McDonald et al., 2011; Neumann et al., 2015). Developing countries like Türkiye, driven by

Table 2. Literature review about urban growth and climate change impacts

Climate change indicators/impacts	Urban growth indicators (UGI)					
	Land-use change	Built environment	Transportation pattern	Population	Economic structure	Quality of life
GHG	D	D	D	D	D	D
Sea level rise	I	D	I	I	I	I
UHI	D	D	I	I	D	I
Flooding	D	D	D	D	D	I
Urban expansion and urban sprawl	D	D	D	D	D	I
Air quality	I	I	D	I	D	I
Water stress	I	I	I	D	I	I

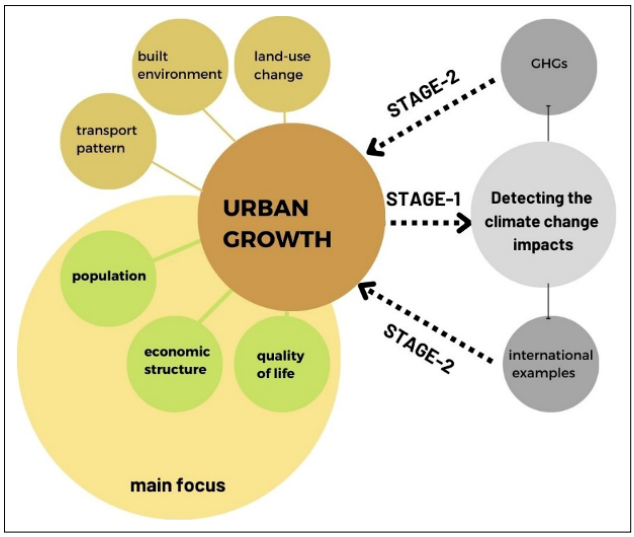


Figure 3. The content of literature review.

their urban expansion ambitions, can exhibit to increase susceptibility to the CCI. To explore the outcomes of urban growth in relation to climate change, Istanbul was chosen as a case study within Türkiye. This choice is underpinned by İstanbul's status as Türkiye's most populous city, as high urban population densities, as evidenced in the literature, tend to intensify CCIs due to anthropogenic factors. As Türkiye's top GHG emitter, İstanbul has a vital role in spearheading mitigation and adaptation efforts. In 2015, İstanbul accounted for about 10% of Türkiye's total emissions, equivalent to 47.3 million metric tons of CO_2 (İMM, 2018) (Figure 4).

As shown in Figure 4, İstanbul's 2015 GHG inventory totals 47.3 million metric tons of CO_2 equivalent. Due to ongoing growth, especially in population, emissions are expected to peak in 2050. Under the Business As Usual scenario, İstanbul's emissions are projected to reach 84.7 million metric tons of CO_2 by 2030 and 117.9 million metric tons by 2050, aligning with Türkiye's Intended Nationally Determined Contribution target of a 21% reduction by

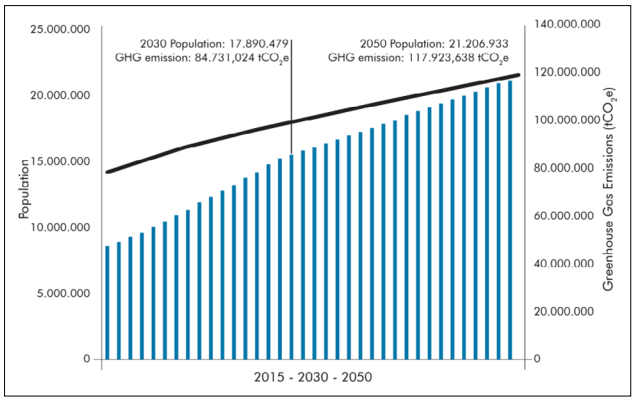


Figure 4. Istanbul's greenhouse gas emissions projections for 2015–2050 (İMM, 2018).

2030. This ambitious goal highlights the need for climate adaptation and mitigation measures, which can bring additional benefits such as improved air quality and QoL. Evaluating population, current economic conditions, and QoL is vital for addressing climate change impacts in İstanbul (İMM, 2018).

First, İstanbul currently hosts an estimated population of around 16 million, the highest in Türkiye, and is projected to reach approximately 18 million by 2025, as reported by TURKSTAT in 2019a (Figure 5).

Figure 3 shows the population rate in past, current, and predicted population in İstanbul. İstanbul with the highest population in Türkiye is totally urbanized city. After 2000s, population increases eventually, which causes dense GHG emissions in the city (İMM, 2018). This can be the main output of economic structure. The economic structure is the second reason why İstanbul was selected as case study. İstanbul accounts for producing some 31% of Türkiye's economy (TURKSTAT, 2019b), so İstanbul is called as the heart of the economy. Likewise, it is explained in İDA report in 2017, İstanbul is defined as economic engine of not only city scale but also country scale growth. This leads to increase urbanized population. Due to the current economic structure and growth energy uses and GHG emissions are concentrated in city (McDonald et al., 2011; İMM, 2018), which triggers CCIs. However, it is approved that economy is more vulnerable and financial collapse can be occurred by the impacts of climate change (Ren et al., 2020; Chen et al., 2014; Yi et al., 2016). Therefore, there are two-side interaction among economic structure and the impacts of climate change.

Figure 6 illustrates the use of average personal disposable income as a metric for measuring urban economic structure at the city scale, based on data from TURKSTAT in 2019a. This choice stems from the initial phase of economy involves augmenting wealth through increased personal income, as suggested by Neumann et al. in 2015. Alongside population and economic structure, QoL emerges as another UGI intertwined with CCIs. Unlike other urban growth metrics, an improvement in QoL corresponds to a reduction in CCIs. To gauge İstanbul's QoL, data from NUMBEO (Url-

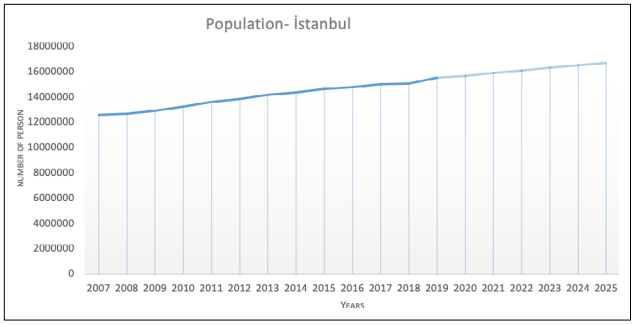


Figure 5. Yearly population rate from 2007 to 2025.

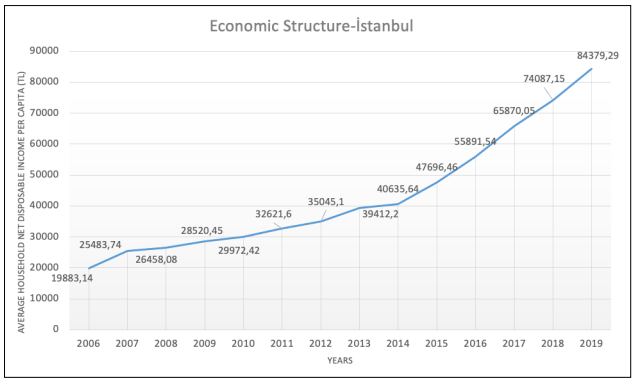


Figure 6. Yearly economic situation from 2006 to 2019.

1), a repository with an extensive cost-of-living database, was employed. This assessment considered various indices, encompassing power, pollution, house price-to-income ratios, cost of living, safety, healthcare, traffic commute times, and a climate index. These factors were incorporated with differing weightings to derive an overall QoL estimate, as depicted in Figure 7.

Figure 7 graphically portrays a consistent decline in İstanbul's QoL index from 2016 onwards. This decline is a direct reflection of İstanbul's enduring urban growth, which encompasses economic, social, and spatial dimensions. İstanbul is not the sole Turkish city with a quantifiable QoL index; other cities such as Ankara and Bursa also possess such metrics. However, İstanbul's QoL index is markedly lower than that of these cities, underscoring its vulnerability to CCIs.

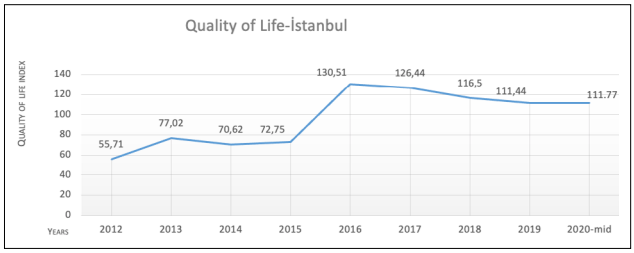


Figure 7. Yearly life quality index from 2012 to 2020-mid.

To avert such outcomes, it is crucial to implement preventive actions in İstanbul. This includes addressing urban growth-related issues and defining solutions through structured planning stages. Identifying primary action areas guided by UGIs drawn from the literature is crucial. Techniques like the FDMT can be employed to ascertain which indicators have the most substantial impact on climate change in İstanbul and propose effective strategies for climate change adaptation. Table 3 synthesizes insights from both the literature review and İstanbul's unique context, with the values for general inputs extracted from Section 2 of the literature review.

Table 3 categorizes values into two groups: One derived from the literature review, and the other from specific to İstanbul, all based on UGIs influencing climate change. To facilitate comparison, logarithmic equations were used to normalize these values. These normalized values hold significance in the execution of a fuzzy logic model in MATLAB.

METHODOLOGY AND APPLICATION

The literature review's second part identified UGIs linked to CCIs, selecting specific indicators for the methodology. Fuzzy logic, defined by Lotfi Zadeh in 1965, offers a variable logic system where truth values range from 0 to 1 (Zadeh, 1973; 2009). Fuzzy models, using IF-THEN rules/predictions and membership functions, allow for visualizing uncertainty and handling imperfect data (García et al., 2014). This approach excels in dealing with uncertain information. To illustrate, in analyzing the UGIs-CCIs relationship in İstanbul, fuzzy logic was employed. Inputs

Table 3. Entries/variables for applying fuzzy logic model

Indicators	Literature review			İstanbul	
	Values in general		Normalized values	Values in 2019	Normalized values
Population (Jiang and Hardee, 2011; UN, 2011)	4 million	low	6.60	15.519.267	7.19
	10 million	medium	7		
	15 million	high	7.20		
Economic structure (OECD, 2020)	82.012 TL	low	4.91	84.379 TL	4.92
	227.331 TL	medium	5.35		
	516.778 TL	high	5.71		
Quality of life (NUMBEO, 2019)	42	low	1.62	112	2.04
	130	medium	2.11		
	203	high	2.30		

included population, economic structure, and QoL, and MATLAB's Fuzzy Toolbox Software was used for analysis. The process unfolded in three modules, revealing CCIs drivers. The following steps provide concrete examples of the MATLAB process:

- Initiating the fuzzy inference system (FIS) editor with entry variables (Figure 8)
- Structuring membership function plots (Figure 9)
- Applying fuzzy operators through membership functions and the rule editor (Figure 10)
- Aggregating all outputs using the results viewer (Table 4) in the evaluation phase (evaluation part).

Figure 8 shows FIS editor which is one of the MATLAB interfaces. FIS was developed as three inputs and one output with Mamdani type.

Figure 9 displays membership function plots for three key indicators: population (measured by the number of individuals), economic structure (represented by net disposable income per capita), and QoL. They were selected due to their pertinence and previous examination in the literature review (Section 2). For the İstanbul case, these indicators have been normalized and assigned membership functions. In addition, specific value ranges (low, medium, high) have been defined and gathered from the from the literature review.

Figure 10 displays the membership function editor, allowing customization of titles, ranges, and parameters for input and output variables. It facilitates IF-THEN predictions using selected membership functions. In this context, there are twenty-seven rules per urban growth dimension, coming from the literature review and TURKSTAT data. In addition, three membership function plots (low, medium, high) assess CCIs in İstanbul. The results reveal how indicators interact, their collective impact on climate change, and which indicator has a dominant role in exacerbating climate change effects. After defining these rules in MATLAB, the aggregation of outputs, influenced by input variables, is presented in the results viewer within the Results and Evaluation section (Figure 11).

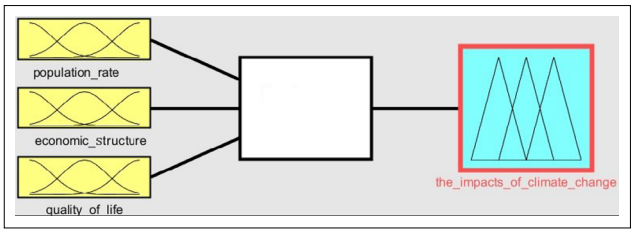


Figure 8. FIS editor.

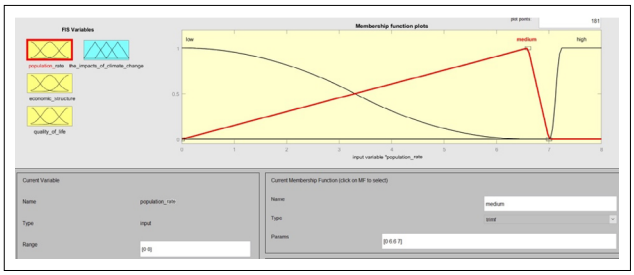


Figure 9. Membership function plots.

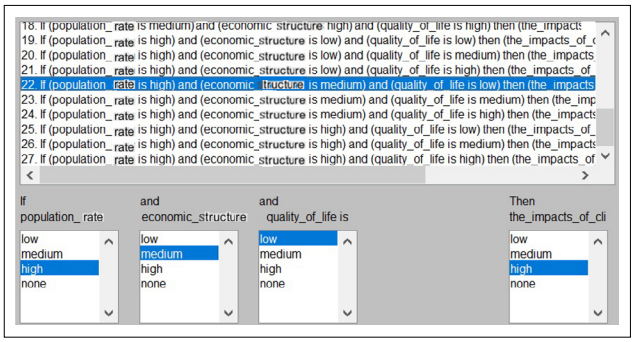


Figure 10. Membership function editor.

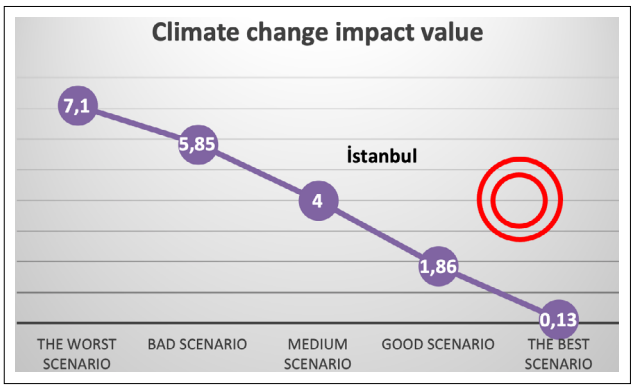


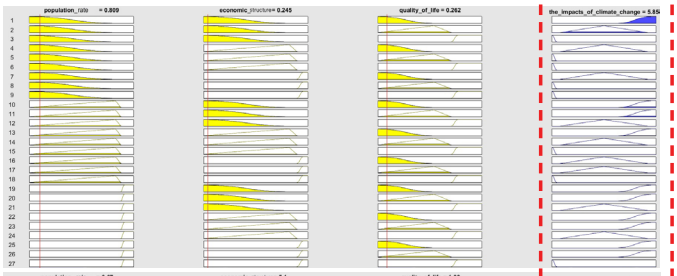
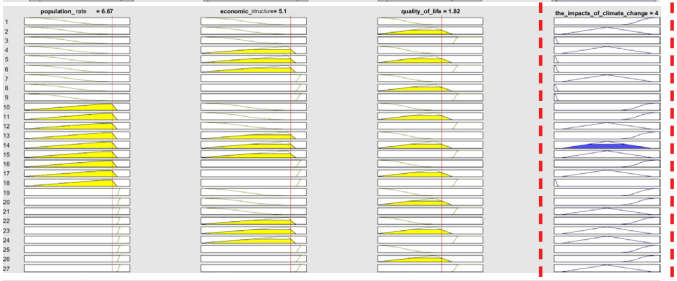
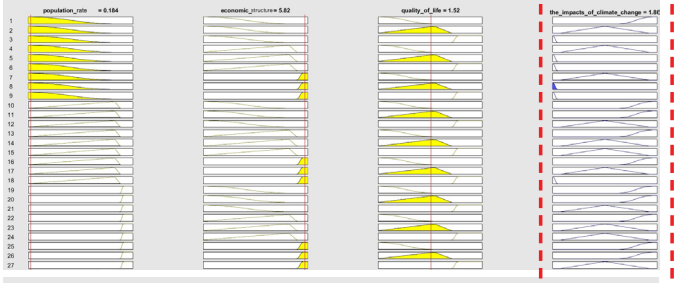
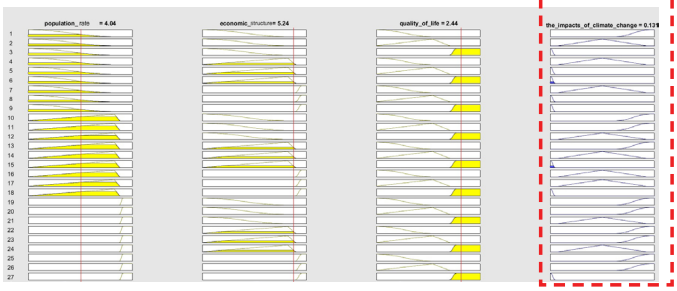
Figure 11. Climate change impact value by scenarios.

FINDINGS

The findings depict the status of UGIs-population, economic structure, and QoL-within the scope of climate change in İstanbul. Drawing from the outcomes acquired from MATLAB Fuzzy Logic, five distinct scenarios are defined, covering outcomes from the least favorable to the most favorable. In these scenarios, initially, all three indicators are considered of equal weight. However, the weights for each indicator change in line with scenario priorities (e.g., low-medium-high). For instance, in one scenario, the population rate may be high while the economic wealth rate is low, whereas in another scenario, this combination may differ (Table 4). In the result column, yellow colors are related to UGIs, and the blue color represents the amount of impacts of climate change.

As evident in Table 4, under the most unfavorable scenario, if the population is high but economic conditions and QoL are low, the potential CCIs can be exceptionally severe. It

Table 4. Evaluation chart

	Population rate	Economic wealth	Quality of life rate	Results
The worst scenario	high	low	low	
Bad scenario	low	low	low	
Medium scenario	high	high	medium	
Good scenario	low	high	medium	
The best scenario	medium	high	high	

is plausible to anticipate that CCI will be strongly felt in İstanbul. In contrast to this worst-case scenario, changes in population rate from high to low alone directly influence the potential climate change scenario in a positive manner. Nevertheless, it can be discussed that CCIs will persist unless improvements are made in QoL and the economy is shifted toward a climate-oriented approach in İstanbul.

When both population and economic conditions are high, and QoL remains at a medium level, the resulting CCIs are moderate, signifying a neutral outcome. These parameters closely align with İstanbul's present situation, reflecting the city's current scenario. However, the study findings offer

insights into how this condition can be improved. When population is low, economic conditions are high, and QoL is at a medium level, the CCIs are rarely severe, indicating minimal effects in İstanbul. This scenario can be realized through increased climate awareness among citizens and support from local and national governments. It serves as a guide for İstanbul in addressing climate change and hints at the city's potential for enhanced sustainability. Furthermore, in a scenario where economic prosperity and QoL are high, coupled with a moderate population, the CCIs would be extremely limited. İstanbul could join the ranks of sustainable, climate-adaptive cities like those in Norway and Finland. CCIs in İstanbul would be systematically managed, aligning with practices seen in climate-adaptive cities.

In summary, this study assessed possible CCIs through five scenarios, analyzing the interaction among climate change and UGIs within a specific case (İstanbul) using FDMT.

CONCLUSION AND EVALUATION

This study used an FDMT based on MATLAB to examine the impacts of UGIs on climate change in an effort to contribute to the literature by conceptualizing a systematic comprehensive approach using the current values at the urban level. The model is exemplified by population, economic situation, and QoL, which could be used by decision-makers to produce climate change adaptation policies with decreasing the area of CCI.

The study evaluated the results in accordance with the research objective. The unique aspect of this study is its comprehensive approach, which brings together UGIs (population, economic structure, and QoL) that are often studied independently in the literature and highlights them in the concept of climate change effects, defining both direct and indirect relationships. This provides a holistic conceptual perspective that does not rely on a single cause for CCIs.

The impact of climate change varies across different scenarios, with the best scenario having the lowest impact and the worst scenario having the highest. İstanbul's current situation aligns with the 3rd scenario (represented by the red circles). If İstanbul's population continues to grow rapidly, it may end up in the worst-case scenario (Scenario 1). However, implementing economic transformations to reduce population density and enhance QoL could lead to the best possible climate scenario. Notably, changes in QoL are closely linked to population rate and economic structure (Figure 11).

In contrast to previous research (Dell et al., 2008; Filion, 2010; Jiang and Hardee, 2011; Mourya et al., 2020) on the topic, this study highlights the need for a thorough and all-encompassing approach to the interplay of factors influencing climate change. Given the model's emphasis on the multifaceted nature of urban growth, policies aimed at mitigating CCIs can be more qualitative and context specific. For instance, İstanbul grappling with dwindling natural resources, a burgeoning population, and a weak economic structure. These considerations must inform measures taken in İstanbul regarding climate change. Controlling population growth through family planning and awareness initiatives is essential to reducing CCIs. Additionally, transforming the current economic growth model by prioritizing green, clean, and sharing economy sectors plays a pivotal role in mitigating CCIs. Once population and the economy, the two primary components of urban growth, are brought under control, the QoL in İstanbul can significantly improve.

It is proofed that while the effects of the selected indicators under the scope of urban growth are initially equally weighted, these weights change in various situations, leading to variations in potential CCIs. Policymakers have the option to formulate comprehensive urban planning strategies that encompass population growth, economic progress, and enhancements in QoL. These strategies should incorporate measures for both mitigating and adapting to climate change. In addition, policymakers can make localized decisions by selecting the most appropriate scenario and prioritizing specific areas. Investing in sustainable and efficient public transportation systems to reduce reliance on individual vehicles, thereby decreasing GHGs and traffic congestion are crucial. They should promote green infrastructure, renewable energy (solar/wind power) to enhance air quality, reduce heat island effects. Incentives for businesses and industries to adopt sustainable and eco-friendly practices, such as tax benefits for green initiatives and energy-efficient technologies should be offered.

This study has some important contributions expected to guide future research in similar areas. The methodological approach (FDMT) used to examine the relationship between UGIs and climate change effects in this study may assist in identifying and analyzing priority problems in different cities in future studies. It also provides insights into how different scenario analyses related to the topic can be created and evaluated. The recommendations developed for policymakers can serve as guidance for improving sustainable growth and climate adaptation in other cities.

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Article

The effect of metro stations on housing prices, Istanbul case

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Hedonic price method; house price; metro lines; real estate; value capture.

ABSTRACT

Metro lines are economic elements that impact the land and real estate values of the urban area, besides the time benefit they produce. According to the literature, metro lines increase housing prices in the service area. The aim of this study is to reveal metro stations' effect on housing prices, based on the examples of two different metro stations in Istanbul. In this context, within the framework of the metro investment, it is aimed to examine the effect of housing typology and urban transportation opportunities on housing prices as a hybrid model. Within the scope of the study, a field study was conducted to determine the effects of metro in two sample stations selected from İstanbul. Accordingly, it has been examined how the housing prices around the Metrokent and Kirazlı stations of the M3-Kirazlı-Başakşehir Olimpiyat Metro line, which was put into operation in 2013, are affected by the metro station. To make this assessment; hedonic price-based regression analysis was applied. This quantitative method is frequently used in determining the factors affecting house prices. A study was conducted on 349 residences whose sales values were examined from the related websites. The findings show that; housing prices in the Metrokent region are strongly affected by the metro station, while housing prices in the Kirazlı region are limitedly affected. In this study, the way real estate prices are affected by the metro station is examined in terms of housing typology and is expected to be a reference for future studies with different criteria.

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INTRODUCTION

Investments in transport infrastructure require a long process and large budgets. In our country, a significant part of the public sector spending is made for the transport sector needs. Due to its high budget requirements, metro lines are vital for urban transportation. Metro lines, which are expected to be the solution to traffic congestion in major cities, are the main backbone of the transport system with their high capacity, predictable quality of service, and sustainable features. Public rail system investments cost high, but they appear to provide significant social benefits when considered by assessment criteria such as accessibility, comfort, safety, and reliability. The proximity of this system to residential areas, which stands out in terms of social impact and intensity of use, is considered an advantage, especially for users living in large cities. This framework aims to ensure that rail systems serve as broad segments

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of society as possible in accordance with existing land use and urban development plans, beyond their economic and technical efficiency. Railway systems with the character of transport corridors provide an advantage to the area on the route within extensive urban land use. In large cities with limited public transportation facilities, it is attractive to live or work near the rail networks. Time advantage, fuel savings, and quality of obtaining high sustainable transport services affect the prices of residential, working areas, and commercial centers which are in the the impact of the rail system (Kırlangıçoğlu, 2016). This advantage raises land and property prices, especially in residential areas. This resulting increase in value is an important research topic, especially in countries that choose aggressive growth in rail systems and are looking for models to overcome high infrastructure costs. Especially in recent years, there has been a significant increase in the number of such surveys due to the development of access to data sets related to real estate sales prices (Dai et al., 2016). In Turkiye, studies are conducted on the effects of urban rail system services that have gained momentum in major cities, properly Istanbul and Ankara.

Kirazlı-Başakşehir-Olimpiyat Metro, which has been serving since 2013 with 15.9 km long and 11 stations in Istanbul, has been discussed in this article. This study compares two station areas observed residential regions of different qualifications. Metrokent is a residential district with a high socioeconomic level of inhabitants, which is constantly developing, with sufficient equipment areas. Compared to Metrokent, Kirazlı is irregular residential area with a low income level, low quality of life for its inhabitants, and insufficient equipment. The hedonic price method has been used to measure the impact in these areas. In the quantitative model, comparative assessments were made to eight different numerical models. According to the research findings, housing prices in the Metrokent area are strongly influenced by the station service, while the metro has had a rather limited impact on housing costs in Kirazlı station area.

Background of Research Area

One of the elements determining the value of real estate is the opportunities and functions of the cities in walking distance. Especially in cities where unplanned and unbalanced public services are offered, the benefit provided by the transport infrastructure plays a leading role in the pricing of land values. The fact that land prices in the city center reach the highest values, increases the demand for nearby land, and the availability of access from these areas to workplaces and the center is determining in preference (Kılınçarslan, 2010).

Haig (1926) calculated land yield and referred to the total transportation expense as "space friction," stating that this friction would be reduced by increasing the accessibility of transport. Thus, users pay as transportation costs (friction costs) for the distance to the city center while utilizing the land. Accordingly, the physical structure of the city is set to minimize costs. Alonso (1964) approached this issue from similar perspective and predicted that employment in the monocentric city model was concentrated in the city center, according to the assumption that the time spent on commitment is an important factor in determining the price curve (Alonso,1964). Accordingly, the highest land value is in the center because the cost of transportation is the lowest in the city center. As observed in these theories, there is a strong relationship between the phenomena that arise in the interaction of urban structures and transport systems. The cities are connected by transportation networks. Urban functions should be related to each other in such a way that transportation costs are as low as possible (Duvarcı and Alver, 2018).

In value capture theories, the prices of housing located close public transport stations are higher than those away from public transport. Therefore, higher budgets can be paid for housing with high public transportation capabilities (Kilpatrick et al., 2007). According to economic theory, this is reflected in the decrease in travel time in the direction of housing prices rising (Hess and Almeida, 2007). Railway systems are also known to be effective in increasing the value of real estate due to factors such as capacity, speed, and safety (Wardrip, 2011).

In addition to the positive aspects of being close to public transport stations, there can also be negative aspects. Especially in the immediate vicinity of public transportation stations, it is necessary to mention negative externals such as noise, pollution, traffic, or traffic jams. For example, disturbing effects in residential areas close to metro stations may cause the price of housing to be lower than a sample located at a reasonable distance from the station. (Wardrip, 2011).

Parameters such as: External factors, needs, and public transport facilities are important elements for housing prices. A large part of the literature prepared with the neoclassical economic concepts deal with the impact of development in transportation facilities on increasing real estate prices.

In this article, research on the impact of the rail system on real estate prices has been gathered into five topics.

Location According to City Center

The impact of the rail system varies depending on the location in the city. New rail system infrastructure affects the value of nearby residential areas. According to the results of this group's research, improved transportation opportunities in the city center reduce the marginal impact of each additional infrastructure investment. However, more intense feeling of transportation needs in the suburbs has more impact on property prices near a newly constructed rail system.

Seasonal Effects of Rail Systems
There are three main stages for railway systems such as the presentation of the project, the construction process, and the operation stages of the railway system are affecting housing prices at different levels. To summarize, the announcement of the rail system project appears to have a shock effect, rapidly positively affecting short-term real estate prices. However, conditions during the construction period (noise, pollution, physical constraints, etc.) can turn this increase downward. Finally, when the construction is completed and the rail system gives service, the real benefit can be measured (Ge et al., 2012).

Land Use Effect
The urban morphology is shaped by the way of people living in the city, physical possibilities, and economic conditions. For example, the access requirement of a house owner in a city varies from the service sector staff. Thus, the impact of the rail system is directly affected by differences in land use and needs.

The Diversity and Size of Economic Activity of Cities
Factors such as income level, car ownership, economic activities, and GDP differentiate the impact of rail systems on real estate prices. Transportation is a field of activity that develops due to economic and social activities. The impact on real estate of the rail system in the city is different. A strong economic and social life, which is diminished or not growing by the impact of the city's railway system, is different.

Infrastructure Typology
In the research area, forms of settlement, transportation facilities, and the efficient integration of these opportunities with urban settlement have been developed in this framework. In essence, the issue is again explained by the balance of supply and demand, which is the basic principles of the economy.

Each group examined in this section is basically dealt with by the value of users in the transport activity. From this perspective, it is clear that each example has its own dynamics. Many factors, such as demographic structure, socioeconomic characteristics, land use, or the type of transportation system, affect housing prices differently. Thus, while each example is similar, it is unique in terms of results and effects.

THE AIM AND METHODOLOGY

In this research, two different residential areas were selected on the M3-Kirazlı-Başakşehir Olympic metro line. The field study area Kirazlı is a residential area that develops irregularly, subsequently legalized, with its narrow streets, limited equipment areas, and low-rise structures that appeal to the middle-lower income level. Metrokent is an area consisting of high-rise, large-volume blocks, developing in the form of sites, where equipment areas are offered within the site, where car ownership is high and residential are middle-upper group.

Detecting the change in housing prices in the area has been the most important challenge of this study. Such data can be obtained through various channels, including from official agencies, large-scale companies serving the real estate market, real estate valuation firms, and web scans. However, because there is no reliable corporate infrastructure for the archiving of real estate sales data in our country, the data used in the study has been provided by the authors.

The supply of data has been collected by a "section analysis" approach covering 2019, before the pandemic. The global pandemic that emerged at the end of 2019 and the ongoing economic crisis have caused a serious rise in overall price levels both globally and nationally. This rise has also affected seriously the housing market in Istanbul, causing prices to rise artificially. Therefore, we believe that the period data considered as the latest realistic data reflects the actual market values.

On the transport side, which is the second important dimension of the study, the "metro system" was chosen as the most powerful social impact producing and widespread example of urban transportation. In this way, the socioeconomic impacts will be achieved more clearly. In this direction, the station areas located in M3-Kirazlı-Başakşehir-Olympic Metro Line have been delimited as a case study. The M3 Metro Line not only serves the residential area but also serves a complex part of the city that includes various service and working area functions. Therefore, it offers an alternative assessment possibility in the form of preferences. In summary, this research aims to address the impact of housing typology and urban transportation opportunities on housing prices within the framework of metro stations.

There are various methods to analyze the impact of rail system capabilities on housing prices. Quantitative methods were frequently and strongly preferred in literature. There are a number of parameters that influence the price of the property. The housing market consists of heterogeneous products due to the uniqueness of the parties interacting in the real estate market and also the structural, physical, and localizational differences of housing in the market (Gündoğmuş et al., 2019). As a heterogeneous commodity, the "Hedonic Price" approach is often used where multiple parameters have an effect on the price. The hedonic pricing method is preferred in this research because it allows an effective assessment in the distinction of many factors such as the qualification, physical characteristics, or location of the housing that constitutes the housing price.

Hedonic Price Model and Variables

The hedonic pricing method is a way for distinguishing the elements that determine the prices of commodities consisting of many components. One of the first to analyze the hedonic price method and housing prices is Rosen. Rosen (1974), used this method because he regarded housing as a heterogeneous asset consisting of the combination of different characteristics. In measuring the impact of empirical accessibility on price, the hedonic price model is the most common analysis technique. The model is a statistical method widely used in the identification of urban value in general and in the modeling of the impact of investment in real estate values in transport infrastructure in particular (Yankaya and Çelik, 2005).

According to Kaya (2012), the hedonic price function is determined according to whether the relationship between the dependent variable and the independent variables is linear. The hedonic price function is basically defined in two different ways as follows: (I) Linear Hedonic Price Function: The house price is the dependent variable and the properties that determine the house price are the independent variables, and it is assumed that there is a linear relationship between them. (II) Non-linear Hedonic Price Function: A nonlinear relationship is mentioned between the dependent variable, the house price, and the independent variables, which include the features that make up the house price. To determine the hedonic price function correctly, it is necessary to determine whether the relationship between the dependent variable, the price of the house, and the independent variables (the year of construction of the house, its quality, the location of the house, etc.) are linear. Kaya (2012) mentions four different functional structures in the analysis of determining the hedonic price function pattern:

- Linear Form
- Double Logarithmic Form
- Linear Logarithmic Form
- Logarithmic Linear Form.

These four forms have been used in various studies to analyze the shift in real estate prices. The independent variable factors used in this study were filtered so that they converged to the normal distribution. On the other hand, multicollinearity in an independent variable is taken into account. In line with these assumptions and precautions, the linear form of the hedonic price function, which is mostly preferred in the literature, has been used. In this framework, the multiple linear regression structure and variables are shown in Equation 1 and explained in Table 1. Accordingly, the dependent variable house/flat sales price (P) and the independent variables are given below;

Phouse price = α+βsize X size + βnumber of room X number

Table 1. Variables in the hedonic price function.

Variables		Explanation
$\mathbf{P}_{houseprice}$	House Price (TL/m^2)	Sales price of the sample house on m^2 basis
$\mathbf{X}_{size}$	Size	Size of the sample house (m^2)
$\mathbf{X}_{number\ of\ room}$	Number of room	Number of rooms in the sample house
$\mathbf{X}_{building\ floors}$	Building floors	Number of building floors of the sample house
$\mathbf{X}_{house\ floorI}$	House floor	On which floor is the sample house located
$\mathbf{X}_{building\ age}$	Building age	The age of the building where the sample house is located
$\mathbf{X}_{using\ status}$	Using status	Whether the sample house is in use or empty
$\mathbf{X}_{parking}$	Parking Garage	Whether the sample house has a parking garage
$\mathbf{X}_{kindergarten}$	Kindergarten	Presence of a kindergarten within 1000 m of the sample house
$\mathbf{X}_{primary}$	Primary School	Presence of a primary school within 500 m of the sample house
$\mathbf{X}_{secondary}$	Secondary School	Presence of a secondary school within1000 m of the sample house
$\mathbf{X}_{high}$	High School	Presence of a high school within 1500 m of the sample house
$\mathbf{X}_{mall}$	Mall	Presence of a mall within 1000 m of the sample house
$\mathbf{X}_{health\ clinic}$	Health clinic	Presence of a health clinic within 1000 m of the sample house
$\mathbf{X}_{hospital}$	Hospital	Presence of a hospital within 5000 m of the sample house
$\mathbf{X}_{busstop}$	Bus stop	Presence of a bus stop within 500 m of the sample house
$\mathbf{X}_{loan}$	Suitability for loan	Whether the sample house is suitable for loan use
$\mathbf{X}_{station}$	Distance to the Station	The distance of the sample house to the metro station in meters

of room + βbuilding floors X building floors + βflat floor X flat floor + βbuilding age X building age+ βusing status X using status+ βparking X parking (1)+ βkindergarten X kindergarten + βprimary X primary+ βsecondary X secondary+ βhigh X high+ βmall X mall+ βhealth clinic X health clinic+ βhospital X hospital+ βbusstop X busstop+ βloan X loan+ βstation Xstation +εi

Both the dependent and explanatory variables related to the sample houses within the scope of the study were handled separately, and the diversity of the data was simplified in accordance with the normal distribution, and the extreme values were removed from the data set.

FIELD STUDY AND DATA COLLECTION

It was previously stated that Kirazlı and Metrokent stations on the M3-Kirazlı-Başakşehir-Olimpiyat Metro Line were selected for the study area. Metrokent Station is in Başak District, one of the most important residential area of Başakşehir, which was opened to settlement in the 2000s.

Metrokent Station is a planned and developing settlement on a high-density, multi-storey, and mostly residential complex with approximately 1000 residences.

In addition, the metro station also serves other mass housing areas in the region such as Başakşehir 5th Stage, Earthquake Residences, Göcmen Residences. Various functions such as retail trade areas, bank branches, social and cultural facilities, and recreational areas have been created around the station. Due to the fact that the Metrokent is far from the city center, office-type service, and working areas are very limited. The fact that the recreation areas are within walking distance of the residences and that the commercial units are close and sufficient. In line with the preference of these structural features, the number of rooms of three or more is planned in the building stock. The physical environment does not allow much to establish and develop strong kinship and neighborly relations. In this sense, residents lead an introverted and nuclear family-oriented life. In the nuclear family living in this region, the fact that both parents are usually involved in working life and being away from home during long working hours shortens the time spent in the residence.

The second selected study area, Kirazlı, is one of the oldest settlements in Bağcılar and was formed in 1992 by the merger of Güneşli and Mahmutbey districts. The district of Kirazlı, which gave its name to the station, is a residential area composed of mostly low-rise apartments. In the station area, the number of floors is increasing, but the apartments, which generally vary between 3 and 8 floors, constitute an important part of the district. In addition, there is a large parking lot next to the station in accordance with the "park and ride" concept. On the other hand, there are production workshops and commercial usage on the first floors of the houses between the neighborhoods. Kirazlı neighborhood has an important potential in terms of producing home-based work and school trips. The selected residential areas and the rail system network relationship are given in Figures 1 and 2.

Unlike Metrokent, there are low-rise and adjacent flats in the Kirazlı Station area. This situation brings with it a social structure that tends to establish relations with each other. Compared to the Metrokent, people with lower incomes came together to support each other using their hometown bond. Citizens who migrated from Eastern Anatolia in the Kirazlı region are concentrated in certain districts and streets. In this building, it has been observed that a residential area where social relations are strong especially neighborly relations.

Data Collection

The most difficult part of this research was the data-finding phase since real estate valuation reports or housing sales/rent data were not recorded in a regular database. Therefore, it is quite difficult to conduct a numerical analysis based on real estate sales or rental data in our country. The most objective and powerful data set in this sector is the street

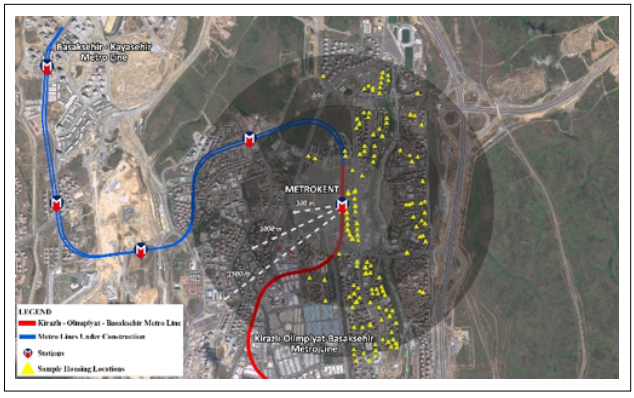

Figure 1. Distance relationship between housing sample and station in Metrokent region.

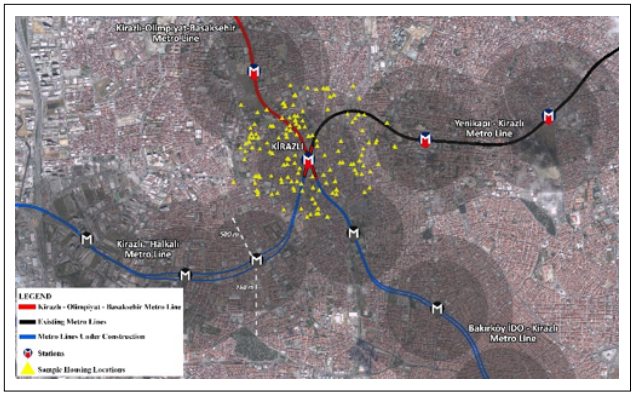

Figure 2. Distance relationship between housing sample and station in Kirazlı region.

fair values determined by local governments for property tax collection. These rates are updated every 4 years by valuation commissions established under the control of tax offices and under the leadership of municipalities. However, the fact that these data determine a very general price without going into the specifics of the building/flat constitutes another dimension of the problem. As a result, clear and fully accurate information regarding with the change in housing prices and the real market value cannot be accessed.

Another source of real estate sales data is the reports prepared by licensed valuation firms. Real estate appraisal firms undertake an important function, especially in the use of bank loans, which is one of the financing resources in housing sales. In this context, there are many valuation reports in both company and bank databases. However, the details of the housing and sales data included in these reports are kept confidential by the institutions within the framework of the Law on the Protection of Personal Data.

Apart from this, there are enterprises that provide services to those who want to invest in the real estate sector by following the real estate markets and determining the sector dynamics. These types of organizations make evaluations using especially brand projects, reports of real estate appraisal companies, investment projects in the city, or field research data. However, this generalized information is far from providing the necessary data for academic research.

In these conditions, the data used in the research were compiled from the primary source, on-site investigation, and internet search. In this way, both a large sample size could be reached and real-like sales amount data could be determined with its location. While compiling the sales data on the internet, the location of each sample was determined exactly. Some of the characteristic and environmental variables used in the hedonic price method were obtained directly from the analysis in the field. In September–October 2019, the sales data of 199 residences for the Metrokent region and 150 for the Kirazlı region were arranged according to date order. In these data obtained from the Internet; sales data, location, and the characteristics of the houses obtained through field. The distance between the sample houses and the stations was calculated with the help of the network analysis module in the GIS software. Environmental parametric variables related to the sample houses within the scope of the research were provided from Istanbul Environmental Plan and Istanbul Transportation Master Plan and the environmental factors determining the price were included in the numerical model as independent variables. Accordingly, the equipment functions and socioeconomic and sociodemographic data in the study area were created by utilizing upper-scale studies such as the 1/100.000 scaled Istanbul Environmental Plan and the Istanbul Transportation Master Plan.

Real walking distances were taken into account in numerical models using the network analysis module in the GIS software to reveal the distance relationship of the sample houses with the urban facilities. Sample house-metro station distances; for Metrokent, distance was determined as three stages, 500 m, 1000 m, and 1500 m, and for Kirazlı, it was determined as two stages, 500 m and 750 m. To produce more realistic results, the sample house-station distances used in the numerical analysis were based on walking distances instead of air distances.

In this direction, the air distances between the house and the station were converted into walking-based, real distances by taking into account parameters such as topography, walking path, slope, or aspect by using the network analysis module in the GIS software. In the framework of sustainable transportation, when a pedestrian leaves the house, they can directly go to the bus stop, market, etc. It is stated that the walking distance should be between 400 and 800 meters (Schiller et al., 2010). Although distance is an important criterion affecting the preference of walking, creating a quality walking environment in a quality, spacious, and safe environment is at least as important as distance (Cirit, 2014). Accordingly, the walking distance and air distances calculated with the help of GIS for each sample house were calculated one by one. Considering the whole sample size, the ratio between walking distance and air distance was determined as 1.43. While this coefficient was reflected to the air distance levels used for the sample, the value of 1.5 was used by rounding and the levels given in Table 2 were formed. Thus, regression analyzes were made by considering the actual walking distance and it was aimed to calculate more accurate results. The air distance and walking-based zone distances for the study areas are given in Table 2.

RESEARCH FINDINGS

In this research, sales data of 199 houses for the Metrokent region and 150 houses for the Kirazlı region were obtained and tested with the hedonic price model. Accordingly, in the analysis, a total of eight numerical models, four of which are Metrokent, three of which are Kirazlı, and one of which are mixed, were established. In this section, it is aimed to evaluate the results of the analyzes comparatively.

Table 2. Distance assumptions considered in the analysis

	Air distance stage	Walking based stage
Metrokent Region	0–500 m	0–750 m
	500–1000 m	750–1500 m
	Over 1000 m	Over 1500 m
Kirazlı Region	0–500 m	0–750 m
	Over 500 m	Over 750 m

Table 3. Descriptive statistics of all factors for the distance-based metrokent model

	n	Minimum	Maksimum	Mean	Standard Deviation
Size	199	64.0	237.0	140.040	39.0159
Number of room	199	2.0	6.0	3.985	0.7281
Building floors	199	2.0	27.0	11.302	4.4312
House floor	199	0.0	20.0	6.000	5.2281
Building age	199	4.0	23.0	11.930	4.1188
Using status	199	0.0	1.0	0.829	0.3905
Parking Garage	199	0.0	1.0	0.161	0.3683
Kindergarten	199	0.0	1.0	0.53	0.500
Primary School	199	0.0	1.0	0.171	0.3773
Secondary School	199	0.0	1.0	0.482	0.5010
High School	199	0.0	1.0	0.930	0.2564
Mall	199	0.0	1.0	0.849	0.3587
Health clinic	199	0.0	1.0	0.417	0.4943
Hospital	199	1.0	1.0	1.000	0.0000
Bus stop	199	0.0	1.0	0.935	0.2477
Suitability for loan	199	0.0	1.0	0.995	0.0709
House Unit Price (TL/m^2)	199	3048.0000	7886.5979	4779.0691	1007.3283
Distance to the Station	199	110.7882	2311.3821	1268.9406	576.9742
N (List)	199				

Table 4. Factor coefficients in the distance-based model of Metrokent

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	SE	Beta		
5	Constant	4245.130	261.875		16.211	0.000
	Building age	−67.859	13.516	−0.277	−5.021	0.000
	Size	11.132	1.189	0.431	9.362	0.000
	House floor	51.199	9.081	0.266	5.638	0.000
	Distance to the Station	−0.372	0.089	−0.213	−4.156	0.000
	Primary School	−297.600	129.265	−0.111	−2.302	0.022

Table 5. Factor Coefficients for Metrokent Close Stage Model (0–750 m).

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	SE	Beta		
4	Constant	3792.214	268.225		14.138	0.000
	Building age	−76.114	12.396	−0.311	−6.140	0.000
	Size	10.758	1.172	0.417	9.183	0.000
	House floor	44.659	9.475	0.232	4.713	0.000
	0–750 m Stage	**570.055**	**132.060**	**0.232**	**4.317**	**0.000**

Table 6. Factor coefficients for Metrokent middle stage model (750m–1500m)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	SE	Beta		
5	Constant	4245.130	261.875		16.211	0.000
	Building age	−67.859	13.516	−0.277	−5.021	0.000
	Size	11.132	1.189	0.431	9.362	0.000
	House floor	51.199	9.081	0.266	5.638	0.000
	Distance to the Station	−0.372	0.089	−0.213	−4.156	0.000
	Primary School	−297.600	129.265	−0.111	−2.302	0.022

Table 7. Factor coefficients for Metrokent far stage model (over 1500 m)

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
5	Constant	4245.130	261.875		16.211	0.000
	Building age	−67.859	13.516	−0.277	−5.021	0.000
	Size	11.132	1.189	0.431	9.362	0.000
	House floor	51.199	9.081	0.266	5.638	0.000
	Distance to the Station	−0.372	0.089	−0.213	−4.156	0.000
	Primary School	−297.600	129.265	−0.111	−2.302	0.022

The explanatory statistical values of the variables in the models created for the Metrokent Region are given in Table 3. In addition, the results of the four models created for the Metrokent region are given in Tables 4-7, respectively.

The factor coefficients of the distance-based model for the Metrokent region are given in Table 4.

In Table 5, the factor coefficients of the model created for the houses located at the stage of 0–750 m from the station in the Metrokent region are given.

In Table 6, the factor coefficients of the model created for the houses located at the stage of 750-1500 m from the station in the Metrokent region are given.

In Table 7, the factor coefficients of the model created for the houses located at the stage of over 1500 m from the station in the Metrokent region are given.

The factor coefficients for the numerical models created for Metrokent are given above. The beta coefficients here show the degree of importance of the factors that determine the housing price and are ranked accordingly. The factor that best explains housing prices is considered to be the age of the building. There is an inverse relationship between the age of the building and its unit price. In other words, housing unit m^2 prices decrease by 67 TL every year as the building ages. The size of the house is the second most important factor affecting the prices. Accordingly, as the size of the houses increase, it is seen that there is an increase of 11 TL in unit prices. The most important reason for this is that the residences allow for quality, luxury, and comfortable use as they grow. The floor of the house is also one of the important parameters that determine the price of the houses. Especially in Başakşehir region, the increasing view with the rising floor and the decreasing degree of exposure to the external environment create effects that increase prices. Accordingly, each floor rise of the house increases the m^2 unit price by 51 TL. The factor of proximity to the metro station ranks first among all urban equipment opportunities and 4th in general, after the physical features of the house. In line with the general expectation and the literary, the housing prices in the Metrokent region increase as they approach the station.

According to the regression results, the m^2 unit prices of residences in the Metrokent region increase by approximately 37 TL for every 100 m approached to the metro station. The last statistically significant factor of the hedonic price-based model is the evaluation of the primary school facility located at the 500 m border of the samples in terms of its effect on prices. An urban equipment facility such as a primary school was added to the regression as a dummy variable. According to this, the presence of a primary school in the borders mentioned in the Metrokent region affects the housing m^2 unit prices positively by 297 TL.

For the Metrokent region, the fact that the users in the houses located at a distance of 0–750 m can reach the metro line with a 10-min walking distance and without using any vehicle, is

Table 8. Descriptive statistics of all factors for the distance-based Kirazlı Model

	n	Minimum	Maksimum	Mean	Standard Deviation
Size	150	60.0	250.0	119.593	33.0747
Number of room	150	2.0	7.0	3.667	0.9317
Building floors	150	3.0	18.0	6.173	3.7573
House floor	150	0.0	13.0	3.127	3.0659
Building age	150	1.0	28.0	8.133	8.2971
Using status	150	0.0	1.0	0.627	0.4853
Parking Garage	150	0.0	1.0	0.353	0.4796
Kindergarten	150	0.0	1.0	0.91	0.292
Primary School	150	0.0	1.0	0.62	0.487
Secondary School	150	1.0	1.0	1.00	0.000
High School	150	1.0	1.0	1.00	0.000
Mall	150	0.0	0.0	0.00	0.000
Health clinic	150	0.0	1.0	0.76	0.429
Hospital	150	1.0	1.0	1.00	0.000
Bus stop	150	1.0	1.0	1.00	0.000
Suitability for loan	150	0.0	1.0	0.900	0.3010
House Unit Price (TL/m2)	150	1760.	4888.	3271.	778.0
Distance to the Station	150	195.4	1187.2	687.4	220.2
N (List)	150				

statistically significant in terms of housing prices, and creates effects that increase the housing prices. According to the results of the Close Stage Model (0–750 m), it can be said that if a 100 m^2 house is located in the 0–750 m range, the house price will increase by 57.000 TL. However, when the distance of the houses from the station is above the walking distance limit values of 750 m, the power of the station to affect the prices gradually decreases and it starts to produce statistically insignificant results after 1500 m.

The explanatory statistical values of the variables in the models created for the Kirazlı Region are given in Table 8. In addition, the results of the three models created for the Kirazlı region are given in Tables 9-11, respectively.

The factor coefficients of the distance-based model for the Kirazlı region are given in Table 9.

In Table 10, the factor coefficients of the model created for the houses located at the stage of 0–750 m from the station in the Kirazlı region are given.

In Table 11, the factor coefficients of the model created for the houses located at the stage of over 750 m from the station in the Kirazlı region are given.

Table 9. Factor coefficients in the distance-based model of Kirazlı

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
6	Constant	4099.060	211.611		19.371	0.000
	Parking Garage	599.949	89.453	0.370	6.707	0.000
	Building age	−38.111	5.086	−0.406	−7.493	0.000
	Size	−7.436	1.032	−0.316	−7.207	0.000
	House floor	55.121	12.162	0.217	4.532	0.000
	Health clinic	−305.909	78.767	−0.168	−3.884	0.000
	Suitability for loan	244.486	122.322	0.095	1.999	0.048

Table 10. Factor coefficients for Kirazlı close stage model (0–750 m)

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
6	Constant	4099.060	211.611		19.371	0.000
	Parking Garage	599.949	89.453	0.370	6.707	0.000
	Building age	−38.111	5.086	−0.406	−7.493	0.000
	Size	−7.436	1.032	−0.316	−7.207	0.000
	House floor	55.121	12.162	0.217	4.532	0.000
	Health clinic	−305.909	78.767	−0.168	−3.884	0.000
	Suitability for loan	244.486	122.322	0.095	1.999	0.048

The effect of the metro station on the housing prices in the Kirazlı Region seems to be quite limited. Although Kirazlı is closer to the city center compared to Metrokent, it is a district with diversified public transportation infrastructure. The possibility of accessing the metro station from any point in the Kirazlı region and its balanced distribution to almost every part of the district have resulted in similar benefits for almost all the residences in the region. Most of the residential areas of the district have access to the rail system within walking distance. For this reason, the residences in the study area are already priced with the effect of the metro station. This ease of access to the rail system does not affect the housing prices in the immediate vicinity of the metro at a high level. The rail system factor ranks lower in terms of housing price components and does not even have a statistically significant effect. For this reason, factors such as the age of the building, the size of the house, and its suitability for loan determine the housing price much more dominantly.

The most important factor determining the housing prices in Kirazlı region is the "Parking Garage" in Table 9. The irregular and old houses in this area are being rebuilt on a parcel basis instead of an comprehensive urban transformation approach. The inadequacy of the car parks and the requirement of parking garage due to the regulation increased the effect of this factor. The parking garage is regressed as a dummy variable and if it exists, it increases the m^2 unit price of the house by approximately 600 TL.

The age of the building is the second most important parameter affecting the housing prices in the Kirazlı region, similar to the car park factor. According to the results of the regression analysis, the age of the building also affects the housing price in the opposite direction as stated before, and the housing unit price decreases by 38 TL for each additional age. In other words, the renovation process of the buildings in the Kirazlı region, which has a very old building stock built in the 1970s, is the most important factor that determines the prices.

Another important factor affecting the housing price in Kirazlı is the size of the house. Unlike Metrokent, it is possible to talk about a decrease in the price of 7.5 TL per m^2 as the size of the house increases. One of the most important reasons for this is the duplex houses in this location. The unit price of the upper floor of the duplex house is lower than the normal floor. The average unit prices of the duplex apartments in the samples are lower

Table 11. Factor coefficients for Kirazlı middle stage model (over 750 m).

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
6	Constant	4099.060	211.611		19.371	0.000
	Parking Garage	599.949	89.453	0.370	6.707	0.000
	Building age	−38.111	5.086	−0.406	−7.493	0.000
	Size	−7.436	1.032	−0.316	−7.207	0.000
	House floor	55.121	12.162	0.217	4.532	0.000
	Health clinic	−305.909	78.767	−0.168	−3.884	0.000
	Suitability for loan	244.486	122.322	0.095	1.999	0.048

than the normal apartments on a single floor. This situation is reflected in the regression as a reverse effect.

The factor related to the floor level of the house is parallel to Metrokent and the general opinion. Accordingly, an increase in the floor of the house increases the unit price of the house by 55 TL.

The issue of "suitability for loan" is also among the factors that increase the housing price and are statistically significant. A significant part of the residences in Kirazlı region do not have settlement or construction permission. For this reason, many apartments are not suitable for loan. Therefore, the suitability of the house for credit also creates effects that increase the unit prices by 244 TL. In other words, the fact that the house was built with its legal status is considered among the important parameters that affect its price.

Housing prices for Kirazlı Region were also analyzed by dividing into two stages with the distance-based model. Both the close-range and middle-range model results give parallel results with the distance-based model. This situation can be explained as follows. Kirazlı region is in a very good condition in terms of rail system infrastructure due to both existing metro lines and metro lines under construction. There is rail system access within walking distance in almost every part of the region. For this reason, the residences in the study area are already priced with the effect of the metro station. In other words, since there is access to the rail system from all sides, this factor ranks lower in terms of housing price components and even does not have a statistically significant effect. For this reason, factors such as the age of the building, the size of the house, and its suitability for loan determine the housing price much more dominantly.

Within the scope of the study, the results of the regression that focused on the relationship between the housing price and the metro station of the Metrokent and Kirazlı regions, which have different settlement characteristics, were given above. Apart from this, the numerical analysis results of the heterogeneous data pool, in which both Metrokent and Kirazlı sample data are handled together, are given in Table 12.

In this research, 199 house sales data were collected in three stages at a distance of 0–1500 m from the metro station in the Metrokent region, and 150 house data varying in two stages between 0 and 750 m in the Kirazlı region were examined in terms of measuring the effect of the metro station on the house price.

In this framework, in the mixed model results, in case the spatial data is differentiated and analyzed in a heterogeneous structure, the dependent variable of the housing unit price can be explained by much more factors, and the number of important factor components increases. From this point of view, being close to the metro station did not create statistically significant results in the mixed model.

To summarize, the outputs in the Metrokent region have shown parallel results with the literature. Mainly the metro creates effects that increase the housing prices. Contrary to the literature, metro stations in the Kirazlı region do not have a statistically significant increase or decrease in the housing price.

The limited public transportation facilities in the Metrokent region have strongly affected the housing prices, especially at the 0–750 m stage of the metro station, this result is important. The strength of this effect decreases as you move away from the station, and it starts to disappear as you go above the walking distance. On the other hand, the possibility of accessing the metro station from any point in the Kirazlı region, evenly dispersing it to almost every part of the district, has caused similar benefits for almost all of the residences in the region. Most

Table 12. Factor coefficients for mixed model

Model		Unstandardized coefficients		Standardized coefficients	t	Sig.
		B	SE	Beta		
9	Constant	3285.986	248.494		13.224	0.000
	Building floors	61.322	12.869	0.253	4.765	0.000
	Mall	976.014	103.429	0.414	9.437	0.000
	Building age	−37.149	6.553	−0.205	−5.669	0.000
	Size	5.682	0.969	0.182	5.866	0.000
	Kindergarten	−281.877	84.054	−0.110	−3.354	0.001
	Primary School	−262.907	80.602	−0.107	−3.262	0.001
	Parking Garage	417.862	132.337	0.152	3.158	0.002
	High School	−475.787	203.178	−0.079	−2.342	0.020
	House floor	20.315	10.049	0.080	2.022	0.044

of the residential areas of the district have access to the rail system within walking distance. For this reason, the residences in the study area are already priced with the effect of the metro station. This ease of access to the rail system does not affect the housing prices in the immediate vicinity of the metro at a high level. The rail system factor ranks lower in terms of housing price components and does not even have a statistically significant effect. For this reason, factors such as the age of the building, the size of the house, and its suitability for credit determine the housing price much more dominantly.

DISCUSSION AND CONCLUSION

In the article, Metrokent and Kirazlı regions, which are two settlements with different characteristics and located in the corridor of the M3-Kirazlı-Başakşehir-Olimpiyat Metro Line, are examined in terms of the effect of the metro station on the housing prices. According to this;

Metrokent is a satellite city settlement and was formed with a legal construction process. It is a developed residential area in the form of high-rise, multi-block sites. The residents are generally in the middle and upper middle-income level. Due to its distance from the city center, transportation opportunities are limited. For this reason, housing prices very close to the metro station are more affected by the station, and the effect of the metro line on the price decreases as you move away from the station. In the Metrokent region, proximity to the station ranks first among the environmental opportunities that can be evaluated within the scope of external elements such as hospitals, schools, and shopping malls, after the physical features of the residences. Accordingly, in parallel with the literature, housing prices in the Metrokent region increase as they approach the station. According to the results of the hedonic price model, the m^2 unit prices of housing in the study area increase by approximately 37 TL for every 100 m approached to the metro station. In addition, for the close-stage model, it can be said that if a 100 m^2 house is located in the 0–750 m range, the house price will increase by 57.000 TL. In other words, this value reveals an effect that increases the average housing unit price value by approximately 12%. This effect is particularly strong in terms of houses close to the station and decreases inversely with walking distance away from the station.

The Kirazlı example presents different results than Metrokent. According to Metrokent, Kirazlı has a construction story that is located in the center of the city and developed illegally in the 1970s and later became legal. Due to the fact that it is an old and dense settlement, a transportation system has developed on the axis of the rail system with public investments. For this reason, it has a transportation network that offers more variety in terms of both rubber-tired and rail systems. In the area where the middle and lower-middle-income social segments live, diversified public transportation opportunities are used intensively. Under these conditions; the effect of a new metro station on housing prices seems rather limited. The metro station can be accessed by walking from any point in the Kirazlı region. This access has resulted in similar benefits for almost all houses in the region. In other words, since most of the houses in the district have the opportunity to access any rail system within walking distance, they are already priced with the effect of the metro station. In this context, this ease of access to the rail system did not statistically affect the housing prices in the immediate vicinity of the metro. There are other dominant factors affecting prices in this region. For example, parameters such as the newness of the building and its suitability for loan largely determine the price. Therefore, the increase in transportation opportunities with a new metro did not produce a high marginal benefit for the people living in the region.

The metro station does not cause the same level of benefit to every settlement it serves. According to the results of the numerical analysis in the research, the different effects of the stations on the housing prices in the Metrokent and Kirazlı regions limit the approaches to generalize the subject. In this respect, each location needs to be examined within its own dynamics and according to changing conditions. In summary, the results of the analysis revealed parallel results with the literature in the Metrokent region and the metro station increased the housing prices in this region. However, in the Kirazlı region, on the contrary, metro stations did not have a statistically significant effect on the housing price.

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Article

The effect of building height and street width on indoor daylight performance according to the town planning code – office buildings for the case of Istanbul and Adana

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ABSTRACT

Due to the concept of sustainability, it has become increasingly important to reduce the energy burden of lighting by promoting the use of natural light. In daylighting design, there are several variables that affect the performance of daylight indoors. "External obstructions," which is one of the variables that significantly affect daylight penetration into the volume, are often limited by legislation such as the zoning plan/ordinance, etc. of the city/settlement. In this article, non-structural obstructions at different heights and distances were first determined for attached office buildings within the scope of the "Planned Areas Type Zoning Regulation" in force in Türkiye. The daylight performance of these spaces in the attached structures of office spaces of 2-storey (B2), 5-storey (B5), and multistorey buildings in Istanbul and Adana were investigated according to TS EN 17037, considering the four window directions (K – North, D – East, G – South, and B – West), three light transmission factors (0.8, 0.6, and 0.4), and a transparency ratio of 0.3. Among the optimal options identified for the office buildings considered in the study, the most positive situations were identified among those with appropriate daylight and luminance according to the function, according to the criteria of TS EN 17037. For the scenarios without negative daylight criteria, suggestions were made to improve integrated lighting systems where natural and artificial lighting coexist. Thus, the performance of the daylight entering the volume would be determined at the design stage and the energy to be spent on artificial lighting could be reduced.

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INTRODUCTION

Sustainability and green design concepts have become increasingly important in recent years due to the decreasing cost of energy resources and the negative impact of energy consumption (Çelik, 2018; Uyan, 2010). The concept of sustainability in lighting design is defined as meeting the visual environment needs with the least impact on the natural environment (Yılmaz, 2019).

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Physical comfort conditions, sustainability, and efficient energy use should also be considered in the design of offices that are actively used during daylight hours. The aim should be to reduce the energy burden of lighting by encouraging the use of natural lighting (Sakınç, 2006). The standard TS EN: 17037:2021, which defines performance criteria for the use of daylight as a passive system in buildings, includes the criteria established to evaluate the performance of daylight in buildings and the methods established to evaluate the performance of daylight (Yener, 2007).

In TS EN 17037:2021 daylighting in buildings, for the whole year is considered, and the idea is that daylight illuminates volumes for a significant part of the year. Daylighting design should therefore be carried out at three successive levels: Settlement scale, building scale, and volume scale (Altuğ-Turan, 2010). Variables that affect daylighting within volumes within the volume scale are listed as follows:

- Type and power of natural light sources
- Characteristics of non-volume obstructions (size, location, light reflectance factor, light reflectance pattern, etc.)
- Ground cover characteristics (light reflectance factor and light reflectance pattern)
- Characteristics of daylight openings (windows) (size, position, number, light transmission factor of the glass, type of light transmission, contamination of the glass, and effective glass area [thickness of the glazing])
- Characteristics of the volume (size, location of observation point, light reflectance of surfaces and shape of surfaces, and contamination of interior surfaces) (Yılmaz, 2019).

One of the variables that have a significant impact on the amount of daylight entering a space is "external obstructions," which, depending on their size and position, reduce the amount of daylight by preventing direct sunlight and skylight from entering the space, while at the same time contributing to the brightness of the interior to some extent by reflecting light from the sun, sky, and earth (Yılmaz, 2019). The size and location of the building in which the volume is located (Özkaynak, 2005), and the size and location of the structures that create the artificial barriers around it, are often limited by laws such as the zoning plan/ordinance, etc. of the city/settlement. In terms of natural lighting design, it is not possible to design or control obstructive features (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022).

The aim of this study is to determine the effect of external obstructions at different heights and distances on the performance of daylight entering the volume and to reveal the data that can be used in natural lighting design. It would provide appropriate solutions in terms of both visual comfort and efficient use of energy through sustainable design proposals in terms of changes in features such as the dimension and location of external obstructions and space together. In this way, the effect of the variables that affect the daylight entering the volume and the daylight existing within the volume would be determined at the design stage.

The article discusses the issue of daylighting, the characteristics of which are defined in the TS EN 17037:2021 daylight in buildings standard, in the context of office spaces in Istanbul and Adana according to the "Planned Areas Zoning Regulation/Adjacent Building" (Üzmez, 2009; Kayacı, 2015; Arslan-Çinko & Eres, 2018; Şahin & Saban, 2020). The office spaces in question were analyzed according to the criteria of the standard. In this context, a brief explanation of the daylight standard is given first, followed by the postulates of the study, the findings, and suggestions.

TS EN 17037:2021 DAYLIGHT STANDARD IN BUILDINGS

TS EN 17037:2021 Standard contains the established criteria for the evaluation of daylighting performance in buildings and methods that can be used in the evaluation of daylighting performance. According to the standard, the criteria for the use of daylight in spaces that are used for long periods and visual tasks performed in all types of buildings, including dwellings, are discussed under four subheadings:

- Daylight Provision
- Protection from Glare
- Assessment for View Out
- Exposure to Sunlight.

Brief explanations of these criteria are given below.

Daylight Provision

As far as possible, daylight should be used to meet lighting requirements within the volume. In this context, barriers outside the volume should be designed to ensure that sufficient daylight enters the volume throughout the year, as required by the regulations.

TS EN 17037 2021 "Daylight Standard in Buildings" recommends three different levels of illuminance minimum, medium, and high (Table 1). Two methods are suggested for calculating daylight illuminance in volume. The first is to use the daylight factor. The second calculation method is based on calculating the illuminance at the calculation points defined on the reference plane in hourly steps throughout the year, using the climatic data of the region where the building is located. The results obtained using this approach are analyzed to check that the required illuminances are achieved at ≥50% and ≥95% of the reference plane for ≥2190 h of the year (Öztürk, 2018).

Table 1. Recommended Degrees in Terms of Illuminance Level for TS EN 17037 Daylight Benefit (TS EN 17037+A1:2021, 2021)

Recommendations for daylight provision in a space	Required level	
	≥50% of the reference plane	≥95% of the reference plane
Minimum	≥300 lux	≥100 lux
Medium	≥500 lux	≥300 lux
High	≥750 lux	≥500 lux

Protection from Glare

Glare is defined as the discomfort caused by the intrusion of high-luminance surfaces into the visual field (Öztürk, 2018). Glare in a room can be caused by direct sunlight entering through a window as well as by the high luminance difference between the high-luminance sky visible from the window and the work area.

Daylight glare is assessed by the daylight glare probability (DGP) in TS EN 17037. The recommended "DGP Thresholds (DGPt)" for the three levels of glare control are given in Table 2. The reference occupancy period is defined as the period during which the area of the room is predominantly occupied throughout the year. This period is assumed to be 8:00–18:00, five working days a week throughout the year.

The maximum allowable threshold for the possibility of daylight glare should not exceed 5% of the reference period. For example, the defined minimum protection level of 0.45 can be exceeded in a maximum of 130 h of the annual reference period – i.e., 2600 h (52 weeks×5 days×10 h) (Öztürk, 2018).

Table 2. TS EN 17037 Recommended Degrees of Glare Protection (TS EN 17037+A1:2021, 2021)

Criterion DGP	
Glare is mostly not perceived	DGP≤0.35
Glare is perceived but mostly not discomfort	0.35<DGP≤0.40
Glare is perceived and often discomfort	0.4<DGP≤0.45
Glare is perceived and mostly intolerable	DGP≥0.45

Assessment for View Out

Visual contact with the outside world fulfills human needs such as information about the location and surroundings of the building, monitoring weather conditions and the passage of time during the day, as well as providing physiological relaxation by resting the eyes and psychological relaxation. The quality of the image entering the field of vision depends on the size of the window, the distance of the person from the window, the number of visible layers, and the content of the perceived environment. Depending on the use of the volume, the windowpane at the eye level of a seated or standing person should be transparent and neutral in color. The image within the field of vision can include three different layers: Sky, natural and/or artificial landscape, and ground (Öztürk, 2018).

In terms of the quality of the visual connection with the outside environment, three levels were defined as minimum, medium, and high (Table 3).

Exposure to Sunlight

For the evaluation of sunshine duration, 21 March was chosen as a reference and it is stated that the volume should receive at least 1.5 h of sunlight on that day. Assuming cloudless sky conditions three degrees of sunshine duration are suggested as minimum, medium, and high as shown in Table 4.

METHOD OF WORK AND ASSUMPTIONS

One of the most important parameters influencing the level of illuminance inside the volume is the "outside obstructions," which is one of the variables that significantly affect the amount of daylight entering the volume. Natural or artificial obstacles outside the volume can be considered

Table 3. TS EN 17037 Recommended Degrees for Visual Connection with the Outdoor Environment (TS EN 17037+A1:2021, 2021)

Variables	Degree of visual connection		
	Minimum	Medium	High
The angle of vision based on the window width	≥14°	≥28°	≥54°
Distance of external obstructions	≥6 m	≥20 m	≥50 m
Layers required to be seen more than 75% of the used area sky, andscape, and ground	Including landscape layer	At least two layers included	All layers included

Table 4. TS EN 17037 Recommended degrees for sunshine duration (TS EN 17037+A1:2021, 2021)

Level of recommendation for exposure to sunlight	Sunlight exposure
Minimum	1.5 h
Medium	3 h
High level of sunshine duration	>4 h

uncontrollable factors in natural lighting design. This is because the size and location of the building in which the volume is located, and the size and location of the structures that create the artificial obstructions around it, are often determined by legal constraints such as the zoning plan/ordinance, etc. of the city/settlement.

While the "Planned Areas Type Zoning Regulation" in force in our country limits the height of the obstruction and the width of the road, it does not give any information about the length of the obstruction. According to the "Planned Areas Type Zoning Regulation," the relationship between the maximum road width and the maximum building height is given in Table 5.

In this study, the effect of two street widths and two building heights on the amount of daylight entering the volume was evaluated by TS EN 170307-2021 for the office spaces assumed to be in Istanbul and Adana according to the "Planned Areas Type Zoning Regulation."

The methodology of the study could be listed as follows.

- To determine the size and location of out-of-volume obstructions using the street width and building heights given in the zoning regulation
- Limiting characteristics such as the size of office space and light reflection factor of the interior surface

Table 5. According to the "Planned areas type zoning regulation" maximum road width maximum building height ratio (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022)

Max. Road Width (m)	Max. Coefficient	Max. Building Height (m)
≤7.00	2	7.2
7.00 <Road W.≤10.00	3	10.8
10.00 <Road W.≤12.00	4	14.4
12.00 <Road W.≤15.00	5	18
15.00 <Road W.≤20.00	6	21.6
20.00 <Road W.≤25.00	8	28.8
25.00 <Road W.≤35.00	10	36
35.00 <Road W.≤50.00	14	50.4
50.00 <Road Width	18	64.8

- To define the orientation and characteristics of the windows in the office space
- To analyze the daylighting performance in the room according to the four criteria given in the standard "TS EN 17037:2021 Daylighting in Buildings" for the assumptions made by the determination, restriction, and definitions.
- Identify the situations with optimal performance according to the results of the analysis
- To make suggestions for improving situations that do not meet the necessary conditions in terms of the daylighting criteria given in the standard.

The assumptions made in the study regarding the analysis of the presence of daylight belonging to a space in the office structure in question are presented in Table 6, and the abbreviation and coding information are presented in Table 7 (Çevre, Şehircilik ve İklim Değişikliği Bakanlığı, 2022).

RESULTS OF CALCULATION

The issue of daylighting, which is defined in the TS EN 17037:2021 standard of daylight in buildings, is discussed in the context of the office function for Istanbul and Adana sky conditions by the "Planned Areas Zoning Regulation/adjacent buildings."

- Daylight Provision
- Assessment for ViewOut
- Exposure to Sunlight
- Protection from Glare.

A review of office spaces included in the standard for the above criteria is given below.

Daylight Provision

Natural illumination levels in the volume for 2-storey (B2) and 5-storey (B5) adjacent buildings in Istanbul and Adana are calculated for four window directions (N, W, S, and E), three light transmission factors (LTF 0.8, 0.6, and 0.4) and TR 0.3, using the Rhino/Climate Studio simulation program, which takes into account the meteorological data of Istanbul and Adana. For IST-B2, IST-B5, ADN-B2, and ADN-B5, the minimum and desired illuminance levels for four directions (N, E, S, and W) and three light transmission factors (LTF 0.8, 0.6, and 0.4) the annual ensuring times (%) at the workplaces were calculated. The obtained results are presented in Figure 1-4.

Assessment for View Out

Within the scope of TS EN 17037:2021 standard, the visible layer of external environment properties is evaluated in three different categories as sky, artificial/natural environment. Ground and external view evaluation is

Table 6. Basic Assumptions Accepted in the Study

Basic assumptions used	City	Istanbul, Adana	Solar control element	YOK	Floor light reflectance factor	0.3
	Obstruction height	**7.2 m, 18 m**	**Room Height (OH)**	3 m	**Ceiling Reflection Factor**	0.7
	Direction	North, South, East, and West	**Transparency Rate**	0.3	**Wall Reflection Factor**	0.5
	Obstruction distance	7m, 15m	**Window Height**	1.5 m	**Light Transmission Factor**	0.8, 0.6, and 0.4 (6 mm double glass+13 mm air gap.)
	Obstruction light reflection factor	0.3	**Window Width**	3 m	**Glass Pollution Factor**	0.8
	Ground cover light reflection factor	0.2	**Parapet Height**	0,85m	**Working Plane Height**	0.85 m, 1.2 m
	Room Width/Depth	**5 m×3 m**	**Lintel Height (lh)**	0,65 m	**Working Plane Grid Spacing**	0.67 m×0.44 m
	Wall Thickness	**0.2**	**Joinery Thickness Factor**	0.85	**Internal Surfaces Pollution Factor**	0.9

Table 7. Abbreviations and coding accepted in the study

City	**Direction (D)**	**Light transmission factor (LTF)**	**Transparency rate (TR)**	**According to the number of floors, distance, and height of the building**		**Floor location code**	
ISTANBUL	NORTH	0.8	0.3	2-STOREY BUILDING: 7m Road Width/7,2 m Obstruction Height	B2	GROUND FLOOR	F0
ADANA	SOUTH	0.6		5-STOREY BUILDING: 15m Road Width/18 m Obstruction Height		FIRST FLOOR	F1
	EAST	0.4					
	WEST				B5	SECOND FLOOR	F2
						THIRD FLOOR	F3
						FOURTH FLOOR	F4

Example scenario related to coding IST-K-LTF 0.8-S0 0.3-B2-K0: Istanbul-Northern Facade-Light Transmission Factor 0.8-Transparency Rate 0.3-2 Storey Building B2-Ground Floor K0; ADN-D-LTF 0.4-S0 0.3-Y5-K4: Adana-Eastern Facade-Light Transmission Factor 0.4-Transparency Rate 0.3-5-Storey Building Y8 Fourth Floor K4

carried out according to the qualities of the layers that are seen from at least 75% of the used space.

In the study, based on the "Planned Areas Zoning Regulation" for IST-ADN -B2 and B5, attached office spaces are shown in the section in Figures 5-7. Layers falling into the visual space of IST-ADN-B2 and B5 adjacent office spaces were determined, and the horizontal visual connections were evaluated.

To determine the illumination distribution within the volume, a grid system according to TS EN 12464-1 was used on the horizontal working plane at a height of 0.85 m above the floor for the location of observation points. For glare control, observer points were used at a height of 1.2 m above the floor in the occupied area of the volume. They are illustrated in Figures 5-7.

In the study, in the scope of "Planned Areas Zoning Regulation," the layers of the office space – which is inspected as IST-ADN-B2 and B5 adjacent buildings and shown in section in Figures 5, 6, and 7 entering the visual field determined and summarized in Table 8 by evaluating the horizontal visual connection.

Sun Exposure Time

According to the TS EN 17037:2021 standard stated that for the sunshine duration criterion, at least 1.5 h of sunlight on 21st March should be received. The solar orbit diagram for Istanbul on 21st March (41° N latitude and 29° longitude) and Adana (37° N latitude and 35° longitude) is presented in Figure 8.

Figure 1. Annual Ensuring Time of Minimum and Desired Illuminance Levels for IST-B2-N,E,S,W -LTF 0.8,0.6,0.4 and TR 0.3 in Work Spaces on Each Floor (%).

Using the diagram given in Figure 8, the sunshine durations of the building for Istanbul conditions were calculated for four directions (K – North, G – South, D – East, and B – West) and different times (sunrise, 09.00, 12.00, 15.00, and sunset). They are shown in Figure 9.

It has been observed that there is a 26-min difference between sunrise and sunset times for Istanbul (sunrise, co-rise: 07.06, and sunset: 19.16) and Adana (sunrise:

Figure 2. Annual Ensuring Time of Minimum and Desired Illuminance Levels for IST-B5-N,E,S,W-LTF 0.8,0.6,0.4 and TR 0.3 in Work Spaces on Each Floor (%).

06.40 and sunset: 18.50). If the building in the example of Istanbul was in Adana, it would not make a difference in terms of total sunshine duration for 21 March. When the windows of the office space of cases B2, and B5 are evaluated according to Figures 8 and 9 for 21st March below results are reached:

- It is seen that the building is not exposed to direct sunlight on the north façade

Figure 3. Annual ensuring time of minimum and desired illuminance levels for ADN-B2 N,E,S,W-LTF 0.8,0.6,0.4 and TR 0.3 in workspaces on each floor (%).

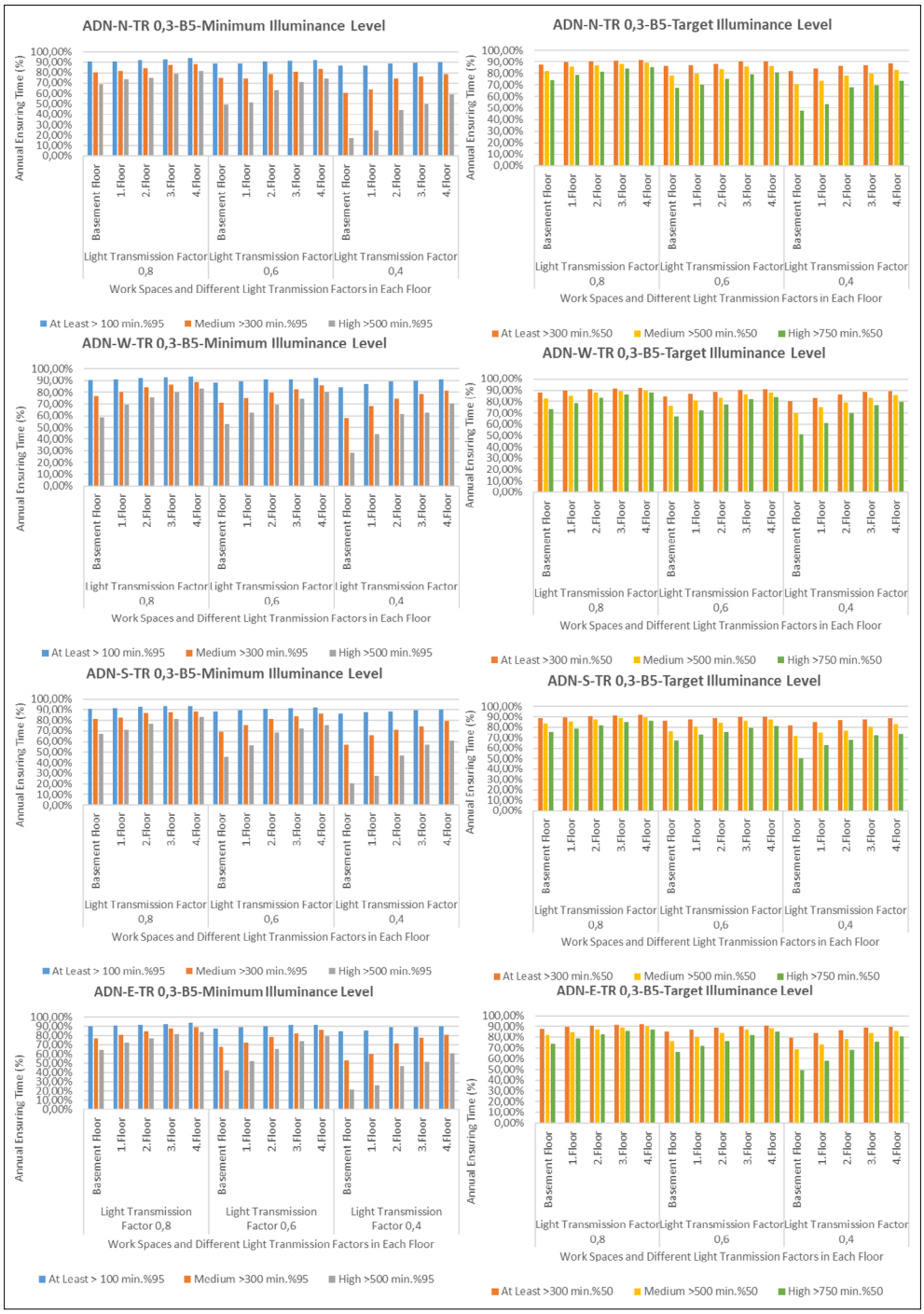

Figure 4. Annual ensuring time of minimum and desired illuminance levels for ADN-B5 N,E,S,W-LTF 0.8,0.6,0.4 and TR 0.3 in workspaces on each floor (%).

- On the southern facade of B2, B5, and each floor receives direct sunlight approximately between 11.00 and 15.00
- On the western facade of B2, B5, and each floor receives direct sunlight effectively from 15.00 in the afternoon until sunset
- On the eastern facade B2, B5, and each floor receives direct sunlight approximately from sunrise to 12.00–12.30.

Protection from Glare

In this study, the four window orientations (N, E, S, and W) and three light transmittance factors (0.8, 0.6, and 0.4) of adjacent 2 (Y2), 5 (Y5) buildings in Istanbul and Adana

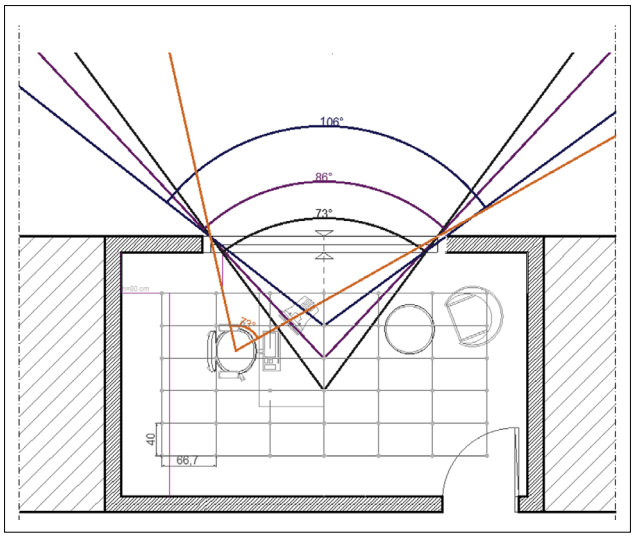

Figure 5. Observer Positions in the Horizontal Plane for IST-ADN-B2 and B5.

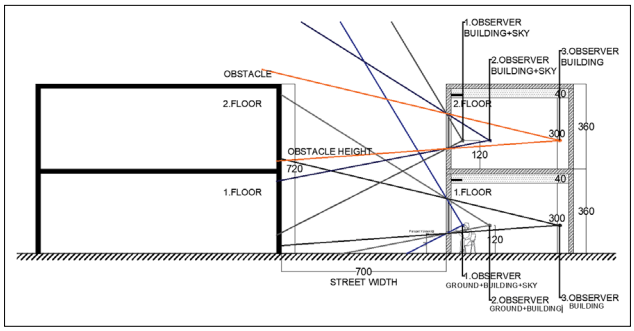

Figure 6. Determination of İST-ADN B2/visual layers

were considered and the DGP values were calculated using the Rhino/Climate Studio simulation program, taking into account the meteorological data of Istanbul and Adana. The graphs of the change (%) of the determined annual DGP values according to the annual supply time in the workspaces on each floor for the North, South, East, and West light transmittance multipliers of 0.8, 0.6, and 0.4 are presented in Figure 10 for İstanbul (IST) and Adana (ADN).

Evaluation of Figure 10 gives the following results.

- On the North-facing facade, discomfort glare is observed for less time than on the other facades
- The glare on the South and West facades is quite high for the reference clocks taken
- The entrance and lower floors of the buildings were found to have less discomfort glare in all directions compared to other floors
- The presence of barrier structures was effective in reducing the glare observed on the ground floor
- As the light transmittance decreases, so does the glare. In particular, when the light transmission rate is 0.4, there are situations with a high level of glare control
- Discomfort glare is observed for a longer period in Adana than in Istanbul.

EVALUATING RESULTS OF CALCULATION

Considered under the same conditions for Istanbul and Adana, the attached office structure has been compared for the parameters of providing sufficient daylight illumination, establishing a visual connection with the

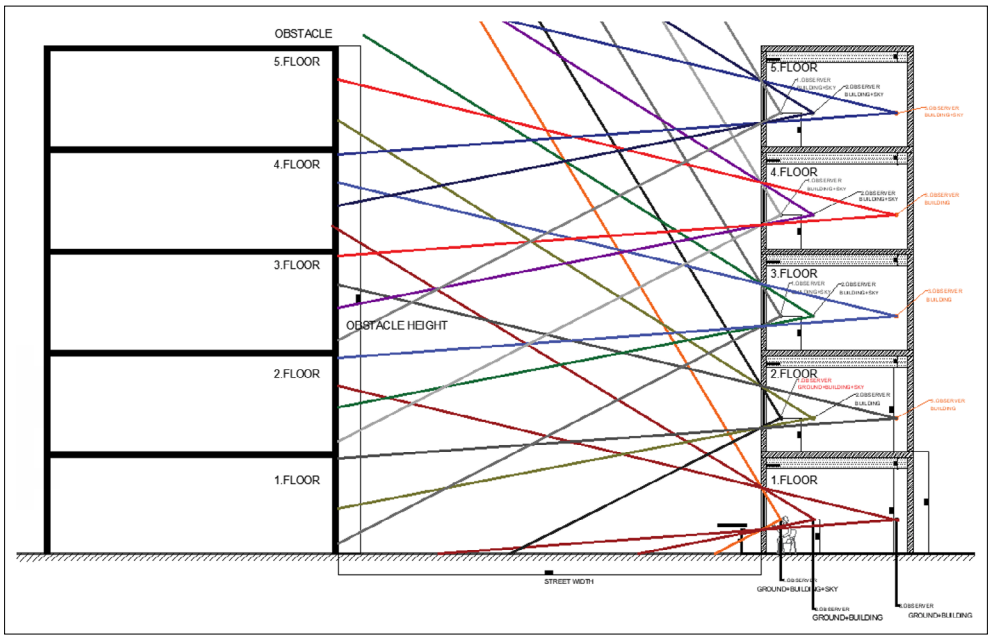

Figure 7. Determination of İST-ADN B5/visual layers.

Table 8. Layers according to observer points in IST-ADN B2 and B5

Visible layers-IST-ADN	1st OBSERVER	2nd OBSERVER	3rd OBSERVER
B2 Obstruction Height 7.2 m/Road Width 7 m			
BASEMENT FLOOR	GROUND+BUILDING+SKY	GROUND+BUILDING	BUILDING
FIRST FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
B5 Obstruction Height 18.8 m/Road Width 15 m			
BASEMENT FLOOR	GROUND+BUILDING+SKY	GROUND+BUILDING	BUILDING
FIRST FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
SECOND FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
THIRD FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING
FOURTH FLOOR	BUILDING+SKY	BUILDING+SKY	BUILDING+SKY

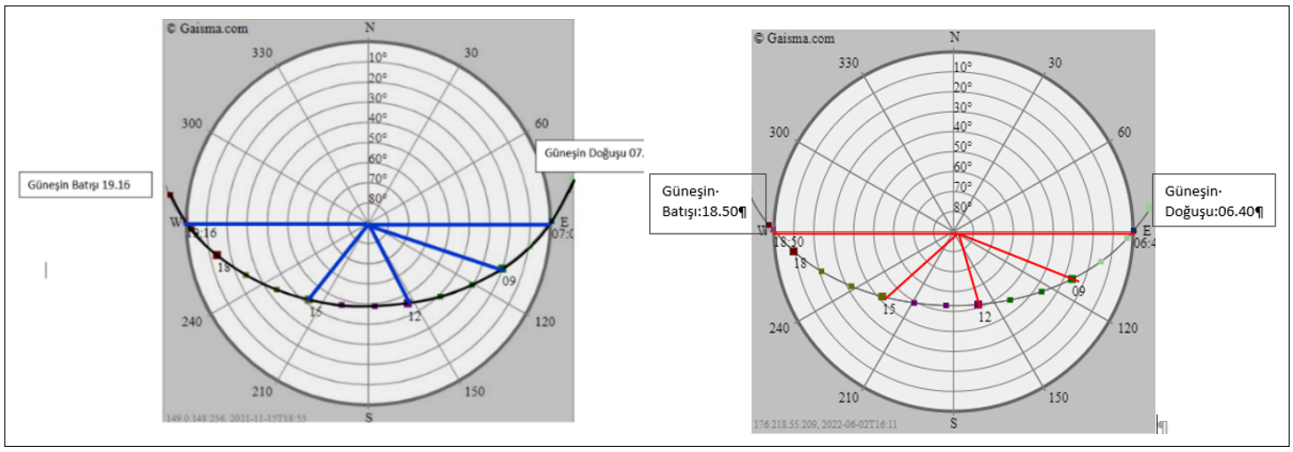

Figure 8. Istanbul and Adana 21 March Solar Orbit Diagram (Gaisma, 2023).

external environment, sun exposure time, and control of daylight-related glare by TS EN 17037. Relative evaluation results are evaluated for below cases,

- Obstruction height, road width, transparency rate, direction, light transmission factor are fixed, and cities change
- Obstruction height, road width, city, and transparency rate are fixed, and window directions change
- Obstruction height, road width, city, and transparency ratio are fixed, and window glass light transmission factor change
- Obstruction height, road width, transparency rate, direction, light transmission factor are fixed, and cities change.

Sufficient daylight is provided in Adana at a higher rate than in Istanbul. It has been observed when similar conditions occurred illuminance level of the target is usually medium in Istanbul – especially for the ground floor – however, for the same conditions lighting level of the target is high in Adana.

It has been observed that glare is higher in Adana than glare in Istanbul.

The fact that the sun has a 26-min difference between the sunrise and sunset times for Istanbul and Adana did not make a difference in the total sunshine duration. The sun exposure time is the same for each floor of the two buildings. The case of handling different cities did not make any difference in terms of visual connection.

Obstruction height, road width, city, transparency rate are fixed, window directions change

Since the northern facade does not receive direct sunlight, the lighting levels are rated as insufficient functionally, while the glare values are lower than the other facades. While the illuminance levels in the reference plane considered on the Southern, Eastern, and Western facades are sufficient for the functionality, results for discomfort glare are negative.

As the Northern facade does not receive direct sunlight, the sunshine duration is minimal.

As the Southern facade is exposed to direct sunlight most of the day, it has a high degree of sun exposure. While there is generally a high level of sun exposure on the Eastern and Western facades, this situation decreases to the middle level only on the ground floors.

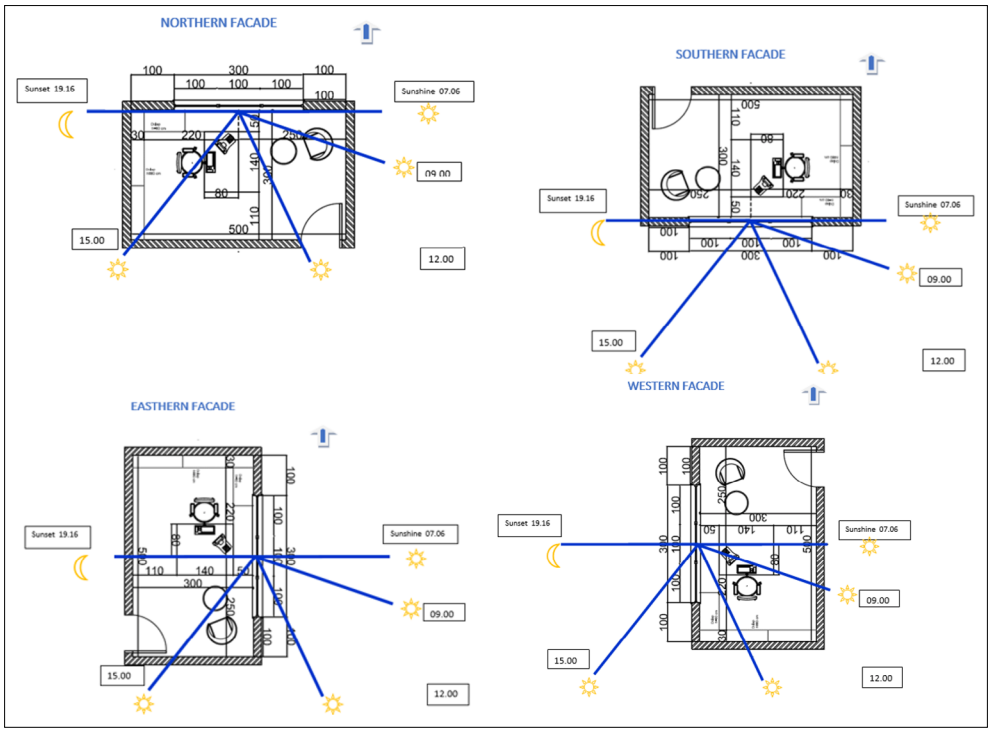

Figure 9. IST/four cardinal points/B2 and B5/obstruction height 7.2, 18 m/road width 7 and 15 m/h sun exposure status on 21 March.

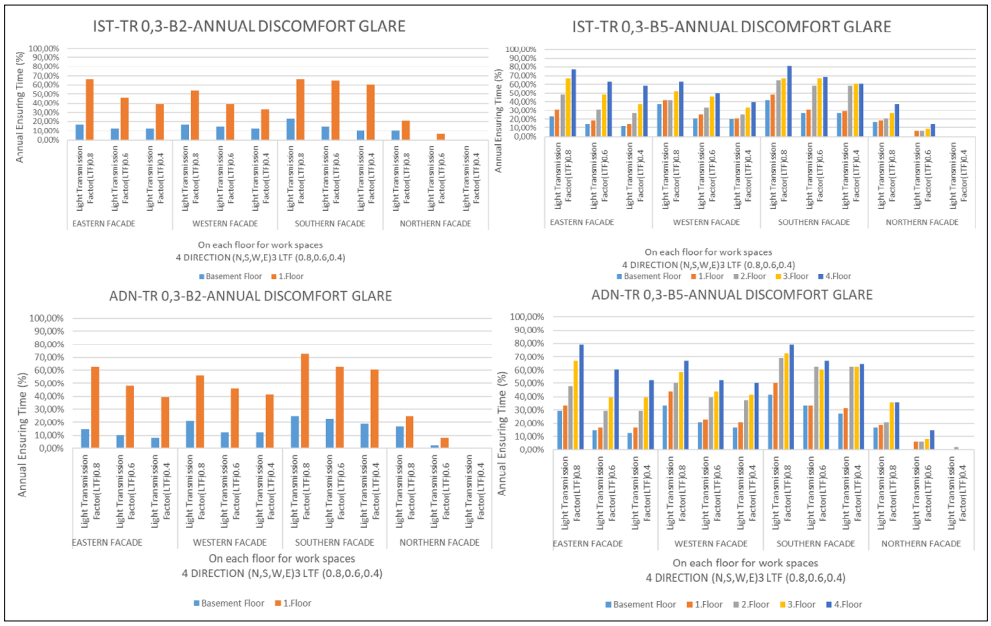

Figure 10. Available duration of annual daylight glare probability values for İST-B2 and B5 and ADN-B2 and B5-N,W,E,S-LTF 0.8,0.6,0.4 at workspaces on each floor (%).

Obstruction height, road width, city, transparency ratio are fixed, window glass light transmission factor change

As the light transmission factor of the window glass decreases, the lighting level and daylight glare values decrease. While this situation produces positive results for glare, it causes negative consequences for the level of lighting required for the function. Especially for lower floors, integrated lighting is needed for cases where the light transmission factor is 0.6 and 0.4.

The matter of establishing a visual connection with the

external environment has the same evaluation for all conditions with road width, obstruction height, and floor height.

EVALUATION AND RECOMMENDATION

In line with the assumptions made in the article study, the daylighting performance of the office spaces under consideration was examined and evaluated according to the parameters of the TS EN 17037 standard. In evaluating the results of this review,

- Adequacy of minimum, medium, and high minimum illuminance levels
- Adequacy of medium and high target illuminance levels
- High-level glare control
- Medium and high sun exposure time
- Minimum and medium assessment for viewing out situations.

Of the 168 scenarios created for Istanbul and Adana, the ones with the most suitable daylight and illuminance for the office function according to the TS EN 17037 criteria were filtered in Excel and identified as 10. As the Northern facade does not receive direct sunlight on 21st March, and therefore the sunshine duration criterion cannot be evaluated, it is not included in this determination. The optimal options determined are presented in Table 9.

Then, 15 scenarios that are positive in accordance with the standard were ranked by one of the decision support systems – the Analytical Hierarchy Process (AHS) method – and the optimum option was determined for Istanbul and Adana. Of the TS EN 18037:2021 standard parameters, the weight scores determined by the AHS method (Saaty, 1994; Dağdeviren, Akay, and Kurt, 2004) and the determined interval values multiplied, and the total score of each scenario were determined by the results for Istanbul and Adana are presented in Table 10.

When the numerical values of the total score in Table 15 are analyzed, it is seen that IST-W-LTF 0.4-TR 0.3-Y5-F2, IST-W-LTF 0.4-TR 0.3-Y5-F3 with the highest total score, ADN-E-LTF 0.4-TR 0.3-Y5-F0 and ADN-W-LTF 0.6-TR 0.3-Y2-F0 options appear to be the most suitable options in terms of sequencing parameters. According to the natural illumination evaluation results of B2 and B5 buildings standing inside the Istanbul and Adana conditions discussed in the article, new arrangements and lighting designs should be done to improve inspected working spaces, especially the Southern facades of them.

Because for these working spaces, there is a negative situation in terms of discomfort glare while adequate lighting is provided in the current situation. Of the inspected office space working places which detected not having suitable lighting conditions, improvement advice is given for the IST-S-LTF 0.8-TR 0.3-Y5 -F0 and F1 (Southern facade-light transmittance factor 0.8-Transparency Ratio 0.3-15m Road Width/18 m Obstruction Height - Ground Floor and 1st Floor of the 5-Storey Building) scenarios.

In these improvements, to provide glare control, a vertical

Table 9. Positive scenarios for Istanbul and Adana office buildings according to TS EN 17037 parameters

Suitable Scenarios After Evaluation	Daylight Provision/ Min.Illuminance Level	Daylight Provision/ Target Illuminance Level	Glare	Assessment for View Out	Exposure to Sunlight
IST-G-LTF 0,4- TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	High
IST-D-LTF 0,6- TR 0.3-Y2-F0	Medium Level	High Level	<0.35	Building	Medium
IST-D-LTF 0,4- TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	Medium
IST-B-LTF 0,6- TR 0.3-Y2-F0	Medium Level	Medium Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y2-F1	Medium Level	High Level	<0.35	Building+Sky	High
IST-B-LTF 0,4- TR 0.3-Y5-F0	High Level	High Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y5-F1	High Level	High Level	<0.35	Building	Medium
IST-B-LTF 0,4- TR 0.3-Y5-F2	High Level	High Level	<0.35	Building	High
IST-B-LTF 0,4- TR 0.3-Y5-F3	High Level	High Level	<0.35	Building	High
ADN-G-LTF 0,4-TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	High
ADN-D-LTF 0,4-TR 0.3-Y2-F0	Min. Level e	Medium Level	<0.35	Building	Medium
ADN-D-LTF 0,4-TR 0.3-Y5-F0	Medium Level	High Level	<0.35	Building	Medium
ADN-B-LTF 0,6-TR 0.3-Y2-F0	Medium Level	High Level	<0.35	Building	Medium
ADN-B-LTF 0,4-TR 0.3-Y2-F0	Min. Level	Medium Level	<0.35	Building	Medium

Table 10. Total scores of scenarios suitable for AHS evaluation in Istanbul and Adana office buildings

Weight values	0.214	0.36	0.285	0.0708	0.0708	Total Points
Parameters	**Daylight Provision/ Min.Illuminance Level**	**Daylight Provision/ Target Illuminance Level**	**Glare**	**Assessment for View Out**	**Exposure to Sunlight**	
IST-S-LTF 0.4-TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.6	0.350
IST-D-LTF 0.6-TR 0.3-Y2-F0	0.3	0.6	0.6	0.1	0.3	0.480
IST-D-LTF 0.4-TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.3	0.329
IST-W-LTF 0.6-TR 0.3-Y2-F0	0.3	0.3	0.6	0.1	0.3	0.372
IST-W-LTF 0.4-TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.3	0.329
ISTWB-LTF 0.4-TR 0.3-Y2-F1	0.3	0.6	0.6	0.3	0.6	0.515
IST-W-LTF 0.4-TR 0.3-Y5-F0	0.6	0.6	0.6	0.1	0.3	0.544
IST-W-LTF 0.4-TR 0.3-Y5-F1	0.6	0.6	0.6	0.1	0.3	0.544
IST-W-LTF 0.4-TR 0.3-Y5-F2	0.6	0.6	0.6	0.1	0.6	0.565
IST-W-LTF 0.4-TR 0.3-Y5-F3	0.6	0.6	0.6	0.1	0.6	0.565
ADN-S-LTF 0.4- TR 0.3-Y2-F0	0.1	0.3	0.6	0.1	0.6	0.350
ADN-E-LTF 0.4-Y2- TR 0.3-F0	0.1	0.3	0.6	0.1	0.3	0.329
ADN-E-LTF 0.4-Y5- TR 0.3-F0	0.3	0.6	0.6	0.1	0.3	0.480
ADN-W-LTF 0.6-Y2- TR 0.3-F0	0.3	0.6	0.6	0.1	0.3	0.480
ADN-W-LTF 0.4-Y2- TR 0.3-F0	0.1	0.3	0.6	0.1	0.3	0.329

and movable solar control element consisting of three parts of 1 m × 1.5 m shown in Figure 11 is proposed.

Each part of the designed solar control element has 11 motionless lamellas that make an angle of 90° with the vertical axis. The wooden solar control element, which has a light reflection factor of 0.40, is postulated to have a specular reflecting surface and isotropic diffuse (matte) light reflection type, a lamella width of 7 cm, a distance of 5 cm between lamellas, the thickness of 3 cm, and distance of 10 cm from the facade (Figure 11).

In the TS EN 17037 2021 "Daylight Standard in Buildings," the maximum allowed threshold for the possibility of daylight glare should not exceed 5% of the reference period. The South facade with high glare values was chosen for the improvement proposal carried out in the study. Thus, it is aimed to provide sufficient lighting levels for office workplaces as well as the glare value levels specified in the standard. In this context, the calculations for the situation in which the proposed solar control element is added are made in Rhino/Climate Studio. The results are shown in Table 11.

As seen in Table 11, a high degree of protection from glare can be achieved when all three of the solar control elements are closed. However, a decrease in the desired and minimum lighting level of the working space was calculated. For this reason, it has been determined that the lighting level that is observed over the target in IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR0.3-B5-F1 at the lowest level should

Figure 11. View and section of the suggested sun control element.

Table 11. IST-S-LTF 0.8- TR 0.3-Y5 - Vertically Driven Sunshade Proposal-Providing Sufficient Lighting Level

Min. Illuminance Level			Duration (Provided Percentage of Daylight Time (4380 Hours)				
Provided Degree	Illuminance Level (Lux)	Area	Light Transmission Factor (LTF) 0.8				
			Basement Floor	1. Floor	2. Floor	3. Floor	4. Floor
Minimum	>100	Min. %95	79,47%	80,80%	83,65%	85,14%	86,10%
Medium	>300	Min. %95	28,70%	33,42%	48,97%	59,75%	63,81%
High	>500	Min. %95	0,00%	0,00%	4,70%	20,78%	31,32%
Target Illuminance Level							
Minimum	>300	Min. %50	68,04%	72,03%	74,32%	77,63%	79,47%
Medium	>500	Min. %50	34,89%	45,68%	56,58%	61,92%	68,84%
High	>750	Min. %50	0,09%	3,74%	20,84%	37,28%	47,03%
İST-G-IGÇ 0.8- SO O.3-Y5- Sugesstion for Vertical Sun Control Element- Annual Discomfort Glare (Based on Thime Spent Per Year)			0,00%	0,00%	0.00%	0,00%	0,00%

be improved to provide a minimum horizontal 300 lux lighting as recommended in TS EN 12464-1: 2021 "Indoor Work Areas Lighting" in terms of artificial illumination for office workspace. The information about the artificial illumination design created for the improvement proposal, and the location and characteristics of the lighting devices used are presented in Figure 12.

Design of artificial illumination with natural illumination having solar control element (integrated lighting) for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 again calculated in Rhino/Climate Studio simulation program. Considering sustainability and energy issues, two different lighting scenarios called D1 and D2, which could be controlled independently of each other, were created (Table 12).

For natural illumination, the Rhino/Climate Studio simulation program uses the measured typical meteorological year (TMY) data measured between 2004 and 2018. For the integrated lighting calculations to be performed for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1, the days to be considered and the appropriate sky models for these days have been determined. In a study conducted in 2008, it was concluded that the day that characterizes a month is the 15th day of that month as a result of natural light calculations for the province of Istanbul (Güvenkaya, 2008). It was decided to use this result in the study.

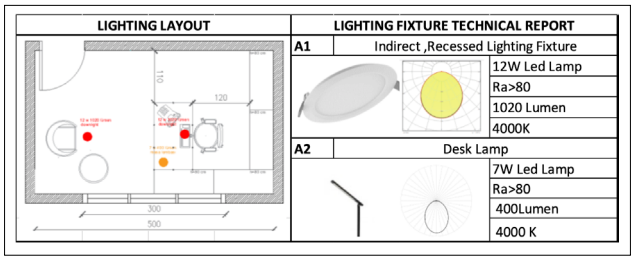

Figure 12. IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 artificial illumination design and technical information of lighting devices.

Table 12. Lighting scenarios

1. Daylighting + Only Table Lamp On	D1
2. Daylighting + Table Lamp + Led Lighting Fixture	D2

Calculations regarding to integrated lighting for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 are made according to 08.00, 12.00, and 16.00 h of 15 December, 15 March, 15 June, and 15 September and national time zone of Türkiye – GMT+3 (Iğdır). The sky models determined for the discussed dates are given in Table 13.

To provide a 300 lux minimum desktop lighting level over the target using minimum energy, different lighting scenarios are applied for different cases. Lighting scenarios for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8-TR 0.3-B5-F1 at 08.00, 12.00, and 16.00 h of 15 December, 15 March, 15 June, and 15 September are shown in Table 13, and scenarios of average lighting levels over desktop are shown in Table 14.

According to Table 15, for IST-S-LTF 0.8- TR 0.3-B5-F0 and IST-S-LTF 0.8- TR 0.3-B5-F1 during referential time (08.00–18.00) in order to provide target desktop lighting level 300 lux as maintained by TS EN 12464-1:2021[1], it is enough to use D1 scenario which table lamp usually open along natural light. It is sufficient to use the D2 scenario only in the evening in March and all-day during winter months. In summer, the level of lighting provided by natural illumination is sufficient at noon.

Table 13. Sky models determined for the calculation dates considered (Şener & Yener, 2012)

Istanbul	15 March	15 June	15 December	15 September
08.00	OVERCAST	INTERMEDIATE	OVERCAST	INTERMEDIATE
12.00	INTERMEDIATE	CLEAR	INTERMEDIATE	INTERMEDIATE
16.00	OVERCAST	INTERMEDIATE	OVERCAST	INTERMEDIATE

Table 14. Applied lighting scenarios

	08.00	**12.00**	**16.00**
15th June			
IST-S-LTF 0.8- TR 0.3-B5-F0	D1	DAYLIGHT	D1
IST-G-LTF 0.8- TR 0.3-B5-F1	D1	DAYLIGHT	D1
15th December			
IST-S-LTF 0.8- TR 0.3-B5-F0	D2	D1	D2
IST-G-LTF 0.8- TR 0.3-B5-F1	D2	D1	D2
15th March			
IST-S-LTF 0.8- TR 0.3-B5-F0	D1	D1	D2
IST-G-LTF 0.8- TR 0.3-B5-F1	D1	D1	D2
15th September			
IST-S-LTF 0.8- TR 0.3-B5-F0	D1	D1	D1
IST-G-LTF 0.8- TR 0.3-B5-F1	D1	D1	D1

Table 15. Average illuminance level results (Lux)

	08.00	**12.00**	**16.00**
15th June			
IST-S-LTF 0.8- TR 0.3-B5-F0	413,6 lux	445,6 lux	440,2 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	436,1 lux	513,5 lux	489,4 lux
15th December			
IST-S-LTF 0.8- TR 0.3-B5-F0	316,8 lux	366,8 lux	396,5 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	333,7 lux	415,5 lux	423,1 lux
15th March			
IST-S-LTF 0.8- TR 0.3-B5-F0	346,9 lux	461,6 lux	360,3 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	368,5 lux	535,3 lux	393,1 lux
15th September			
IST-S-LTF 0.8- TR 0.3-B5-F0	371,6 lux	463,8 lux	447,6 lux
IST-G-LTF 0.8- TR 0.3-B5-F1	397,5 lux	506,6 lux	486,8 lux

CONCLUSION

Office buildings, that are used for a long time and have a high artificial energy consumption, should be structures that provide visual comfort conditions, use energy effectively and efficiently, and cause the least damage to nature/environment (Yücel, 2019). In each space, it is possible to provide the necessary minimum visual comfort conditions with a precise lighting system design that responds to the requirements where energy is actively used. Making use of natural lighting in the lighting design phase to provide the required amount of lighting will contribute to a significant reduction in the energy used for artificial lighting.

This paper presents the first results of a study aimed at evaluating the daylighting performance of offices used during the day according to the "Planned Areas Type Zoning Regulation" in force in our country, based on the criteria of TS EN 17037: 2021 "Daylight Standard in Buildings."

The regulation includes basic data with limitations such as street width, building height, etc. In cases where these data are used, it will be beneficial to consider the variables of daylighting performance in the volume: Window orientation, window light transmittance, and the hours of use of the volume during the day and the days of use in the year in the context of the function of the building, while designing the lighting system with a view to reducing the use of artificial lighting energy using natural lighting as much as possible. As a result, the performance of the daylight entering the volume would be determined at the design stage and the results will contribute to sustainable lighting design while reducing the energy spent on artificial lighting.

NOTE

[1]TS EN 12464-1:2021, T. E. (2021). Işık ve Aydınlatma: Çalışma Yerlerinin Aydınlatılması - Bölüm 1: Kapalı Çalışma Alanları (Light and Lighting - Lighting of Work Places - Part 1: Indoor Work Places).

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Article

Knowledge map of stakeholder management in construction projects

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ABSTRACT

Stakeholders are an important part that can affect the conditions and performance of construction projects or be affected by project conditions and performance. Stakeholder support plays a crucial role in the success of construction projects. Understanding and meeting stakeholders' expectations and goals can only be achieved through stakeholder management, which also involves organizing and managing their internal relationships. This study provides a comprehensive understanding of the development of stakeholder management in a global context by using bibliometric analysis. The study aims to explore stakeholder management's role within the broader concept of project management and its relationship with other management concepts within different time periods. Bibliometric analysis will be used to create a knowledge map in the field of stakeholder management. Data was collected from the Scopus and Web of Science databases and analyzed using the "VOSviewer" software. The output is utilized to develop a knowledge map about stakeholder management in the construction management literature. The results indicate that researchers have been addressing stakeholder management-related topics since 1985, with 762 articles published during this period. Key topics are examined in-depth, considering different time periods, and a research model presents the evolution of stakeholder management worldwide. The analysis identifies that new trend topics in construction projects are related to stakeholder management. Additionally, this analysis is an ongoing process that can be updated with future publications, providing a reliable foundation to visualize the evolution of stakeholder management over time.

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INTRODUCTION

The notion of the stakeholder was firstly developed in the management field by Stanford Research Institute in 1963, where stakeholders were defined as any groups or individuals who have great importance on the survival of the organization (Freeman, 2010). Since there is a wide variety of stakeholders in terms of profession, culture, educational level, and gender, each stakeholder affects the outcome of projects. These stakeholders generally offer a wide range of interests on the project, which are to be met throughout the process (Oppong et al., 2017).

Construction projects contain many uncertainties because of their long periods of outdoor production (De Meyer et al., 2002). All construction projects are complex, unique, and composed of multi-stakeholders (Cleland and Ireland, 2004). Some of the stakeholders in the construction projects are defined as the internal stakeholders (the owner, design group,

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consultant, contractor, subcontractor, and supplier) who are either affected from or affect the project directly, while some of them are described as the external stakeholder (central and local governments, etc.) who are affected from or affect the project indirectly (Aaltonen et al., 2008). Savage et al., (1991) categorized stakeholders as *supportive, non-supportive, mixed blessing, and marginal*. Newcombe (2003) emphasized that even though marginal stakeholders may have fewer impact on the project, they should not be underestimated because of their connection to other stakeholders, which may lead to different types of disruptions.

Stakeholder management emerges stakeholder concerns to the surface. It helps an effective approach for developing stakeholder relationships in complex projects (Olander, 2007). Stakeholder relations play an important role in the completion of the project because stakeholders and their relations effect project's outcome positively or negatively. (Liu et al., 2016; Waghmare and Bhalerao, 2016). Generally, a lack of managing the stakeholders' increase conflicts and controversies on the implementation phase of construction projects (Olander and Landin, 2005). Non-supportive stakeholders need to be managed for the purpose of removing their negative effects on project success (Harris, 2010). Supportive stakeholders not only build trust in the project but also prevent budget and time overruns. They enhance the quality of the project and increase safety in the project area (Harris, 2010). Stakeholder management is a dynamic process and must be updated on each phase of projects. The importance of this issue has been revealed by the bibliometric studies, realized with certain periods (Mok et al., 2015; Oppong et al., 2017; Xue et al., 2020; Yang et al., 2009, 2011). For these reasons, stakeholder management studies in construction projects have been increased in the recent years.

Bibliometric analysis is defined as "the analysis of publication data (author, citation, sources, subjects, country, year, etc.) using statistical methods in any discipline" (Small, 1999). Bibliometric analysis is tailored for a method to summarize studies in the literature in terms of specific indicators (Thelwall, 2008).

Bibliometric analysis is preferred for the purpose of performance analysis and science mapping. Performance analysis indicates authors' or institutions' studies and publications' reviews. Science mapping examines the scientific research structure and dynamics. This mapping comprises classification and visualization (Boyack and Klavans, 2013). Three methods are used in bibliometric studies – focusing on the structure, focusing on the dynamics, and focusing on a narrow research question (Zupic and Čater, 2015). Focusing on structure analyzes authors, institutions, publications, and their relation to each other. Focusing on dynamics divides publications into several time periods and depicts the structure of the field for each period. Focusing on a narrow research question also addresses researcher's specific question and proves researcher's claims (Zupic and Čater, 2015). To compare the pace of scientific development and to determine periodic changes, focusing on the dynamics of the literature has been preferred in this study.

Knowledge maps, also known as concept maps or cognitive maps, are visual representations of the relationships between different concepts or ideas within a specific domain or field of knowledge. They provide a panoramic view of the key concepts, activities, and their interconnections, allowing researchers and practitioners to gain a comprehensive understanding of a particular subject area (Wang, 2022). Using a knowledge map, the studies of stakeholder management can be categorized into different periods to understand the evolution of the field over time. This categorization allows for a systematic analysis of the trends, theories, and methodologies that have emerged in stakeholder management research throughout the years.

There were some researchers conducted in-depth analysis on stakeholder management in previous studies (Mok et al., 2015; Oppong et al., 2017; Xue et al., 2020; Yang et al., 2009). Yang et al., (2009) provided an overview of previous studies in the field of stakeholder management until 2009. The review was handled manually, and they grouped the outcome in terms of descriptive, instrumental, and normative with manual review. The impact and definition of the stakeholder in the project were emphasized. Mok et al., 2015 analyzed existing stakeholder management approaches focusing on the initial planning of the construction project phase and suggested that a multi-purpose stakeholder management model can be integrated with the entire project life cycle. This study covers stakeholder interest and influences, the stakeholder management process, stakeholder analysis methods, and stakeholder engagement between 1997 and 2014. Traditional stakeholder analysis adopted in mega construction projects. Oppong et al. (2017) pointed out the lack of comprehensive tools to improve stakeholder management performance in construction projects and presented a cognitive model to manage and measure the performance of the stakeholder management configuration. The study's findings offer researchers and professionals the opportunity to benefit from increased flexibility in adapting project stages, project types, and project nature to enable more efficient management. This flexibility facilitates them to tailor their approaches and to better align with stakeholder needs, ultimately enhancing the overall project management process. Xue et al. (2020) have explored stakeholder management bibliographic research with different method contraries to traditional literature review approaches. Previous studies were evaluated on seven topics, including stakeholder concept, method, identification, assessment, management, influence, and complexity. As a result, society, sustainability, tool, and project were determined to be the most studied stakeholder management research topics until 2017.

All previous studies, in general, aimed to conduct a situation assessment of stakeholder management. Yang et al., 2009 revealed a critical review of stakeholder management. Before 2009, very few methods and tools were defined to analyze stakeholders and their interests; previous studies remained

mostly theoretical frame. No assessment has been made regarding the relationship between stakeholder management and other factors influencing the project, as well as the managerial relationships associated with it. Mok et al., 2015 indicated a need to determine the impact of national culture on the discipline and revealed that traditional stakeholder analysis methods were predominantly adapted to mega-construction projects. Moreover, an emphasis was made on the necessity of social network analysis for managing stakeholder relationships. However, in their study, selective articles were chosen between 1997 and 2014. Most of the study was conducted in the domestic market. Oppong et al., 2017 suggested a conceptual model for managing project performance indicators and success factors. Their study focused only on obtaining the checklist of performance parameters related to stakeholder management. Although there were many more publications on stakeholder management until 2016, the study has been limited to 110 articles. Xue et al., 2020 examined 752 peer-reviewed academic papers until 2017 in Web of Science (WOS). The study has concluded that there is a lack of research on stakeholder engagement in sustainable urban projects. It has also identified that stakeholder studies in complex projects cannot be easily generalized and can be limited to implementation in uncertain project environments.

This study provides a comprehensive understanding of the development of stakeholder management in a global context using bibliometric analysis. It seeks to explore stakeholder management's role within the broader concept of project management and its relationship with other management concepts within different time periods. Bibliometric analysis will provide the means to create a knowledge map in stakeholder management. The knowledge map that has been generated indicates three phases of stakeholder management in construction. These stages encompass (1) gathering and generating data along with constructing a stakeholder management framework and database for each period; (2) identifying the trends of stakeholder management in construction projects toward which topics; and (3) unveiling the insufficiently explored topics.

It will provide a basis to draw a path where the stakeholder management evolved in time while analyzing the stakeholder management in construction projects articles, carried out between 1985 and 2023 for researchers. This study helps in identifying relevant resources and exploring the boundaries of research, subsequently presenting recommendations for forthcoming studies and other researchers. Nearly, every part is utilized to establish clustering relationships within the knowledge map through cluster analysis, to identify the current state and potential research directions of stakeholder management in the construction field. Thus, future researchers can benefit from the trends identified in the periodization and knowledge map of stakeholder management studies in their research subjects.

RESEARCH METHODOLOGY

During the past two decades, there has been an increase in the use of bibliometric analysis (Mukherjee et al., 2022). Bibliometric analysis consists of several mathematical and statistical methods for utilizing bibliometric data (Donthu et al., 2021). This analysis technique aims to explain the mutual affinity among journal citations and demonstrates the present research topic. The data, widely utilized in a bibliometric analysis, can be retrieved from different citation indexes such as Scopus and WOS. For instance, it evaluates the impact and the quality of scientific literature, sources, research institutions, and researchers depending on the citations (Meyer et al., 2018). The bibliometric analysis examines the quantitative evaluation of article attributes (i.e., publications, citations, keywords, territories, years, and publishers) and their relationship with each other. In other words, bibliometric analysis is beneficial for revealing and mapping the cumulative scientific knowledge, and it also explains the meaning of the unstructured data on large scales regularly. Eventually, bibliometric researches can give some opinions for the development of a special field, identifing knowledge gaps, generating new ideas for investigation, and setting their contributions to the specific field (Donthu et al., 2021). Unlike the manual review, bibliometric analysis is used when the data are too broad. To obtain considerable results in bibliometric analysis, at least 200 papers are suggested for review (Rogers et al., 2020). Keyword filtering, trial and error methods, and sample size are adequate for bibliometric analysis (Glänzel, 2003).

The succeeding subsections, describing the research framework of this study, are shown in Figure 1.

One of the most important steps is choosing an appropriate database to extract the data from the literature in the bibliometric research. The data in this research were collected from the Scopus and WOS database. *The important feature*

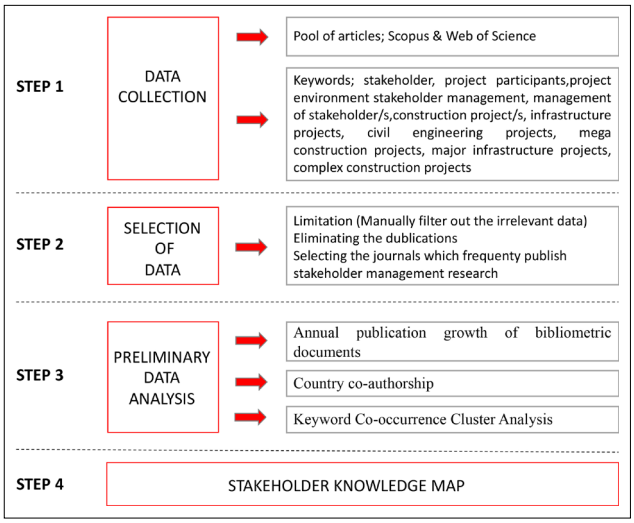

Figure 1. Research framework.

of these databases is that they are the most comprehensive database and they include all article types, and index all authors, institutional addresses, and bibliographic references for each article (Mongeon and Paul-Hus, 2016). Using the keywords listed in Figure 1, search was run in both databases. The initial number of articles was 2229. In the second stage, limitation was applied to eliminate the irrelevant data. First, the articles which have the inappropriate use of keywords were eliminated manually. Second, publications were eliminated based on their coverage of the topic. The publications which have sporadic articles in SM were also eliminated. That elimination provides the top-ten journals that cover SM recurrently. Within this pool of journals, 661 articles from Scopus and 312 articles from WOS were retrieved. Afterward, 271 articles were eliminated because of the duplication in both databases.

While conducting a bibliometric analysis, performance analysis, bibliometric mapping, and network analysis are priority issues. The performance analysis is a descriptive method for evaluating the publication and citation-related metrics. Bibliometric mapping provides the analysis of the influences and strengths of relationships among different article attributes which are depicted by the co-occurrence weight, and total link strength of the items. It may include citation analysis, co-citation and co-authorship analysis, bibliographic coupling, and keywords analysis. Bibliometric mapping outcomes can be enhanced through network analysis, where the evaluation of network metrics, clustering, and visualization are commonly used.

Moreover, bibliometric mapping and network analysis were performed with the file extracted from the data source using a computer program called VOSviewer (ver.1.6.18). This software was designed by van Eck and Waltman for the purpose to help the creation and visualization of bibliometric maps (van Eck and Waltman, 2010). Through this software, all data can be analyzed easily in terms of publications, keywords, countries, co-authors, and co-citations (Nielsen and Nielsen, 2018). Nevertheless, this study was limited by documents, the country, keywords, the co-authorship, and journal publishing analyses for the bibliometric mapping, and the visualization of the network analysis.

The network visualization, overlay, and density are types of visualization of VOSviewer software. In this study, the network and the overlay visualizations were used. While the network visualization shows the co-occurrences of words, co-authorship, or country of origin, the overlay visualization expresses the date of publication. VOSviewer depicts the mutual keywords within these attributes, and the line between two attributes in the visualization approximately indicates the connection (Romero and Portillo-Salido, 2019).

DATA ANALYSIS

This study comprised the two essential searching terms. One was stakeholder-related words such as "stakeholder," "project participants," "project environment," and "stakeholder management." The other one was construction project words, including "construction projects," "infrastructure projects," "civil engineering project," etc. All the keywords in previous review studies (Mok et al., 2015; Oppong et al., 2017; Xue et al., 2020; Yang et al., 2009, 2011) were included in this study to take a holistic assessment. All keywords and searching limitations are summarized in Figure 2.

The performance analysis was investigated using Scopus and WOS to create bibliometric map. In this study, the productivity of publication, total citations per-year, most cited articles, and most relevant articles collected from Scopus and WOS. The relevant articles in Scopus were extracted in a ".csv" file, where WOS was extracted in a ".xls" file. These two formats were combined in a ".csv" file for further analysis. In the initial stage of the research, there were 2229 publications retrieved about SM in construction projects in 604 different journals since 1985. Although many journals covered variety of research topics about stakeholder management in construction projects, 34% of articles were published in ten journals, as shown Table 1.

Stakeholder Publications' Annual Trend of Bibliometric Documents

The principle understanding of the performance of a publication in a particular field is to observe the annual publication frequency of scientific articles. In Figure 3, the annual publication rate of articles within 762 articles since 1985 is displayed.

Figure 3 indicates that the number of studies in stakeholder management studies in construction project publications have increased steadily per year. Based on the trend slopes, stakeholder management publication progress is divided into three periods, which are Period I: *initial exploration*

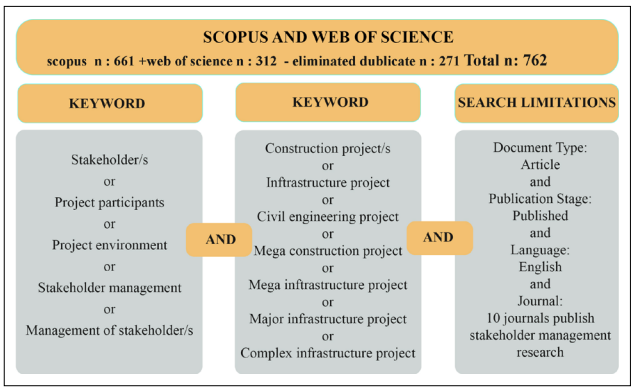

Figure 2. All keywords and search limitations for data collection in Scopus and Web of Science.

Table 1. Journals that frequently publish stakeholder management research

No	Journal	#of Articles
1	Journal of Construction Engineering and Management	132
2	Engineering Construction and Architectural Management	104
3	International Journal of Project Management	85
4	Journal of Management in Engineering	83
5	Sustainability	81
6	Construction Management and Economics	67
7	International Journal of Construction Management	65
8	Built Environment Project and Asset Management	53
9	Buildings	49
10	Automation in Construction	43

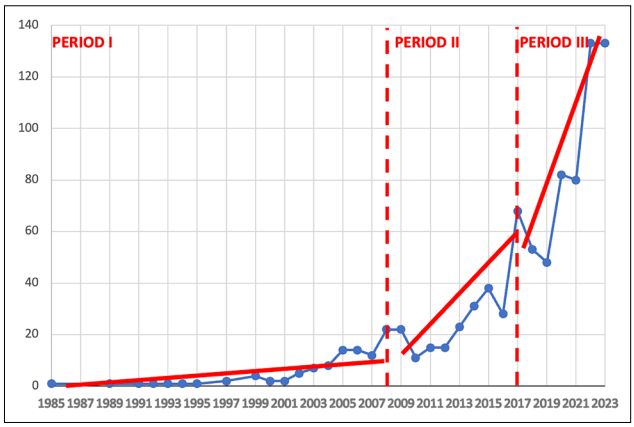

Figure 3. Annual publication growth of stakeholder management articles since 1985.

stage (1985-2007), Period II: *steady development stage* (2008-2016), and Period III: *booming growth stage* (2017-2023). Period I contains 77 articles, Period II 205 articles, and Period III 481, respectively. In other words, 63% of the articles about stakeholder management in construction projects were published within the past 6 years.

Although the number of articles published in Period I is fewer than other periods, this period is the reference period in regard to stakeholder management studies in construction management literature (Figure 4). Therefore, total citations in Period I are as high as other periods. Most cited articles in each period are displayed in Table 2. In period I, articles on project success indicators, critical success factors, and stakeholder impact in construction projects were most cited. This period is defined as *initial exploration stage* because studies in this period focused on the importance of stakeholder management in construction project success. Even though similar studies continued in Period II, studies evolved in model building on stakeholder management such as BIM and social network. On the last period, as BIM studies advanced Internet of Things (IoTs) and fuzzy techniques were used with BIM in Period III. In this period, the number of studies increased the topic of sustainability and sustainable project management issues within stakeholder management apparently.

Country Co-authorship

VOSviewer was used to visualize country co-authorship (international collaboration) for stakeholder management in construction projects since 1985. In Period I 22 countries, in Period II 42 countries, and in Period III 74 countries contributed to the stakeholder management studies through international collaboration.

A large proportion of articles' co-authorship in stakeholder management come from Hong Kong, Australia, China, the United Kingdom, the Unites States, and Canada. However, in recent years, the article was published from other countries such as Turkey, the Netherlands, and Nigeria. To demonstrate international influence, countries were grouped into six groups, which in Figure 5 indicates with stacked columns. In Figure 5, it can be seen that more than 85% of the articles published in stakeholder management are from Hong Kong, Australia, China, the United Kingdom, and Canada in Period I. Interestingly, the number of articles from the United States increased compared to Canada in Period II. However, the dominance of these countries in this issue fell from nearly 85% in Period I and II to about 55% in Period III. Country co-author geographic spread shift toward other countries indicates that stakeholder management studies are in the attention to many international scholars and growing as a research field.

Keyword Co-occurrence Cluster Analysis

Keywords are highly beneficial in terms of the bibliometric analysis while looking forward for the information about specific academic fields (Zhang et al., 2016). The main objective of including keywords into articles is increasing their accessibility for the ease of academic studies (Vargas-Quesada et al., 2017). The frequency of the keywords is extracted from articles in the dataset and keyword co-occurrence analysis was utilized.

A hundred forty-three keywords used in articles were included in the analysis after the cut-off point of 5 references, and this amounted to 5096 keywords. While the keywords were being determined, general conceptual words such as "stakeholder management," "construction project," and "stakeholders" and irrelevant words were ignored in this study. The number of keyword citations increased in

Table 2. Most cited articles in each period

No.	Period I		Period II		Period III	
	Article	# of Citation	Article	# of Citation	Article	# of Citation
1	Causes of delay in large construction projects (Assaf and Al-Hejji, 2006)	927	BIM implementation throughout the UK construction project lifecycle: An analysis (Eadie et al., 2013)	437	Prefabricated construction enabled by the Internet-of-Things (He et al., 2017)	222
2	Understanding the key risks in construction projects in China (Zou et al., 2007)	540	Beyond the 'iron triangle': Stakeholder perception of key performance indicators (KPIs) for large-scale public sector development projects (Toor and Ogunlana, 2010)	345	Mapping the managerial areas of Building Information Modeling (BIM) using scientometric analysis (He et al., 2017)	202
3	Critical success factors for different project objectives (K H Chua et al., 1999)	416	Stakeholder management studies in mega construction projects: A review and future directions (Mok et al., 2015)	338	Sustainable project management through project control in infrastructure projects (Kivilä et al., 2017)	178
4	Exploring critical success factors for partnering in construction projects (Chan et al., 2004)	317	Social network model of construction (Chinowsky et al., 2008)	261	Megaproject Management Research: The Status Quo and Future Directions (Yuan et al., 2021)	14
5	Evaluation of stakeholder influence in the implementation of construction projects (Olander and Landin, 2005)	317	Trust in projects: An empirical assessment of owner/contractor relationships (Pinto et al., 2009)	249	Governing Behavioral Relationships in Megaprojects: Examining Effect of Three Governance Mechanisms under Project Uncertainties (Zheng et al., 2019)	138
6	Factors affecting cost performance: Evidence from Indian construction projects (Iyer and Jha, 2005)	299	Quantifying performance for the integrated project delivery system as compared to established delivery systems (Asmar et al., 2013)	214	Improving Information Sharing in Major Construction Projects through OC and POC: RDT Perspective (Zhang et al., 2020)	138
7	Stakeholder impact analysis in construction project management (Olander, 2007)	265	Assessing risk and uncertainty inherent in Chinese highway projects using AHP (Zayed et al., 2009)	207	From BIM to extended reality in AEC industry (Alizadehsalehi et al., 2020)	133
8	Stakeholder management for public-private partnerships (El-Gohary et al., 2006)	260	Quantifying schedule risk in construction projects using Bayesian belief networks (Luu et al., 2009)	186	Strategic responses to external stakeholder influences (Nguyen et al., 2023)	132

Table 2. Most cited articles in each period (Cont.)

No.	Period I		Period II		Period III	
	Article	# of Citation	Article	# of Citation	Article	# of Citation
9	From client to project stakeholders: A stakeholder mapping approach (Newcombe, 2003)	236	Review of the application of social network analysis (SNA) in construction project management research (Zheng et al., 2016)	174	Fuzzy Synthetic Evaluation of the Critical Success Factors for the Sustainability of Public Private Partnership Projects in China (Deng et al., 2021)	121
10	Critical factors affecting schedule performance: Evidence from Indian construction projects (Iyer and Jha, 2006)	155	Stakeholder salience in global projects (Aaltonen et al., 2008)	172	Stakeholder Management-One of the Clues of Sustainable Project Management-As an Underestimated Factor of Project Success in Small Construction Companies (Klaus-Rosińska and Iwko, 2021)	117

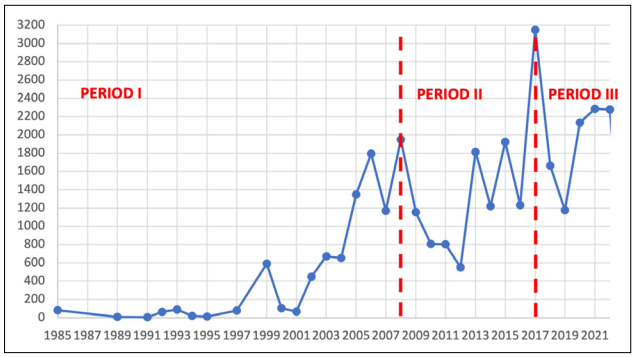

Figure 4. Annual total citations of articles.

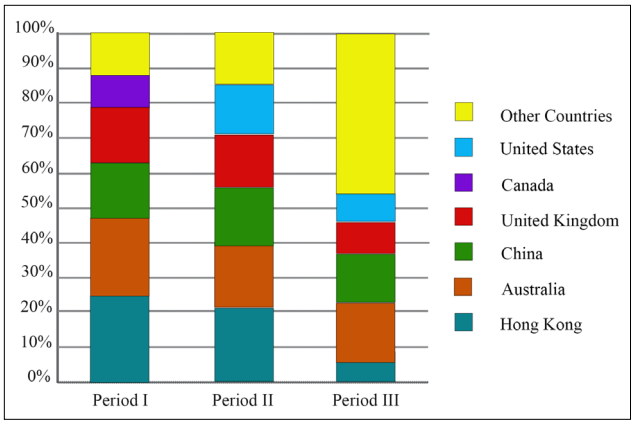

Figure 5. Country of co-authorship.

three periods consecutively from 13 citations (1985–2007) to 40 citations (2008–2017) and finally to 90 citations (2017 to present). The distribution of keywords is displayed in Figure 6. As can be seen from the figure, risk management, cost, decision making and contractors are used commonly in all periods while others are actively used only in one or two periods.

The evolution in keywords was analyzed further by ranking them by time periods. Although mutual keywords (cost, risk management, decision-making, and contractors) are cited in 3 periods, their total link strength is different in each period. To be comprehensive in keyword co-occurrence clusters, a minimum number of five occurrences per keyword is selected as the threshold in VOSviewer analysis. The dimension of the circles, color, and texts in each cluster represents the strength of their co-occurrence with the other keywords, and the distance of the items and the lines demonstrates the connection and linkages of the keywords, respectively. Accordingly, keywords were displayed the connection and total link strength depending on time variation is presented in Figure 7.

In the first period, only 13 keywords are included for stakeholder management in construction projects because this field has been explored recently. The keyword "contracts" became the most important keyword for this period in terms of total link strength which indicates that stakeholder management in construction projects was explored within contract management (Glagola et al., 2002). This period evolved in the topics of "contractors," "performance" (David Weston I and Edward Gibson Jr, 1993), "scheduling" (Kartam, 1999), "optimization" (X. Zhang and Asce, 2005), which indicate that stakeholder management's effect over the outcome in other words success factors of construction projects. In this period, stakeholder management was studied from project management perspective (Newcombe, 2000).

The keyword co-occurrences network analysis from 2008 to 2016 is shown in Figure 8, which highlights the frequent occurrence of keywords by larger nodes. In this period, project management aspects were intensified, including

Figure 6. Keywords by period.

risk management and human resource management. The keyword occurrence analysis regarding this period indicates that the second period comprises three main topics: Project management (Zheng et al., 2016), type of stakeholder (Hanna, 2016), and project life cycle (Liu et al., 2015). In this period, as stakeholder management evolves contextually, the research methods used in studies also evolved with various models and analysis. In this period, along with project management principles, stakeholder management studies were also influenced by the developments in management science literature (Osipova, 2015). Furthermore, most of the studies focused on contractors who are one of the major stakeholders in projects. Moreover, it is observed that the project life cycle approach was considered a necessity for the success of stakeholder management (Park, 2009)

In the third period, 90 keywords within 2856 keywords met the threshold for the publications in keyword occurrence analysis since 2017. Figure 9 presents the keyword occurrences depending on time variation for Period III. While 33% of these keywords were the continuation of previous periods, 67% of them were the new keywords used in this period. "Design/methodology/approach" is commonly used keywords. This period consists of five main topics. Besides the topics of project management, type of stakeholder, and project life cycle, which were addressed in Period II, waste management, relation management, knowledge management, Blockchain, supply chain management, modular construction concepts, and Covid-19 were discussed from stakeholder management perspective. These keywords were discussed from the concept of stakeholder management perspective along with the following topics;

- Modular construction (total link strength is 42) was examined with a critical success factor (Mignacca and Locatelli, 2021), risk management (Enshassi et al., 2020), and blockchain (Jiang et al., 2023).
- Waste management (total link strength is 37) was evaluated with public participation (Wang et al., 2022), sustainability (Omotayo et al., 2020), system thinking (Omotayo et al., 2020), design-build projects (Yu et al., 2021), risk allocation (Wang et al., 2022).
- Knowledge management (total link strength is 34) was

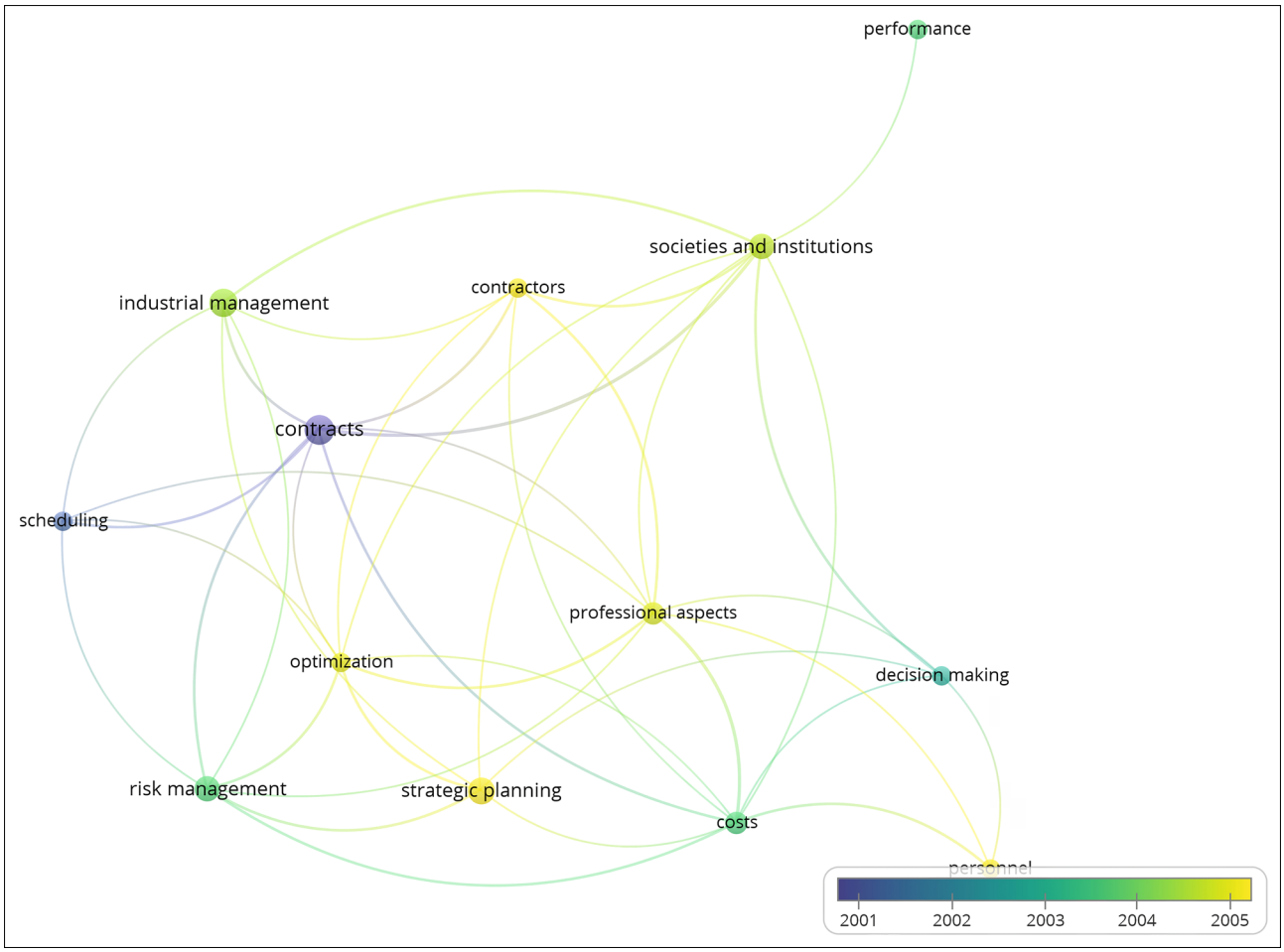

Figure 7. Keyword occurrences depending on time variation for Period I.

discussed with smart technologies (Ngo and Hwang, 2022), health and safety (Deepak and Mahesh, 2019), key stakeholder expectations (Staykova and Underwood, 2017).

- Covid-19 (total link strength is 24) was related to value management (Bennett and Mayouf, 2021), health and safety (Araya and Sierra, 2021), project performance (Tekin, 2022), delays and cost overrun (Abubakar et al., 2022).
- Blockchain (total link strength is 16) was researched with BIM (Lee et al., 2021), smart contract (Ameyaw et al., 2023), supply chain management (Kiu et al., 2022), modular integrated construction (Jiang et al., 2023).

Along with the contractor, other stakeholders (construction companies, external stakeholders, and the public sector) were also taken into consideration and their relation to project was discussed. Different types of projects, environmental and health conditions, were the new research fields for stakeholder management in construction projects.

The new keywords, waste management and knowledge management, have begun to evaluation.

In this period, advanced research models (i.e., game theory, numerical model, reliability analysis) were used to determine and analyze topics as well as building models in stakeholder management within the construction management literature.

DISCUSSION

In bibliometric analysis, not only the central themes were determined in the field of stakeholder management in construction projects but also the interaction between these core topics and their evolution over the years. Bibliometric analysis enables to understand and grasp the relevant features, and directions of stakeholder management in construction projects. In this type of study, the literature is analyzed in regard to the research status and facilitates discussion on important aspects of research associated with the literature. Bibliometric analysis provides guidance on future developments and research trends on a subject.

Based on the bibliometric analysis, a knowledge map of stakeholder management was analyzed using three scientometric analysis (Figure 10). The knowledge structure

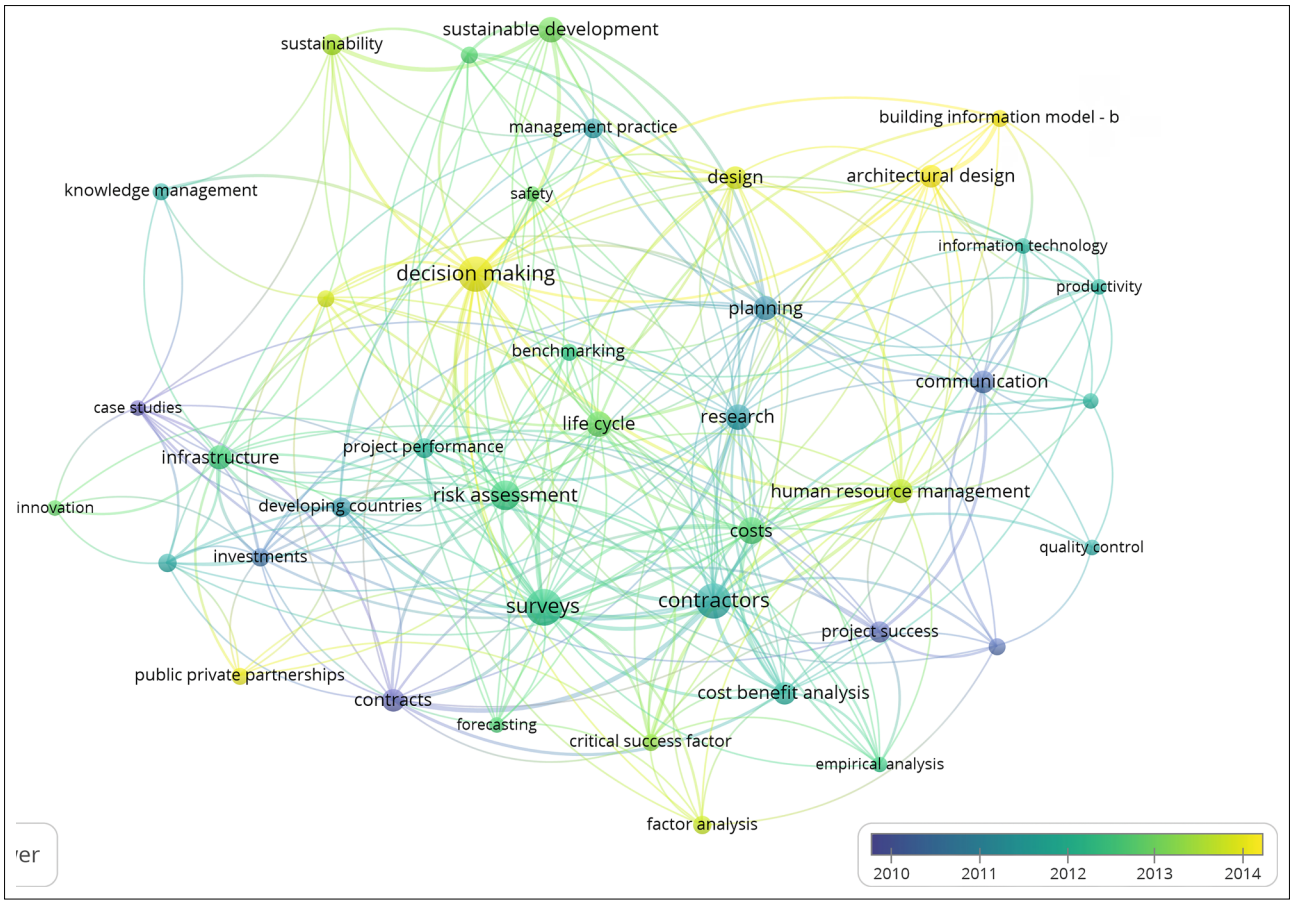

Figure 8. Keyword occurrences depending on time variation for Period II.

of academic research was explored through cluster analysis of the co-citation network of articles, country co-authorship, and keyword co-occurrence. The analysis results were integrated to explore the knowledge map of stakeholder management in construction projects. The key research topics of stakeholder management in construction projects showed significant differences across three periods.

The *initial exploration stage* (Period I) conveyed the critical success factors and project's success indicators of stakeholder management in construction projects. Consequently, stakeholders in construction projects were considered as an essential engagement to improve the possibility of project success by prioritizing stakeholder concerns. In this period, the majority of the publications on stakeholder management were authored from developing countries such as Australia, the United Kingdom, Canada, and Hong Kong. Their influence in this field may be related to the advancements of the industry and companies. This condition lasted till the third period; since 2017, stakeholder management has become a common research area globally.

Keywords were evaluated according to total link strength. In period 1, stakeholder management was related to the body of project management (link strength 68.60%), which was followed by determining the types of stakeholders (link strength 25.65%). Majority of research was carried out for contractors. As this period was determined as *initial exploration stage*, most of the studies were focused on descriptive aspects, nevertheless, the most common research model was "decision making" with a rate of 5.75%.

In the second period, the studies were advanced stakeholder relationships, risk management, and stakeholder model, which constitute the main research topic. Period II was defined as a steady *development stage*. Analysis of the keywords used in this period was a good starting point for assessing their evolution in this field. Keywords characterized the focus of project management, research model, project life cycle, and type of stakeholder provided general ideas concerning research trends. Risk management, human resource management, cost management, contract, management practice, safety, and quality control are the most used keywords under project management at a rate of 36.8%. Unlike Period I, a variety of stakeholder models has been asserted, such as factor analysis, BIM, and empirical analysis with a rate of 29%. Project environment, sustainability, project performance, and communication came into prominence. These are defined as project life cycle with a rate of 26.80% for the successful completion of the project. Contractor, one of the stakeholder types,

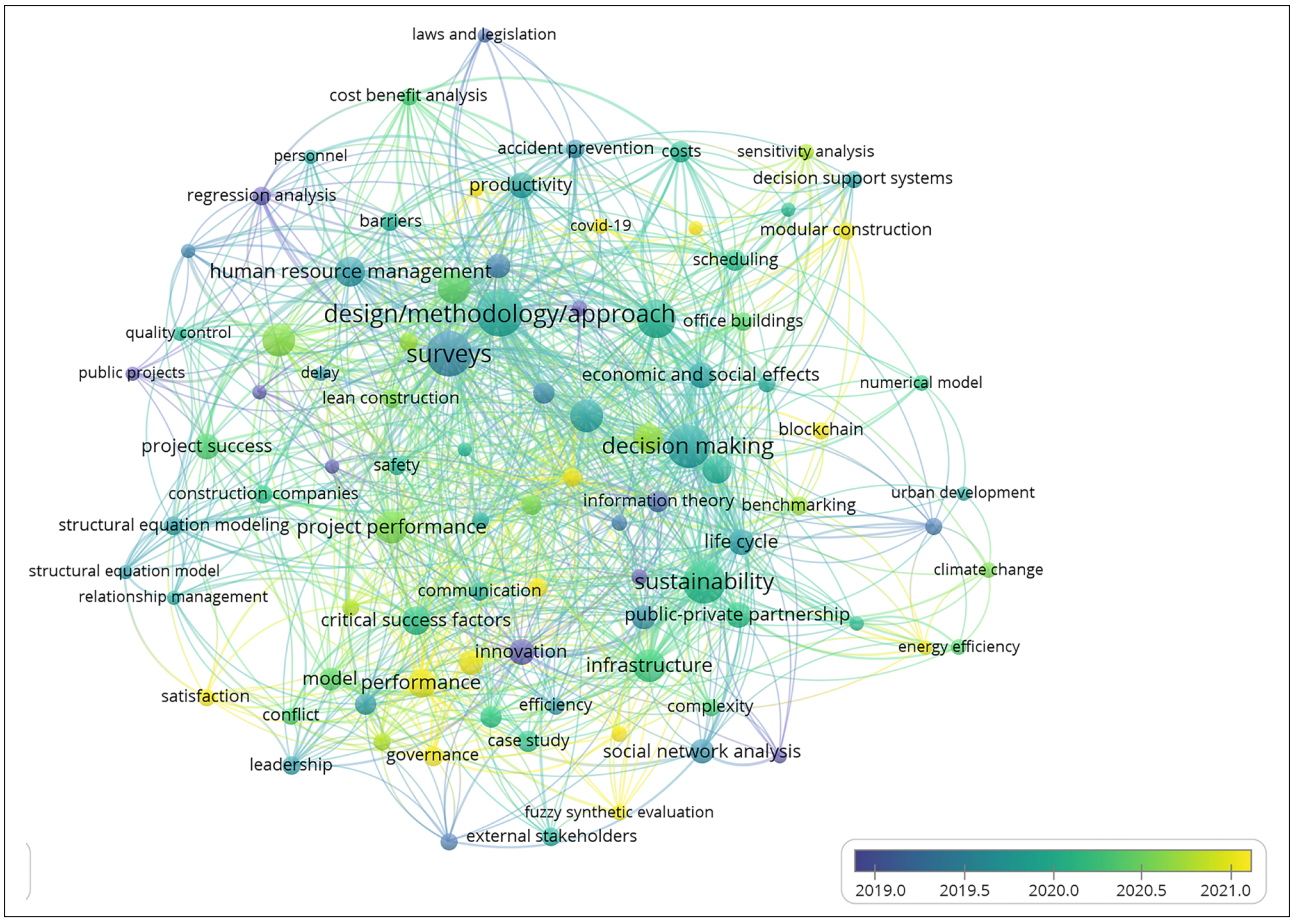

Figure 9. Keyword occurrences depending on time variation for Period III.

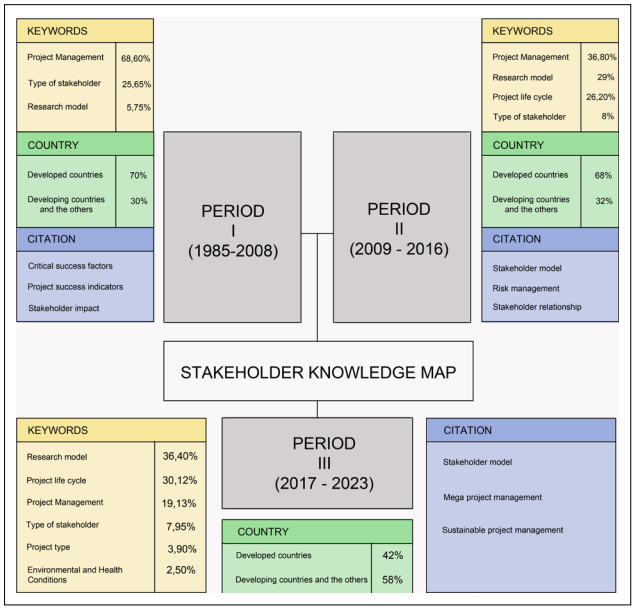

Figure 10. Knowledge map of stakeholder management in construction projects.

took an active part in this period as well at the rate of 8%. Nevertheless, there is no study focusing on stakeholders such as suppliers, consultants, architect, etc. except contractor. In other words, the importance of stakeholder management was still depending on the contractor.

Compared to the *initial exploration* (Period I) and *steady development stages* (Period II), stakeholder management in construction projects studies has been systematically increased at the *booming growth stage*. This stage is named as Period III. It has been determined that model development articles were produced instead of stakeholder conceptual frameworks. In addition, project types and sustainability have gained importance in this period. The number of publications and the variety of topics about stakeholder management in construction projects have increased, as well as the number of countries. The studies carried out in this field are not only limited to developed countries but also have begun to spread throughout the world.

All topics are associated with each other, but their strengths are different. The research model is in the first at the rate of 36.40%. A wide range of methods ("Social Network Analysis," "Regression Analysis," "Multivariant Analysis," "Sensitivity Analysis," "Game Theory," "Analytical Hierarchy Process," "Numerical Model") was used to develop models. Studies on "Project Life Cycle" and "Project Management" were supported by these models. In this period, the project life cycle was examined more than in period II. In this

context, studies on the complexity of projects, barriers, and uncertainties were related to stakeholders in projects.

In the third period, "Project Type" and "Environmental and Health Conditions" topics with stakeholder management have the highest frequency. Because of their unique structures and production processes, "mega projects" and "public projects" were studied from the stakeholder management perspective in the last period. On the other hand, recent publications have explored the relationship between "environmental and health conditions" and project stakeholders. In this period, studies revealed that "Covid-19," "carbon emission," "energy efficiency," "urban development," and "environmental effect" have impacts on the selection and management of stakeholders.

CONCLUSION

The research findings unveiled a steady rise in the quantity of published works overtime, which mirrors the keen interest of researchers in the field and underscores the significance of this domain. This study's primary contributions encompass an examination of bibliographic connections and the identification of conceptual structures. The former illuminated emerging research patterns and key topics of discourse, while the latter utilized co-citation analyses to ascertain the works closely linked to the latest articles.

This study reviewed the existing literature on stakeholder management in construction projects published from 1985 to 2023 through scientometric analysis. The academic communities, key research topics, and knowledge map of the existing research were quantitatively analyzed and visualized. Based on the results of the quantitative analysis, a knowledge map of stakeholder management in construction projects was constructed and discussed. According to the analysis of 762 retrieved articles from Scopus and WOS, interest in research in this field has been increasing since 2017. This development shows that stakeholder management has gained importance in construction projects in recent years, as outlined below.

- In the Period I defined as "initial exploration," the foundations of stakeholder theory were established. The necessity of stakeholder management in project success was advocated, and the conceptual aspects of stakeholder management were addressed. The model proposals related to stakeholder management in construction projects have remained quite shallow. The emphasis on the importance of stakeholders has mostly been placed on contractors, while other types of stakeholders have not been deeply examined.
- In period 2 characterized by steady developmental stages, stakeholder management has evolved through stakeholder relations and risk management. The presented research model studies have begun, and factor analysis, BIM, and empirical analysis have been used in the development of the stakeholder model. Studies have been conducted on the feasibility of achieving project life cycle and sustainability through stakeholder management.
- In period 3 described by the booming growth stage, studies on stakeholder management have been undertaken in various project types, such as mega projects, public projects, and public-private partnership projects. New research models have been proposed using regression analysis, analytical hierarchy process, and numerical models. In contrast to other periods, uncertainties and barriers in projects have been examined through stakeholders in this period. Environmental and health conditions have recently begun to be explored.

According to the results of this study, several important issues require more attention in future studies. Limited studies have been done to identity the relations stakeholder management and "blockchain," "Covid-19," "carbon emission," "climate change," "supply chain," "modular construction," "waste management," and "knowledge management." However, in recent times, there is a lack of studies that utilize artificial intelligence analysis actively used in many fields, to make recommendations in this area.

Knowledge mapping represents significant areas that can influence stakeholder management. Future studies will build upon the trends identified here because knowledge mapping serves as a driving force in the development of stakeholder management. The emerging trends identified here open the door to new research opportunities. In conclusion, this study highlights fertile areas that need to be explored, including project types, environmental and health factors, and digital technology that examines stakeholder management in construction projects.

Unlike other studies, this study has considered a significantly larger number of article searches. It is also a more up-to-date study compared to others, including the past 6 years, and is the first study to demonstrate the booming growth stage in which stakeholder management in construction projects has spread to a much broader network. The study not only evaluates the historical development of stakeholder management periodically but also highlights its relationship with other project management disciplines. In addition, it examines the current themes within stakeholder management. The contribution of this study is creating a new knowledge map about the stakeholder management in construction projects to determine the trend of the development of the related literature over the domain and the time. Therefore, the proposed knowledge

map comprehensively indicates the past, current, and future of stakeholder management in construction projects. Furthermore, the knowledge map can be updated regularly with the development of new stakeholder management practices in the construction projects.

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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 importance of geographical information systems in urban and landscape planning: A bibliometric analysis

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ABSTRACT

Since the 1970s, Geographic Information Systems (GIS) have gained increasing recognition in the literature, drawing the attention of numerous scientific disciplines, particularly within technical and environmental sciences. What initially began as computerized map production in the 1970s has evolved with advancements in computer processing power and capacity, supported by various software packages. This study aims to reveal the general tendencies in research studies conducted in the fields of urban planning, spatial planning, and landscape planning. To identify these trends, a bibliometric analysis was conducted by examining literature on studies published worldwide, including Türkiye. For this purpose, 2,354 research and review articles published between 1990 and 2022 and indexed in the Web of Science database were analyzed using VOSviewer software, which is suitable for scientific mapping and bibliometric analysis. The analysis focused on the most frequently published journals, highly-cited authors and countries, collaborative authorship relationships, and the most cited authors, journals, and research topics in Türkiye. As a result, it has been observed that, considering the emergence of modern GIS concepts in the late 1970s and subsequent development based on spatial data from the 1980s, studies in the fields of Urban and Regional Planning, Urban Design, and Landscape Architecture have gained momentum since the 1990s. Research establishing the relationship between GIS and planning in Türkiye has been increasing since 2004, with the primary focus of these studies being categorized into three clusters: site selection, spatial mapping, and mathematical modeling.

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INTRODUCTION

A Geographic Information System (GIS) is a tool that defines space as points, lines, or areas and reveals its attributes (Dueker, 1979). Unlike other computerized systems, such as spreadsheets, word processors, and database management systems, GIS processes and manages spatial data. While word processors and spreadsheets handle text and numbers, respectively, GIS processes maps, images, and other types of spatial data with specific references to locations on Earth's surface (Zhu, 2016). Modern concepts of GIS were first introduced in the late 1970s (Dueker, 1979). In the following decades, definitions of GIS began

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to expand and diversify. Marble et al. (1984) described GIS as a set of tools for the input, storage, organization, and analysis of spatial data, while Cowen (1988) defined it as a decision support system utilized in the problem-solving and decision-making processes involving spatial data. Chrisman (1999) broadened the definition to include not only spatial data but also social phenomena as integrated tools within the system. Goodchild (2004) delineates GIS as a tool that combines nomothetic elements in its software and algorithms with idiographic elements in its databases. Since the 2000s, modern GIS has provided two-dimensional (2D) and 2.5-dimensional (2.5D) map representations using traditional cartographic approaches, as well as visualization techniques that enable users to navigate the real world in virtual reality with three-dimensional (3D) maps. It has also facilitated the creation of maps that can be presented and distributed through various media (hard copy papers, computer screens, mobile devices, etc.) (Zhu, 2016). For centuries, maps have served as data storage tools to fulfill societal needs. Prior to the computer revolution, maps were produced mainly by hand or through photochemical procedures known as photomechanical map generation (Robinson et al., 1995). The feasibility of computer-aided GIS emerged with the development of microcomputers and operating systems. The history of computer-aided GIS implementation began in the mid-1960s with the development of the Canadian Geographic Information System (CGIS), which aimed to assist the Canadian Federal Government in managing rural Canada's natural resources and land capacity (Tomlinson, 1967). The CGIS introduced new approaches such as digitization and classification (Waters, 2017).

In the 1970s, GIS evolved into a computer-aided process that automated map production. Various cartographic data structures were developed to encode map data (Peuquet, 1984; Zhu, 2016). The ODYSSEY GIS, developed by the Computer Graphics and Spatial Analysis Laboratory at Harvard University, was a pioneer in data structuring for digitally encoding line and area features on maps (Peucker & Chrisman, 1975). These structures laid the foundation for the development of data models and management systems for spatial data in modern GIS. However, this period's GIS had shortcomings, such as inflexible spatial data entry, poor data management, limited cartographic representation, and simple map processing, all managed on large host computers in batch mode. The first GIS applications were mainly used for land and natural resource inventories, such as CGIS, the Minnesota Land Management Information System (MLMIS), and the Land Use and Natural Resources Inventory System (LUNR) (Coppock & Rhind, 1991).

The 1980s marked an upswing for GIS. As computing power increased, basic spatial data management and analysis functions evolved, integrating with computer mapping, database management, and analytical capabilities. The introduction of hardware such as X-Windows, Microsoft Windows, and Apple's Macintosh simplified the use of GIS software. A notable development was the release of ARC/INFO, the first commercial GIS software package for microcomputers in the 1980s. Additionally, positional query functions were developed, allowing users to retrieve information from GIS databases based on geographic locations or perform geo-queries to create maps. This period experienced a rapid demand for spatial data, leading to the emergence of the spatial data industry and a market for digital spatial data. Medium-resolution digital remote sensing, particularly through the Landsat Earth observation satellite program, became a significant source of digital spatial data for GIS. Advances in spatial data management and techniques such as digitization, map creation, map scale transformation, geometric measurement, buffer creation, overlay analysis, and digital terrain modeling were introduced in most GIS (Berry, 1987; Dangermond, 1983). Map algebra concepts and techniques were also developed, enabling the processing of maps as variables through mathematical operations. However, GIS of the 1980s lacked spatial analytics and modeling capabilities (Goodchild, 1990). With the advent of the Internet in the 1990s, GIS applications expanded from computerized mapping and natural resource inventories to environmental analysis, modeling, and decision-making. Yet, GIS lacked the spatial analysis and modeling features required for complex environmental modeling and decision-making tasks. With GIS software like IDRISI, the range of spatial analysis applications supporting environmental modeling expanded. Links between statistical packages (e.g., S-Plus, ArcView) and GIS were established to enhance GIS-based statistical modeling (Openshaw, 1998). By the late 1990s, remote sensing images were being integrated with GIS.

Also, in the late 1990s, Light Detection and Ranging (LIDAR) technology marked an important milestone in the collection of high-resolution and highly sensitive digital surface and digital terrain models. The availability of very high-resolution remote sensing images and LIDAR data has enabled the development of a new level of GIS analytical capability in the 2000s, allowing for more accurate and detailed environmental analysis and modeling.

Since 2006, a series of online mapping platforms have emerged, providing an innovative approach to the collection of environmental data by engaging with the wider community (Zhu, 2016).

Since the early 2000s, rapid advancements in computer technologies have been pivotal in the development of spatial query and analysis systems within the field of GIS. Today, this era, known for its lasting impact, has seen an increase in the use of ArcGIS software for spatial decision support systems in numerous studies (Miller & Goodchild, 2014). Access to spatial data and the diversification of

information, alongside spatial databases, computation-based mathematical approaches, spatial analysis, modeling, and visualization methods, have become increasingly prominent within the GIS field (Haining, 2003).

GIS has become a fundamental tool for spatial planning and management, primarily due to its utility in the planning process through the incorporation of multi-criteria decisions regarding land use. Therefore, its applications are crucial not only for visualization and data management but also for evaluating alternative choices based on spatially relevant criteria. This decision support tool is invaluable for assessing and managing various spatial data, integrating the preferences of those involved in the decision-making process, such as decision-makers, planners, stakeholders, and policymakers (Latinopoulos & Kechagia, 2015).

GIS is a technology that caters to the spatial data management needs of users, combining the spatial positions and related attributes of real-world objects. It collects, stores, manages, processes, analyzes, displays, and defines geographic distribution data concerning all or part of Earth's surface. GIS technology enhances the scientific basis of planning and design by ensuring the basic data is detailed, reliable, and accurate. Over the past two decades, spatial planners and designers have increasingly utilized it both for the ease and speed of creating and dynamically updating various plans, tables, and reports (Li & Wang, 2022), and for its use in spatial distribution analysis and map production (Raillani et al., 2022). GIS technology, with its versatile and dynamic structure, enables efficient planning and applications by providing rational and systematic analysis, aiding in swift decision-making. Moreover, GIS assists in understanding what is occurring at a specific location, gathering information about geographical areas that meet certain conditions, detecting anomalies that do not fit the geographical pattern of their location, and determining the outcomes of particular actions (Dekolo & Oguwaye, 2005).

In urban and regional planning, GIS is widely utilized to process spatial data and support decision-making. It provides data and techniques needed at different stages of the process, such as setting goals, conducting resource inventories, analyzing current situations, modeling and projecting, developing and selecting planning options, and implementing, evaluating, monitoring, and providing feedback for the plan (Santos et al., 2021).

In landscape planning, GIS is used to assess location suitability, examine proposal feasibility, allocate uses within an area, and predict the effects of different decisions (Bilous et al., 2021). GIS applications concentrate on the interaction between landscape processes and morphological aspects and address the aesthetic, functional, social, and ecological relationships between natural and human systems. Furthermore, GIS is employed in traffic and transportation models, planning models, economic models, cognitive models, multi-actor models, nature and environmental models, agricultural models, and energy models (Nijhuis, 2016). It is also an analysis method used in landscape ecology to study changes in spatial landscape patterns (Sun Q. et al., 2022). Additionally, GIS is instrumental in incorporating biodiversity knowledge into the planning phase and assessing the potential impact of existing plans on biodiversity conservation in urban green spaces (Yeo et al., 2022).

In the planning and design field, the general potential applications of GIS, which particularly connect maps and attribute data, are as follows (Dekolo & Oguwaye, 2005):

- Natural resource management topics such as vegetation (Islam et al., 2023), forest inventory (Rana et al., 2023), modeling of forest areas (Tiamgne et al., 2022), production forecasting and management (Dunaieva et al., 2019), access planning (Lee et al., 2019), ecosystem change detection (Bhattacharjee et al., 2021), water resources potential and management (Chatterjee & Dutta, 2022), and monitoring the use of water resources (Sun T. et al., 2022).
- Land topics such as land use and inventory (Kang et al., 2021), preparation and management of agricultural inventories (Calina & Calina, 2022), and soil resources inventory and management (Papadopoulos et al., 2017).
- Environmental planning and management topics such as environmental impact assessment (Zarubin et al., 2021), environmental risk management (Filho et al., 2010), and environmental monitoring (Kipkemboi et al., 2023).
- Emergency planning and management topics such as monitoring of natural hazards (Feng et al., 2020), hazard analysis (Pollino et al., 2022), and fire risk analysis and planning (Coşkun & Toprak, 2023).
- Transportation topics such as transportation planning (Waleghwa & Heldt, 2022), network analysis (Moreno-Navarro, 2022), and transportation demand modeling (Lopes et al., 2014). Additionally, this list of potential application areas can be expanded.

The expansion of spatial data systems has unlocked significant potential for big data studies in the fields of GIS and planning. However, the diversity and volume of data present challenges in shaping geographic information and creating accurate, understandable data-driven models (Haining, 2003).

Spatial information and the ability to apply it are crucial in developing complex systems such as cities. The diversification of spatial data and information has propelled the advancement of geographic information science and technology. In this context, GIS is considered an essential tool in urban studies and related disciplines (Cowen, 1988).

In the planning process, maps are invaluable, serving as a reference and a platform to reflect physical decisions in the relationship between settlements and physical space. The creation of these maps during the planning process benefits from various and abundant data layers. Integrating, combining, and preparing data for dynamic querying is essential in processes that involve diverse economic, social, and physical parameters related to space. Comprehensive analyses, establishing relationships between data, and the successful execution of processes necessitate the use of specialized software programs. These programs are critical not only in the analysis and evaluation stages but also throughout the planning process. GIS, as computer-based software, plays a significant role in the planning discipline by acting as a source of information, a tool, and an evaluation platform in the preparation and decision-making processes.

This study aims to highlight the importance of GIS in the disciplines of City and Regional Planning, Urban Design, and Landscape Architecture, which are actively involved in spatial analysis, evaluation, and modeling processes, based on scientific research. To this end, a bibliometric analysis was performed using statistical techniques to evaluate the scientific literature published through the Web of Science database. The study, spanning the years 1990-2022, examined articles and review articles indexed in the Social Sciences Citation Index (SSCI), Science Citation Index Expanded (SCI-E), Emerging Sources Citation Index (ESCI), and Arts & Humanities Citation Index (AHCI). It evaluated the general trends first in the international literature and then in Türkiye.

The study primarily seeks to address two questions:

- How do advancements in the field of GIS impact the planning disciplines?
- In which areas have studies focusing on planning related to the development of GIS in Türkiye concentrated?

By doing so, this study underscores the influence of GIS on planning disciplines and emphasizes the significance of research in the literature on planning and design. Moreover, it provides a more detailed analysis of GIS's contribution to the planning disciplines and the research trends in Türkiye, thus serving as a guide for future studies.

METHODOLOGY

Although GIS-based analysis and evaluation methods vary, there are studies covering many scientific disciplines and fields. In this study, a bibliometric analysis was carried out to reveal the research carried out on disciplines such as urban planning and urban design and landscape architecture, which mostly work on spatial analysis. The process, which started with revealing the general situation in the dimension of international literature in the analysis, evolves into Türkiye and reveals the place of GIS in planning and design disciplines. The process of "search criteria", "selection", "analysis" and "evaluation of the results" is shown in Figure 1.

Bibliometric Analysis

Bibliometrics is the quantitative analysis of the bibliographic properties of literature (Hawkins, 2001; Kokol et al., 2020). Bibliometric analysis (BA) represents a new form of meta-analytical research or meta-review of literature (Harsanyi, 1993; Kim & McMillan, 2008; Fetscherin et al., 2010). It is a statistical technique used to assess the quality and quantity of published scientific literature and analyze trends in a particular area (Sweileh et al., 2017; Buber & Koseoglu, 2022). As an objective and rational tool, it is employed to analyze the impact and value of research achievements (Ying et al., 2023).

It is also utilized to observe and assess the growth, trends, and knowledge structures of different fields across various academic disciplines (Priovashini & Mallick, 2021; Ghosh et al., 2022).

Bibliometric methods are frequently employed to reveal trends in research publications. The foundation of bibliometric methods can be traced back to Campbell's (1896) statistical methods for determining subject distributions. Subsequently, bibliometric analyses, which found application in diverse fields and methods, expanded to different stages with the development of computer programming and software.

Scientific mapping, or BAs, aims to illustrate the structural or dynamic aspects of scientific research. Presently, there are various databases such as Web of Science (WoS), Scopus, and Google Scholar, which store scientific studies, documents, and their citations. These databases aid in the search and acquisition of information about scientific fields and studies. However, databases do not uniformly cover all scientific fields and journals.

BAs commonly employ descriptive terms and phrases, authors, citation numbers, and topics such as cited authors, journals, and countries. Subject headings are derived through titles, abstracts, or combinations of these. Depending on the chosen analysis units, different facets of the research area can be analyzed (Börner et al., 2003; Shamsi et al., 2020; Radu et al., 2021).

In conducted studies, the social structure of the field (Gänzel, 2001), the international dimensions of the institutions to which authors are affiliated, the conceptual structure and prevalent concepts they address through descriptive terms and words, and the intellectual structure of the research area can be analyzed through citation structure (Cobo et al., 2011). Software is used for bibliometric analyses to ensure quantitative and accurate conclusions are drawn without deviations from subjectivity (di Montanara et al., 2022).

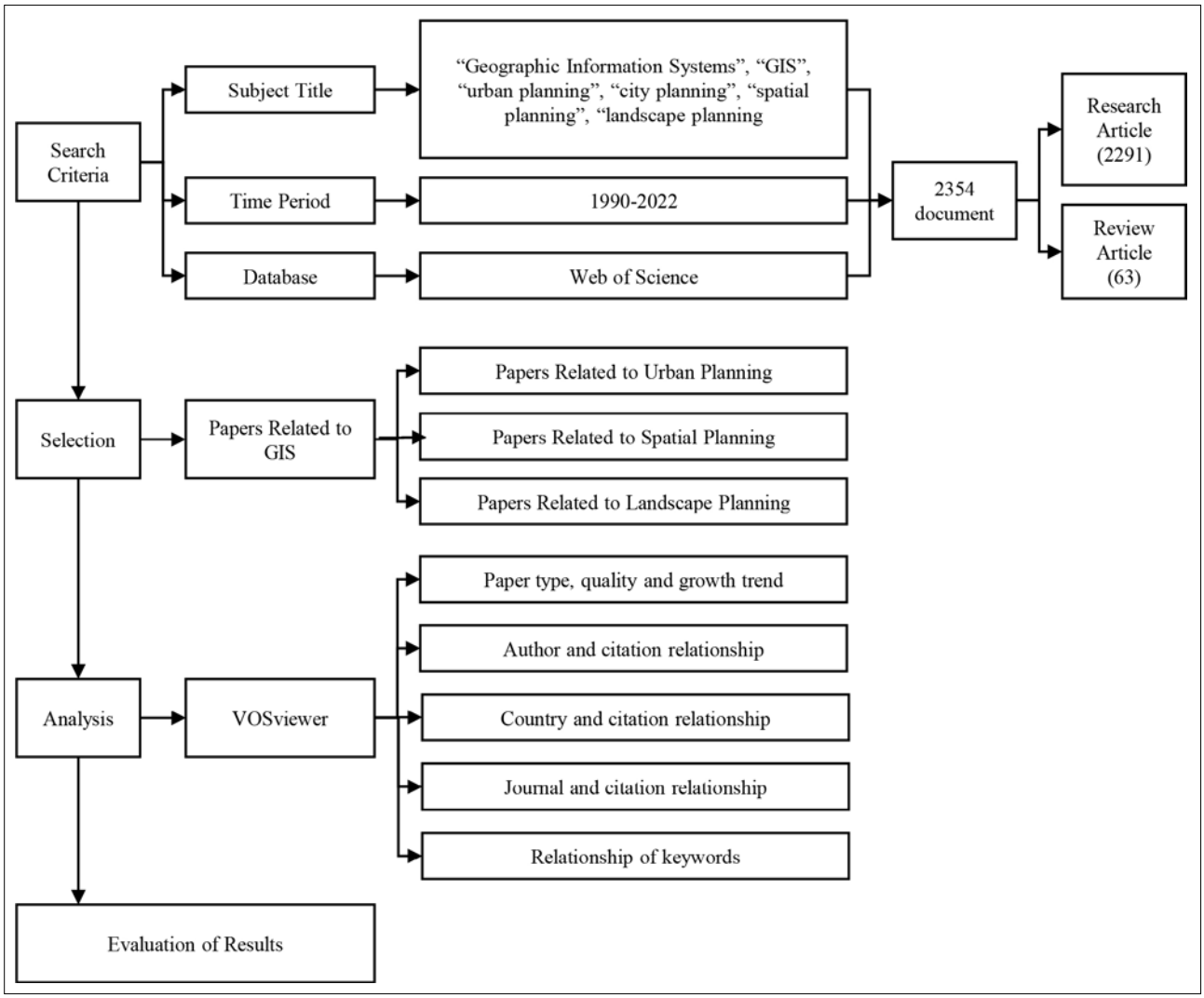

Figure 1. Stages of the Study Method.

Research Rules

Bibliometric analyses consist of various steps, including database selection, determination of subject categories, identification of search keywords, data preprocessing, selection of analyses to be used, visualization techniques, and interpretation of results.

The databases selected for bibliometric analysis data include citation indexes provided by Web of Science (WoS), namely, SSCI, SCI-E, ESCI, and AHCI. There are two key reasons for selecting these citation indexes. The first is that since the 1900s, these databases have indexed the most significant and influential research outputs across various disciplines. The second reason is their comprehensive reference information, which facilitates tracking the developmental process of research in various fields (Wang & Liu, 2014; Kiriyama & Kajikawa, 2014).

In this study, articles published from 1990 to 2022 were retrieved from the Thomson Reuters' Web of Science database, which encompasses SSCI, SCI-E, ESCI, and AHCI indexes.

When determining subject categories, the initial goal is to uncover the use of GIS across different disciplines in the international literature and its role in the planning, urban design, and landscape architecture disciplines in Türkiye. Documents retrieved from the WoS database were evaluated using VOSviewer, a software program developed by Nees Jan van Eck and Ludo Waltman of Leiden University for creating and displaying bibliometric maps (van Eck & Waltman, 2010). VOSviewer is instrumental for generating network maps and analyzing document types, years, authors, co-cited authors, countries, institutions, journal sources, co-cited journals, keywords, and co-citations (Zhang et al., 2020).

This study utilized bibliometric indicators at the document level (number of documents, document type, number of citations, highly cited documents, average citations, h-index, and number of publications by countries) and author level (number of authors, average authors per document, most productive and most cited authors, and authors' countries). Additionally, the information structure

of this dataset was analyzed, and networks were visualized at the levels of social structure (co-authorship network and international collaboration network) and conceptual structure (co-occurrence network for keywords).

Within the scope of this study, the research rules in the WoS database are defined as follows:

Topic Search = ("Geographical Information System" OR "GIS") AND ("urban planning" OR "city planning" OR "spatial planning" OR "landscape planning"), with the wildcard character (*) used to broaden search terms. The study spans the years 1990-2022.

The selection of key concepts, including City and Regional Planning, Urban Design, and Landscape Architecture disciplines, is based on two important considerations. Firstly, subject headings such as revealing existing land uses, preparing and mapping inventories for agriculture, forests, and pasture areas; environmental risk assessment and impact analysis; transportation-oriented analysis, planning, and modeling; functional use access analyses; and current city situations and future projections (such as population, energy, employment) are related to keywords in planning, urban planning, city planning, spatial planning, and landscape planning. Secondly, these two professional disciplines' studies, which pertain to physical space, require software to perform various visualization and mapping studies during the analysis, evaluation, and planning creation process. Within these software programs, GIS-based applications offer various spatial visualization and evaluation techniques. As a result, GIS enables the presentation of various space-based evaluation techniques with speed and objectivity. Therefore, to elucidate the approaches discussed in these two disciplines utilizing GIS, the relationship between GIS and planning was established from the subject search criteria in the study.

ANALYSIS

Overview

Based on the established criteria, a total of 2,354 articles were identified. The distribution of articles published in prominent journals is detailed in Table 1. Of the 2,354 articles, 2,291 (97.32%) were research articles, while 63 (2.68%) were review articles. Publications spanned across a total of 713 journals, with the most frequent appearances in journals such as 'Sustainability,' 'Landscape and Urban Planning,' 'ISPRS International Journal of Geo-Information,' 'Land Use Policy,' and 'Land.'

Table 1. List of journals with the most articles published.

	Journal Title	Number of Papers
1	Sustainability	135
2	Landscape and Urban Planning	103
3	ISPRS International Journal of Geo Information	57
4	Land Use Policy	48
5	Land	34
6	Computers Environment and Urban Systems	33
7	Ecological Indicators	32
8	Environment and Planning B Planning Design	29
9	International Journal of Geographical Information Science	28
9	Remote Sensing	28
9	Sustainable Cities and Society	28
Total		555

The trend of changes in the number of articles published from 1990 to 2022 is depicted in Figure 2. Since 2004, there has been a consistent upward trend, with the peak number of publications occurring in 2020 and 2021.

Countries and Regions

While authors from 115 countries or regions have contributed to the study, the top 10 countries with the highest number of contributors are listed in Table 2. Notably, the majority of the studies were conducted in the People's Republic of China and the United States.

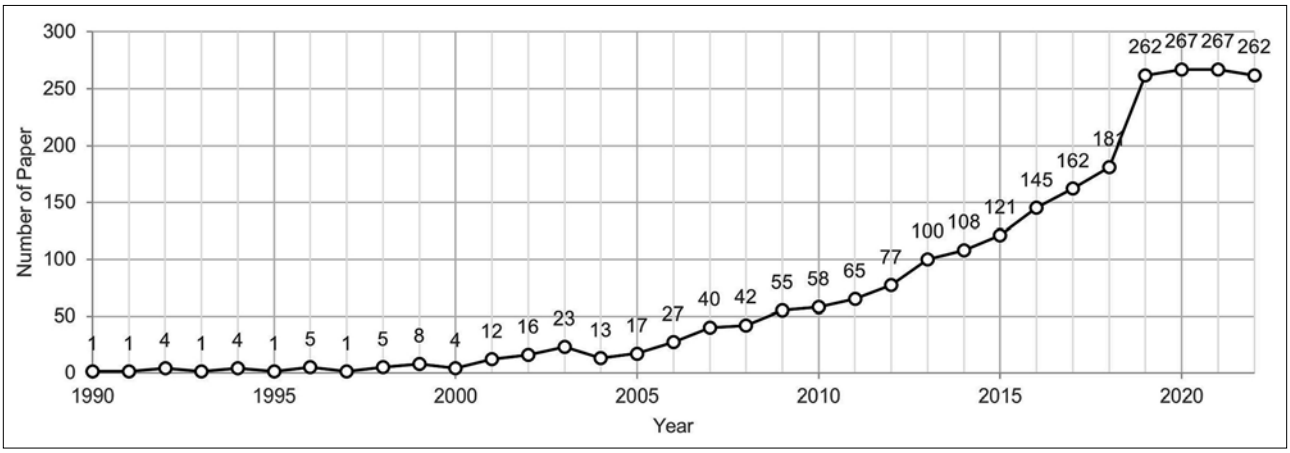

Figure 2. Number of published papers from 1990 to 2022.

Table 2. List of countries that have produced the most studies by authors

	Country	Total Number of Papers	Percentage of All Papers (%)
1	People's Republic of China	383	16,3
2	United States of America	304	12,9
3	Italy	184	7,8
4	Germany	141	6,0
5	Türkiye	129	5,5
6	England	123	5,2
7	Spain	111	4,7
8	Australia	107	4,5
8	Netherlands	107	4,5
10	Indian	91	3,9
Total		1680	71,3

Other significant contributors include Italy, Germany, Türkiye, England, Spain, Australia, the Netherlands, and India.

When examining the co-authorship between countries, there is a parallel between the countries with a high number of articles and those with evaluations based on at least 5 publications and 5 citations. As depicted in Figure 3, according to the co-authorship relationship, the People's Republic of China and the United States of America are the most prominent in terms of publication volume. In contrast, Germany, the United States, the United Kingdom, the Netherlands, and Canada stand out in terms of average citations. Thus, as indicated in Table 2, the People's Republic of China and the United States of America are observed to have the most substantial international collaboration in the field of GIS.

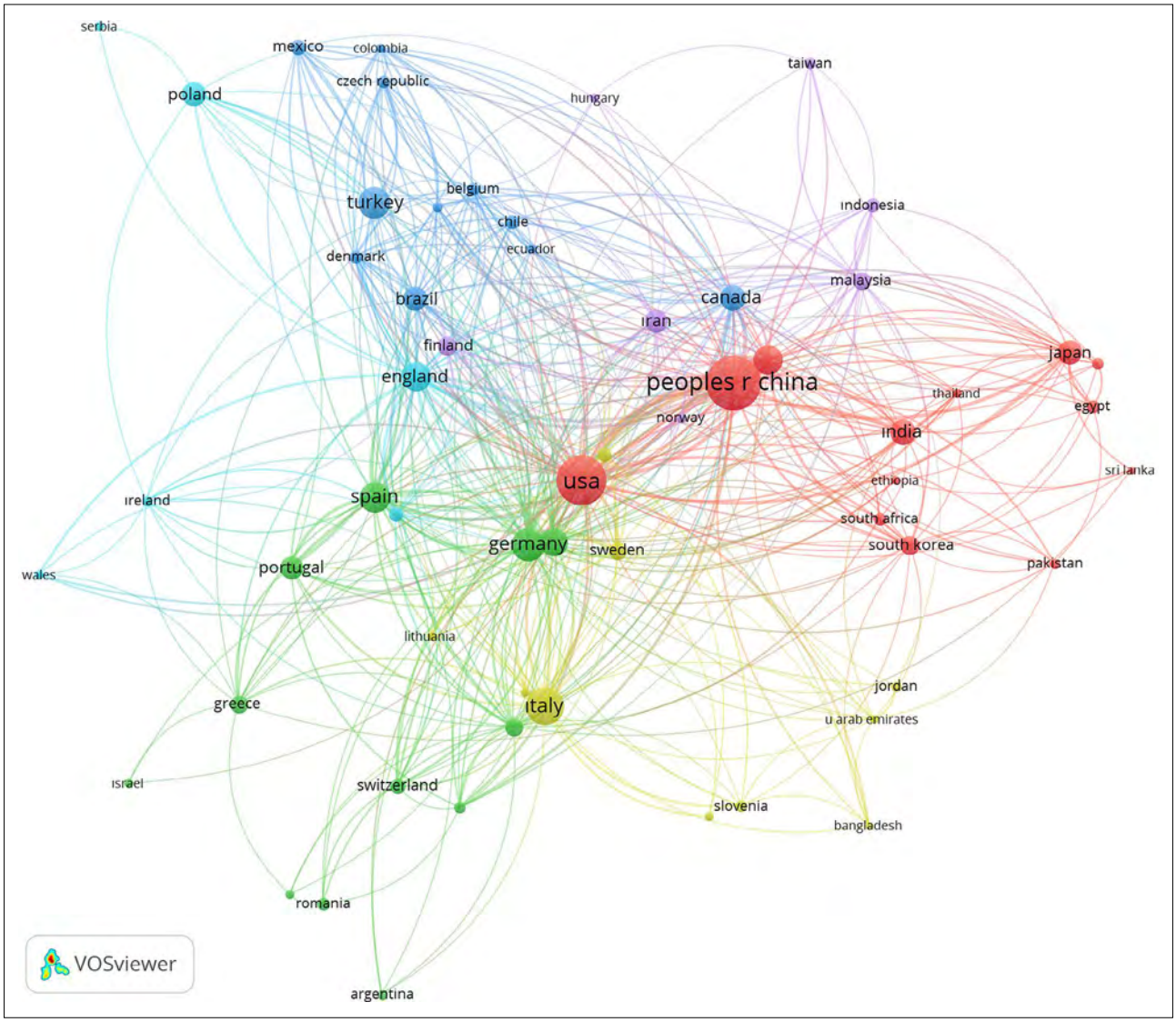

Figure 3. Network visualization showing co-author and country relationships.

Authors

A total of 7,360 authors have contributed to studies on urban planning, city planning, spatial planning, and landscape planning. When evaluated based on a threshold of at least 2 publications and 2 citations, Çetin, M. (12 publications), Murayama, Y. (12 publications), and Pradhan, B. (11 publications) are leading in terms of the number of publications. In terms of total citations, Li, X. (805 citations), Liu, X. (790 citations), and Çetin, M. (750 citations) have made significant contributions to the literature. The top 10 most-cited authors, in terms of citation count, are listed in Table 3.

In determining the most influential authors, the 'cited authors' analysis was utilized in the form of 'co-citation' analysis. The criteria for this analysis required a minimum of 50 citations, leading to the identification of 75 authors. Their interconnections are presented in Figure 4. According to the results of the co-citation network analysis, Malczewski, J., Batty, M., Li, X., Brown, G., and Saaty, T. L. emerge as the most influential authors. The analysis discerned 6 distinct clusters, illustrated in Figure 4 with purple, green, yellow, blue, red, and turquoise.

In the purple cluster, featuring authors such as Malczewski, J. and Halpern, B. S., GIS and multi-criteria decision-making are highlighted. The green cluster, which includes Brown, G. and Goodchild, M. F., brings GIS studies related to public participation and landscape planning to the forefront. The yellow cluster, with authors like Saaty, T. L. and Çetin, M., is associated with studies on the Analytic Hierarchy Process (AHP) and GIS. The blue cluster, where authors such as Batty, M. and Li, X. are featured, focuses on GIS and network modeling. In the red cluster, formed by authors like Seto, K. C. and Bhatta, B., topics related to remote sensing, urban growth, and landscape metrics are

Table 3. List of authors featured in terms of the number of citations.

	Author	Number of Citations	Number of Papers
1	Lee, X.	805	9
2	Liu, X.	790	9
3	Çetin, M.	750	12
4	Ng, E.	691	6
5	Ren, C.	662	5
6	Chen, L.	580	3
7	Bathrellos, G.	552	4
7	Skilodimou, H.	552	4
9	Pradhan, B.	550	11
10	Haase, D.	495	4
Total		6427	67

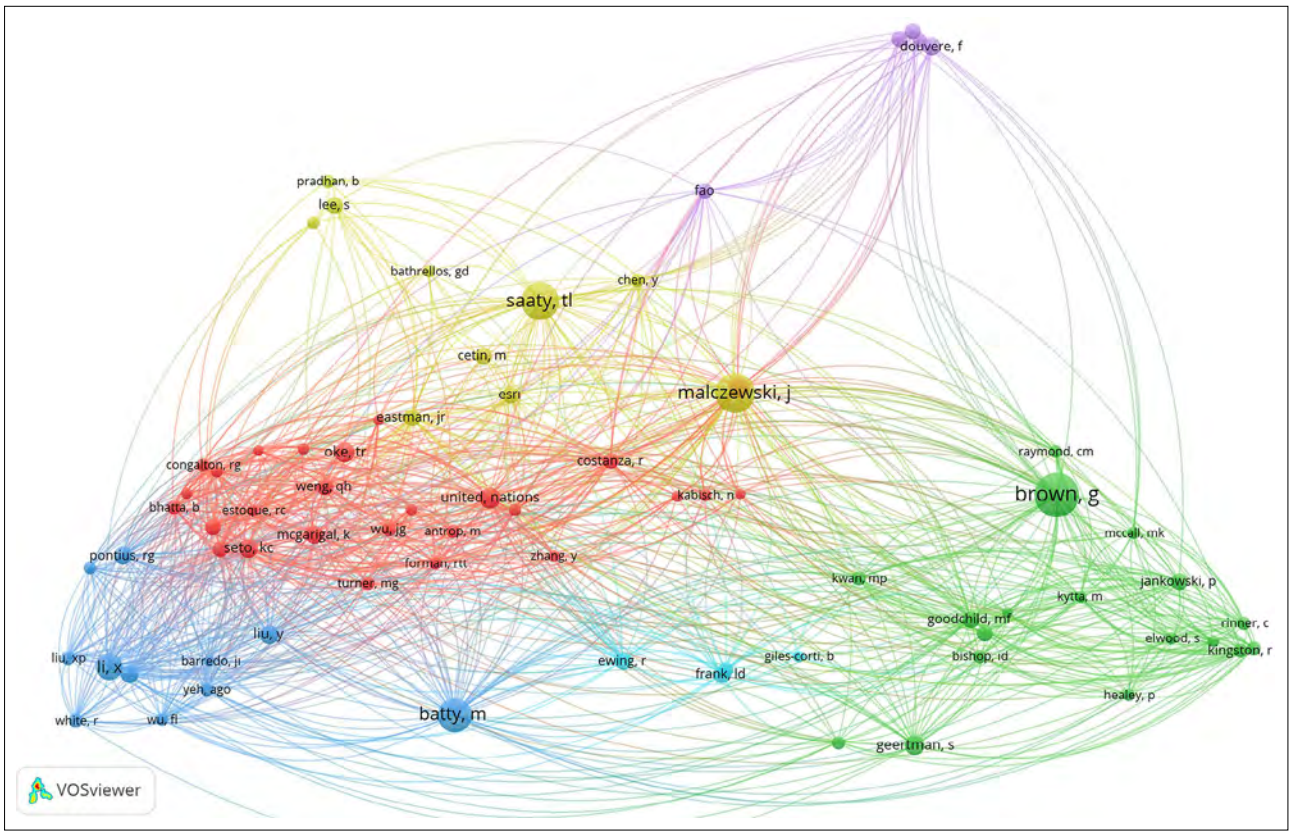

Figure 4. The common network relationship of the most influential authors.

emphasized, while the turquoise cluster includes Frank, L. D. and Ewing, R., who conduct studies on urban form and meta-analysis.

Co-occurrence Analysis

The relationships among keywords used by authors are illustrated in Figures 5 and 6. Larger circles represent the

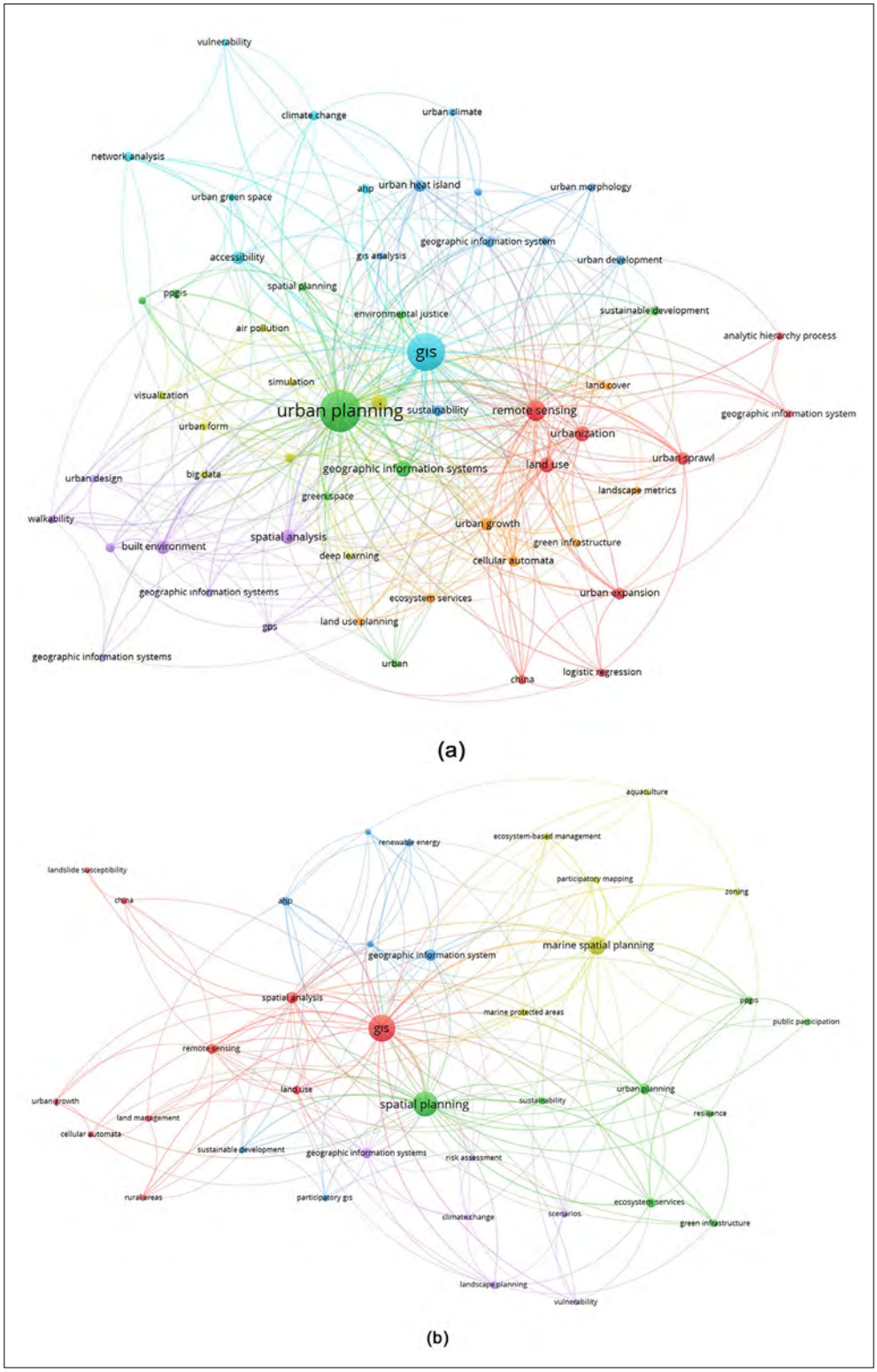

Figure 5. The network that shows the relationships of words in the fields of **(a)** urban planning and **(b)** spatial planning that the authors use most together.

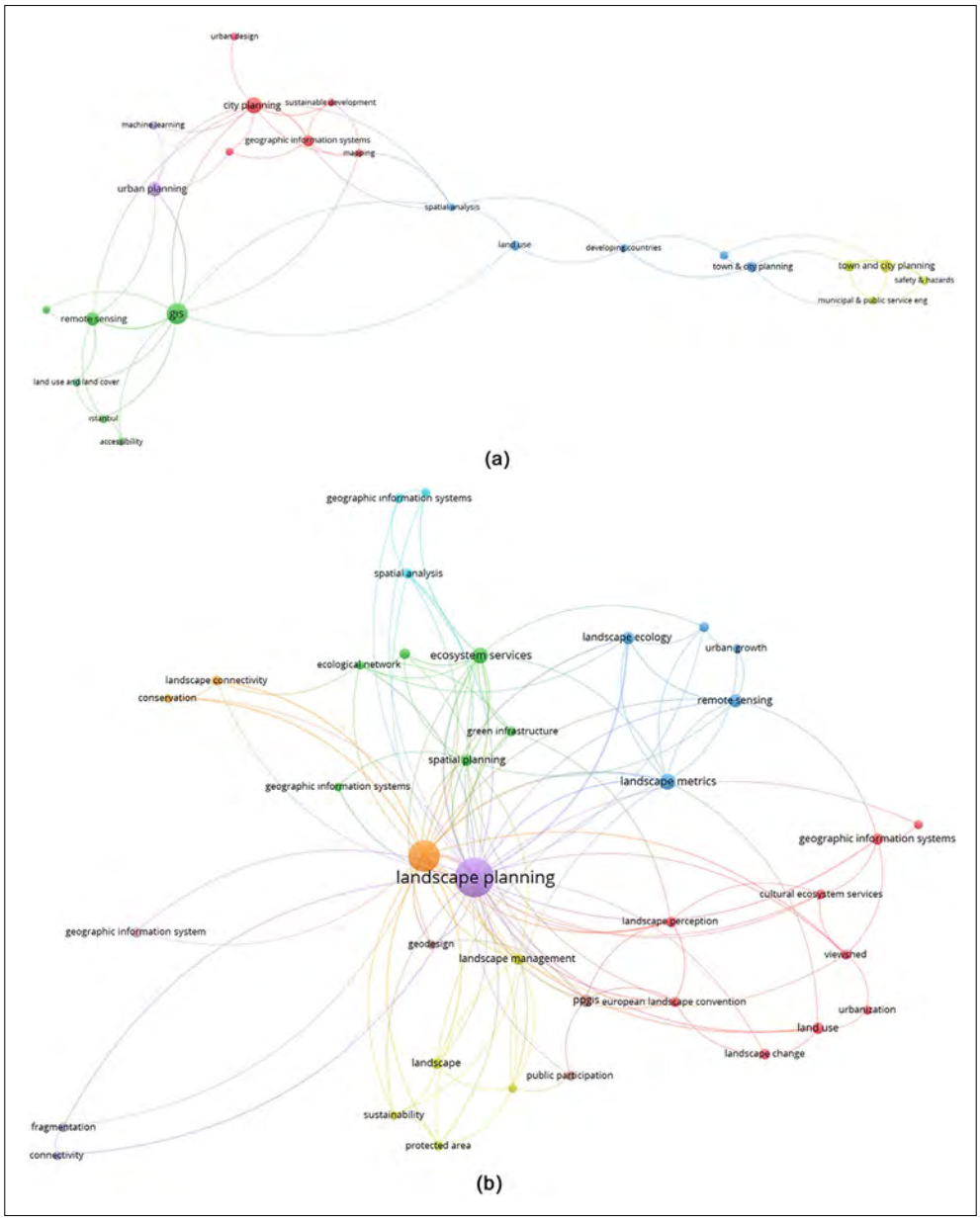

Figure 6. The network that shows the relationships of words in the fields of **(a)** city planning and **(b)** landscape planning that the authors use most together.

most frequently used words within these relationship networks, while studies that are interconnected are denoted by the same color.

Accordingly, urban planning, remote sensing, and spatial planning are prominent in the context of GIS. As we approach the present day, it is evident that there is a growing research interest in concepts such as urban sprawl, accessibility, the Analytic Hierarchy Process (AHP), urban design, urban morphology, multi-criteria decision-making, renewable energy, green infrastructure, and walkability. Additionally, land use planning, public participation, landscape metrics, climate, logistic regression, and landscape ecology are among the most frequently interconnected concepts.

In the realm of urban planning, the following concepts are particularly noteworthy: land use, climate change, sustainable development, urban morphology, resilience, sustainability, renewable energy, ecosystem services, green infrastructure, GIS, and spatial analysis. In spatial planning, a distinct emphasis is found on concepts like urban growth, GIS, AHP, sustainability, multi-criteria decision analysis, spatial analysis, and resilience. For landscape planning,

certain clusters revolve around concepts such as landscape ecology, ecosystem services, network analysis, spatial analysis, and sustainability. These clusters represent the core areas of research and inquiry within the respective planning disciplines.

CONCLUSION

This study aims to elucidate the relationship between GIS and planning through bibliometric analysis, referencing the Web of Science (WoS) database. Research and review articles indexed in SSCI, SCI-E, ESCI, and AHCI from 1990 to 2022 were scrutinized. Initially, the international literature was appraised, followed by an exploration of general trends in Türkiye.

The study's first research question asks, "How do the advancements in the field of GIS impact the planning disciplines?" The developments in GIS have expedited the integration of various methods and approaches within planning disciplines. Notably, the surge of big data in data-driven studies has established GIS as a pivotal element in the objective decision-making process.

In countries leading in the interplay between GIS and planning, analyses and evaluations predominantly cover urban planning. Country-specific study distributions are as follows:

- In the People's Republic of China, 74% of the total studies focus on urban planning, with 17% on spatial planning and 9% on landscape planning.
- In the USA, 69% of studies center on urban planning, 19% on spatial planning, and 12% on landscape planning.
- In Italy, 55% of the work is dedicated to urban planning, 28% to spatial planning, and 17% to landscape planning.
- In Germany, 47% of work pertains to urban planning, 38% to spatial planning, and 15% to landscape planning.

The People's Republic of China, which leads in publication volume, predominantly publishes in urban planning, with topics such as remote sensing, urbanization, urban sprawl, and land use frequently associated with GIS. While analysis and evaluation methods are prominent in the GIS-planning nexus, the employment of GIS based on mathematical or statistical evaluations appears limited. In leading countries like the United States, Italy, and Germany, there is a marked inclination toward urban planning, though the number of publications in spatial planning and landscape planning has risen recently. Topics like ecosystem services, accessibility, landscape planning metrics, and spatial analysis have gained increasing attention in the planning literature and are being linked to GIS in Italy and the USA (Figures 7 and 8).

Reflecting on the advent of modern GIS concepts in the late 1970s and their evolution based on spatial data since the 1980s, it is evident that studies in City and Regional Planning, Urban Design, and Landscape Architecture have found significant traction since the 1990s. As planning disciplines are fundamentally reliant on spatial data and as data diversity and complexity grow, there is a burgeoning necessity for interpretive decision analysis and evaluation systems that encompass multifaceted and dynamic processes. GIS fulfills this need by offering a crucial rational and systematic decision-making framework (Murayama & Thapa, 2011; Latinopoulos & Kechagia, 2015). Literature reviews indicate that GIS is predominantly utilized as a visualization tool in urban planning and landscape planning for spatial mapping. Moreover, analyses and evaluations incorporating statistical and mathematical models generally remain secondary (Maness & Farrell, 2004; Lee & Sambath, 2006). It appears that the most influential authors on topics bridging GIS and planning tend to concentrate on multi-criteria decision-making methods for site selection studies and their relationship with GIS. The process involves overlay analyses in spatial mapping, beginning with the AHP (Saaty, 1980), to finalize site selection. Recently, there has been a growing focus on topics such as renewable energy (Baban & Parry, 2001; Wiginton et al., 2010; Sánchez-Lozano et al., 2013), urban growth (Herold et al., 2003; Cheng & Masser, 2003; Moghadam & Helbich, 2013), land use changes (Guan et al., 2011; Palomo et al., 2013; Liping et al., 2018), and landscape metrics (Kong et al., 2007; Fichera et al., 2012; Liu & Yang, 2015).The second research question of the study asks, 'In which areas have studies focused on planning related to the development of GIS in Türkiye?'

In Türkiye, planning and GIS studies commenced later than in the international literature, but a surge in research activity in recent years has placed it among the most influential countries. Consequently, GIS has been increasingly utilized in planning studies. Since 2005, pioneering studies have begun to establish the relationship between spatial planning and GIS. By the end of 2022, 60% of the total works in Türkiye were in urban planning, with 20% in spatial planning and 20% in landscape planning.

The main thrust of the studies conducted in Türkiye falls under three clusters: site selection, spatial mapping, and mathematical modeling. Site selection studies

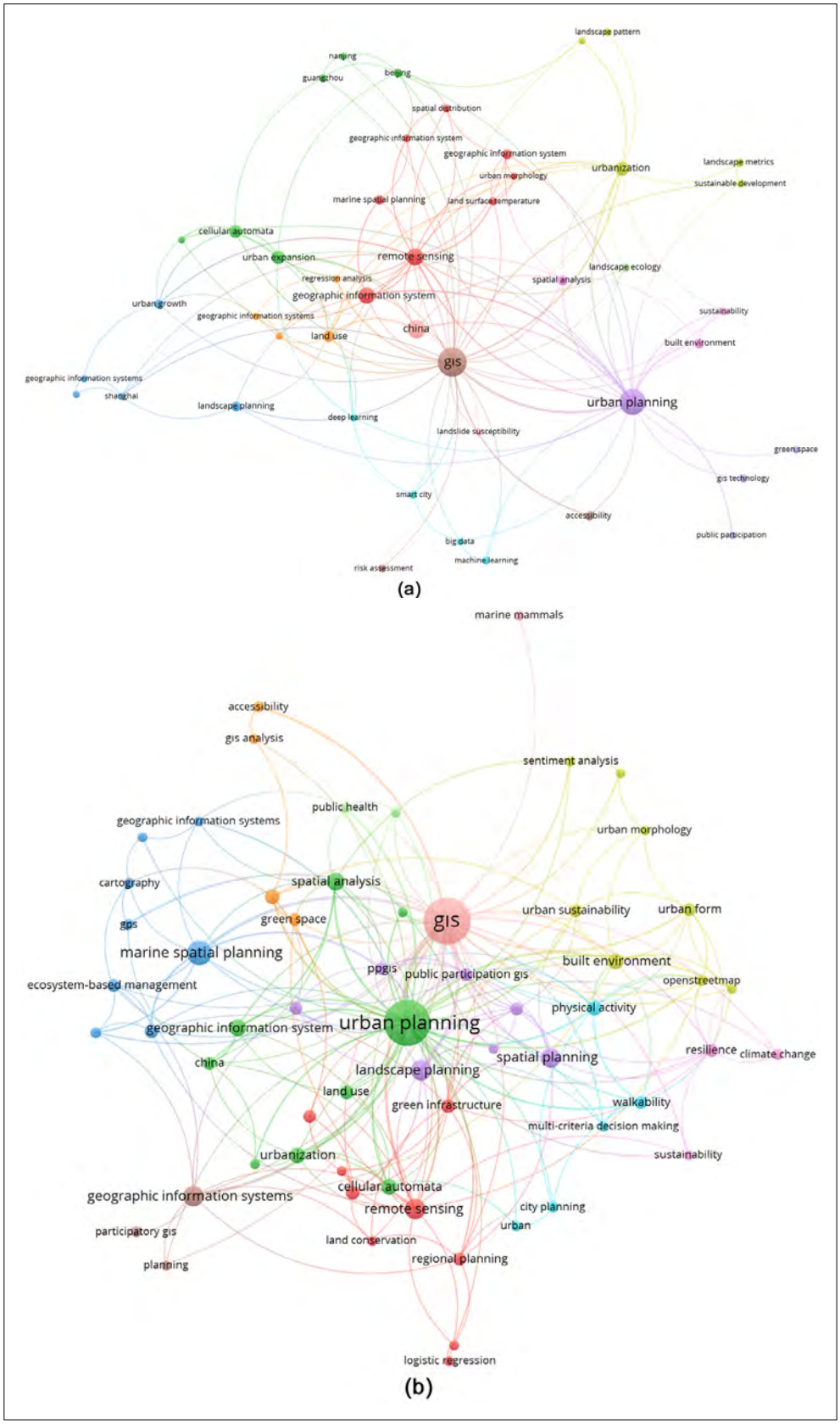

Figure 7. Key concepts that come to the fore in the relationship between GIS and planning **(a)** The People's Republic of China and **(b)** United States.

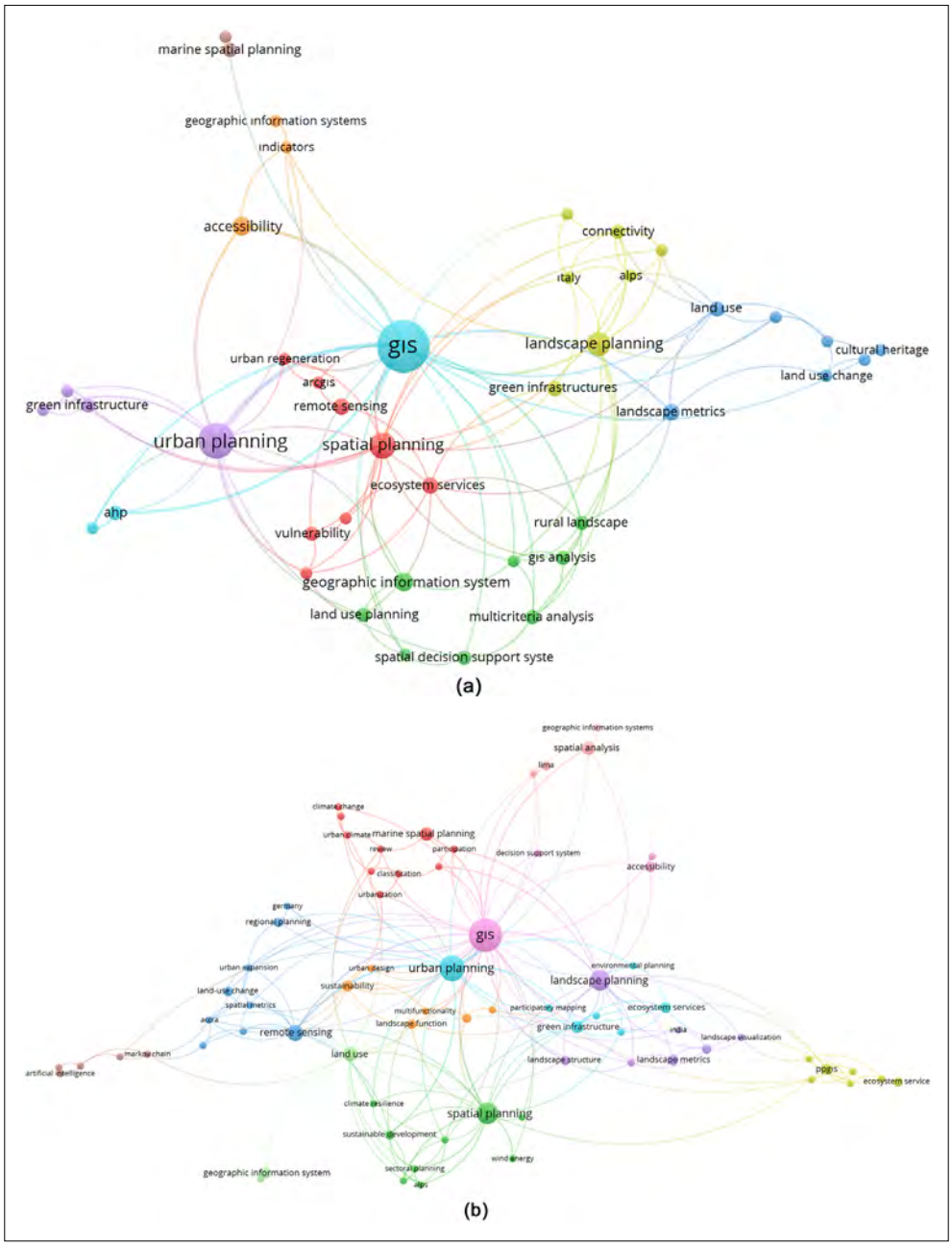

Figure 8. Key concepts that come to the fore in the relationship between GIS and planning **(a)** Italy and **(b)** Germany.

predominantly involve mapping various criteria over renewable energy resources within a GIS environment, using overlay analysis. Spatial mapping studies are primarily focused on mapping spatial data, with a process that often relies on remote sensing and land use analysis. Although studies on mathematical modeling are scarce, the primary approach is centered on optimization studies (Table 4).

The general profile of researchers in the fields of urban planning, spatial planning, and landscape planning tends to consist of scientists who favor a technical mapping perspective over a planning discipline approach. It is observed that authors predominantly publish their studies in planning-related journals. Given that planning disciplines operate on the basis of cumulative effects in spatial evaluations and regard GIS applications as methodological tools, there is a growing need for researchers with expertise in planning to contribute more significantly to this body of work.

Consequently, future research should encourage planning experts to adopt GIS as a significant methodological approach in various land use processes for multi-criteria and multi-objective decision strategies.

Table 4. Purpose of the most influential authors working in Türkiye to use GIS and clustering list (WoS database, date of last access: 10.06.2023)

Cluster	Authors - Year	Journal	Citation	The Purpose of the Use of GIS
Site Selection	Aydin, N. Y.; Kentel, E; Duzgun, S. (2010)	Renewable & Sustainable Energy Reviews	200	Determination of the location selection of wind energy facilities by GIS and AHP (weighted overlay analysis)
Mathematical Modeling	Baskent, E. Z.; Keles, S. (2005)	Ecological Modelling	170	Use of mathematical optimization and meta-heuristic techniques in GIS in solving the spatial forest management problem
Site Selection	Çetin, M. (2015)	Environmental Monitoring and Assessment	146	Demonstration of areas based on bioclimatic comfort with GIS
Site Selection	Çetin, M.; Adıgüzel, F.; Kaya, Ö. F.; Sahap, A. (2018)	Environment Development and Sustainability	129	Demonstration of areas based on bioclimatic comfort with GIS
Site Selection	Çetin, M. (2019)	Air Quality Atmosphere and Health	109	Assessment of the impact of bioclimatic comfort zones on urban planning using GIS and remote sensing
Spatial Mapping	Çetin, M.; Zeren, I.; Şevik, H.; Çakir, C.; Akpinar, H. (2018)]	Environmental Monitoring and Assessment	109	Determination of natural parks with GIS within the sustainability of tourism potential
Spatial Mapping	Yilmaz, I. (2007)	Engineering Geology	104	Identification of geologically objectionable areas using remote sensing data with GIS
Site Selection	Uyan, M. (2014)	Environmental Earth Sciences	91	Determination of the location of solid waste facilities by AHP and GIS
Spatial Mapping	Çetin, M.; Şevik, H. (2016)	Environmental Monitoring and Assessment	83	Determination of the potential of recreation areas with GIS
Site Selection	Torkayesh, A. E.; Zolfani, S. H.; Kahvand, M.; Khazaelpour, P. (2021)	Sustainable Cities and Society	57	Determination of landfill facilities by GIS
Spatial Mapping	Karakus, C. (2019)	Asia-Pacific Journal of Atmospheric Sciences	45	Determination of land use changes by GIS and remote sensing
Site Selection	Kılıçoğlu, C.; Çetin, M.; Arıcak, B.; Sevık, H. (2021)	Theoretical and Applied Climatology	45	Location selection of residential areas using GIS and MCDM methods
Site Selection	Adıgüzel, F.; Çetin, M.; Kaya, E.; Şimşek, M.; Güngör, Ş.; Sert, E. B. (2020)	Theoretical and Applied Climatology	39	Identification of suitable areas for bioclimatic comfort in land management and planning with GIS
Site Selection	Baz, İ.; Geymen, A.; Er, S. N. (2009)	Advances in Engineering Software	37	Suitability analysis according to natural thresholds using GIS
Spatial Mapping	Çetin, M.; Önaç, A. K.; Sevık, H.; Cantürk, U.; Akpinar, H. (2018)	Arabian Journal of Geosciences	37	Demonstrating the sustainability of natural and cultural resources with GIS

Table 4. Purpose of the most influential authors working in Türkiye to use GIS and clustering list (WoS database, date of last access: 10.06.2023) (Cont.)

Cluster	Authors - Year	Journal	Citation	The Purpose of the Use of GIS
Spatial Mapping	Yanar, T.; Kocaman, S.; Gökçeoğlu, C. (2020)	ISPRS International Journal of Geo-Information	31	Creation of hazard sensitivity maps by GIS and fuzzy AHP method
Spatial Mapping	Yilmaz, I.; Marschalko, M.; Bednařík, M. (2011)	Carbonates and Evaporites	31	Mapping of areas in danger of collapse with GIS
Spatial Mapping	Güngör, Ş.; Çetin, M.; Adıgüzel, F. (2021)	Air Quality Atmosphere and Health	30	Determination of the development of thermal perceptions over time by GIS
Mathematical Modeling	Erener, A. (2013)	International Journal of Applied Earth Observation and Geoinformation	29	Evaluation of the performance and accuracy of the classification algorithms obtained with GIS
Spatial Mapping	Arca, D.; Kutoğlu, Ş. H.; Bęcek, K. (2018)	Environmental Monitoring and Assessment	28	Evaluation based on GIS and multi-criteria decision-making method in determining landslide sensitivity in mining areas
Spatial Mapping	Coşkun, H. G.; Algancı, U.; Usta, G. (2008)	Sensors	28	Determination of land use changes by GIS and remote sensing
Spatial Mapping	Marschalko, M; Yilmaz, I; Kubecka, K; Bouchal, T; Bednarik, M; Drusa, M; Bendova, M. (2015)	Arabian Journal of Geosciences	25	Creation of maps using GIS to identify new areas for settlements affected by collapses in underground mining
Site Selection	Tercan, E.; Eymen, A.; Urfalı, T.; Saraçoğlu, B.Ö. (2021)	Land Use Policy	24	Evaluation of conformity analysis of solar power plants using GIS and multi-criteria decision-making techniques
Site Selection	Adıgüzel, F.; Sert, E.B.; Dinç, Y.; Çetin, M.; Güngör, S.; Yuka, P.; Doğan, O.S.; Kaya, E.; Karakaya, K.; Vural, E. (2022)	Theoretical and Applied Climatology	23	Developing a GIS-based decision-making strategy to identify the most appropriate areas in tourism activities
Spatial Mapping	Uzun, O.; Müderrisoğlu, H. (2011)	African Journal of Agricultural Research	21	Visualization of landscape quality in landscape planning with GIS
Site Selection	Tercan, E.; Tapkın, S.; Latinopoulos, D.; Dereli, M.A.; Tsiropoulos, A.; Ak, M.F. (2020)	Environmental Monitoring and Assessment	19	Determination of the location selection of offshore wind energy facilities by GIS and MCDM method
Site Selection	Günen, M.A. (2021)	Renewable Energy	18	Performing conformity analysis using GIS and MCDM method
Site Selection	Nyimbili, P.H.; Erden, T. (2020)	ISPRS International Journal of Geo-Information	18	Performing conformity analyses of urban emergency facilities with GIS and multi-criteria decision-making methods

Table 4. Purpose of the most influential authors working in Türkiye to use GIS and clustering list (WoS database, date of last access: 10.06.2023) (Cont.)

Cluster	Authors - Year	Journal	Citation	The Purpose of the Use of GIS
Mathematical Modeling	Öztürk, D. (2017)	Journal of Environmental Engineering and Landscape Management	17	Fractal analysis based on GIS and remote sensing systems
Spatial Mapping	Das, H.O.; Sönmez, H.; Gökçeoğlu, C.; Nefeslioğlu, H.A. (2013)	Landslides	16	Demonstrating the impact of seismic activity on landslide areas with GIS
Spatial Mapping	Demir, G. (2018)	Natural Hazards	14	Determination of landslide sensitivities using GIS and MCDM method
Spatial Mapping	Alphan, H.; Güvensoy, L. (2016)	Journal of Environmental Engineering and Landscape Management	13	Demonstrating land use change using GIS
Site Selection	Peker, F.; Kurucu, Y.; Tok, H.H.; Saygılı, E.; Tok, E. (2013)	Journal of Environmental Protection and Ecology	13	Conformity analysis with GIS in determining ecological thresholds
Spatial Mapping	Soycan, A.; Soycan, M. (2009)	Arabian Journal for Science and Engineering	13	Creation of digital high models with GIS
Site Selection	Dereli, M.A.; Tercan, E. (2021)	Environment Development and Sustainability	11	Determination of the location of solid waste storage facilities by GIS (weighted linear combination)
Site Selection	Kaya, O.; Alemdar, K.D.; Campisi, T.; Tortum, A.; Codur, M.K. (2021)	Energies	11	Conformity analysis of electric vehicle charging stations using GIS and multi-criteria decision-making methods
Spatial Mapping	Kumlu, KBY; Tudes, S. (2019)	Natural Hazards	10	Evaluation of earthquake risk areas by GIS and MCDM method
Spatial Mapping	Salata, S.; Ronchi, S.; Giaimo, C.; Arcidiacono, A.; Pantaloni, G.G. (2021)	Sustainability	10	Assessment of flood-risk areas with GIS
Spatial Mapping	Uzun, O.; Gültekin, P. (2011)	Scientific Research and Essays	10	Spatial mapping in landscape planning using GIS

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Article

Analyzing design factors affecting users' interactions in public spaces

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ABSTRACT

Public spaces are now considered the most important environments that play a key role in shaping citizens' social interactions. Due to uneven development in urban design, this role has become less important. Therefore, it is necessary for architects and urban planners to fill this gap by considering the design factors. This study aims to identify and classify the design factors that influence social interactions in public spaces and present a conceptual framework for designers and future studies. The field study method is used to identify the design factors and the descriptive-analytical survey study is used to evaluate them. Shahriyar Park of Tabriz, Iran, was selected as a case study. 268 users of the park participate in survey including 6 design factors and 22 measurements, which are recorded on Likert scale. LISREL software has been used to analyze the data. The results of the study show that the 'safety factor' as the first priority, 'vitality, activity, psychological and behavioral factors' as further priorities, and the 'physical factor' as the last priority influence the level of users' social interaction in the public spaces of Shahriyar Park. In this respect, variables such as accessibility, visibility, topography, material diversity, planting, and furniture were found to play a positive role in making the park more pleasant and enhancing social interaction between users. Accordingly, it has been suggested that these factors and variables should be considered by designers as a viable approach when designing urban public spaces, particularly parks, to encourage social interactions among city users.

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INTRODUCTION

One of the most significant roles of the built environment is to provide a platform for creating and enhancing social relationships. Such relationships are often formed in work and activity environments or arise in the form of social interactions in public spaces. In this respect, as meeting points of social encounters, urban spaces organize users' spatial behaviors and experiences and contribute to preventing social anomalies as much as possible (Askarizad & Safari, 2020). Meanwhile, piazzas, green spaces, and neighborhood parks have been the basis for social interactions since long ago (Cao & Kang, 2019). The growth of modern urban life has reduced the social interactions of citizens. As settings involved in citizens' actions and communication, public spaces play a leading role in performing functional activities and rituals that create social bonds and collective memory (Uysal Bilge, 2020). Pleasant public spaces, commensurate

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with culture, environmental conditions, and social needs, can be considered an undeniable value in the desirability of contemporary urban life (Silaci & Vitkova, 2017). Being in the open urban space increases the sense of citizenship, cooperation, and belonging to the place and improves social interaction and quality of life (Zhang Y. et al., 2022).

Nowadays, public spaces are often not responsive to the expectations of humans, and people regard urban space as a way to pass through; indeed, instead of inviting people to establish social relations, urban spaces encourage them to avoid them (Lopes et al., 2020). Therefore, the sense of belonging to society, the opportunity for face-to-face meetings, and social interactions become less significant as essential needs (Carmona, 2021). In this regard, to create retreats and private spaces for meeting people of any gender, age group, and social class, as well as to create spaces for presenting and developing individual and group skills, public spaces can be effective as behavioral settings (Han et al., 2022; Jalalkamali & Doratli, 2022). Parks and urban public green spaces are among the public spaces that strengthen cohesion, collective identity, social vitality, social trust and participation, sense of security, mental health, and the quality of social interactions in terms of having architectural components and activity areas (Enssle & Kabisch, 2020; Jennings & Bamkole, 2019). Hence, the present study aims to identify and categorize the design factors of public green spaces to propose practical approaches to designers, architects, and urban planners. In this context, the study seeks to answer the following questions:

1. What are the design factors affecting social interactions in public green spaces?
2. How is the prioritization of design factors affecting social interactions in public green spaces determined?

In this regard, due to playing a significant role as a cultural center involving historical, religious, and monumental buildings, as well as its location in the center of the Sorkhab neighborhood, one of the most ancient neighborhoods of Tabriz city in Iran, as a place for recreational and social interactions, Shahriyar Park has become the reason for the appearance of distinct behavioral patterns in social behaviors. Therefore, it is considered a suitable case for investigating the effective design factors of public spaces in promoting social interactions. To this end, through descriptive-analytical and field study methods, the design factors of urban public spaces were identified as the conceptual model of the study and measured by a survey study method conducted at Tabriz Shahriyar Park. Lastly, design factors affecting users' interaction in public green spaces were classified according to the impact of the coefficient, and results were analyzed to promote social interaction.

CONCEPTUAL FRAMEWORK

Urban spaces are defined open and public spaces that reflect the nature of social life. Accordingly, by being present in public spaces, people are involved in various social activities whose dynamics and efficiency require social and diverse interactions (Tibaldez, 2015). Public spaces such as piazzas, maidans or green spaces demonstrate the life of a city, its identity, its movement and the vitality of its citizens. As arenas of public life, such places have great importance for urban planning. Public open spaces are remarkable elements of sustainable development and livable urban development (Belleme et al., 2021). In a broader concept, public open space creates various functions that define it as an outdoor public gathering place in the outside environment and spaces between buildings. These spaces can be introduced as urban open spaces such as cafes, retail markets, parks, green spaces, and sidewalks. In their research, Tahmasebi et al. (2022) introduced usability of space for individuals, provision of psychological and physical comfort, individuals' satisfaction with being in the space, security, pleasantness, and social activity as the basis of process of social interaction in the community and improvement of collective life in public space. Other studies have considered attractiveness, beauty, security, tranquility, accessibility, and hierarchy as physical characteristics of public open spaces to increase social interactions (Kamińska & Mularczyk, 2021; Sadeghian et al. 2021). Amran & Fuad (2020) and Carmona (2021) consider physical features and social activities as influential factors to enhance social interactions and sense of belonging to a place. According to Whyte (2012), the physical features of public space such as monuments, stairs, fountains, form, size, landscape, furniture, and lighting encourage people to interact and improve the quality of public space. Garau and Annunziata (2022) emphasized the physical quality of public space and natural elements as factors that enhance environmental stimulation and vitality, pleasant experiences, and social well-being.

Nowadays, the existential dimensions of human beings are more considered by urban planners and designers, and people are more likely to stay and participate in the public space of cities (Gehl & Svarre, 2013). In addition to physical factors, there is a direct relationship between psychological aspects, design factors, social activities, and perceptions of the environment. Sociability in public spaces is based on individuals' need to communicate. Public spaces should provide opportunities for people to communicate and interact. Comfort, safety, security, relaxation, social participation, and discovery are the most important behavioral and psychological aspects of urban public spaces (Peng et al., 2021; Wan et al., 2020). Hampton et al. (2015) introduced activities and

accessibility as factors to promote social life in urban public spaces. In this context, Mouratidis and Poortinga (2020) identified diversity of activities and urban vitality as factors that influence social activities and accessibility in public spaces. Najeeba and Raffaello (2019) found that the permeability, accessibility, and presence of citizens for their activities in the city influence people's behavior and interactions. Other studies have suggested place behavior as an important concept related to social interactions. For example, Tamir and Hughes (2018) emphasize form, private space, solitude, and crowd as influential dimensions of place behavior. Faghirnavaz et al. (2021) have considered sidewalks, public/semi-public spaces, and private/semi-private spaces as behavioral settings that enhance social interactions in public spaces. Many studies have introduced safety as a factor that influences social interactions and sociability in public spaces. In this context, Levasseur et al. (2015) believe that increased social participation promotes feelings of security. Backer (2018) highlights visibility as an important criterion for control, recognition, and safety in public spaces. Pakzad et al. (2019) demonstrated the direct relationship between visual control and visual controllability and the patterns of static presence in the central part of the square. Sumartojo (2022), Klaudiusz and Guminska (2020) and Gokhale (2013) consider the significant role of lighting in public spaces in creating security during the day and night life. Vitality is another effective factor in increasing user interaction. Functional variety, excuses to linger in the space, provision of seating or walking opportunities, consideration of human scale, and the ability of space to create memorable feelings have been cited in many studies as components that influence spatial interactions (e.g., Zheng et al., 2023; Zhang F. et al., 2022; Hataminejad et al., 2018). In general, as Figure 1 illustrates, the conceptual framework of the present study has been developed in six categories—physical, psychological, activity and behavioural attitudes, security, and vitality—based on a review of theories and studies on social interactions in public spaces. These categories were extracted from a review of related studies and literature, and each factor involves the most effective elements—for example, size, landscape, and furniture for the physical factor or comfort, safety, discovery, and relaxation for psychological factor—for establishing social interactions in public spaces like parks. Factors and components considered in this model serve as a benchmark for designing survey questions and as gauge for assessing how well the case study's spaces facilitate users' social interactions.

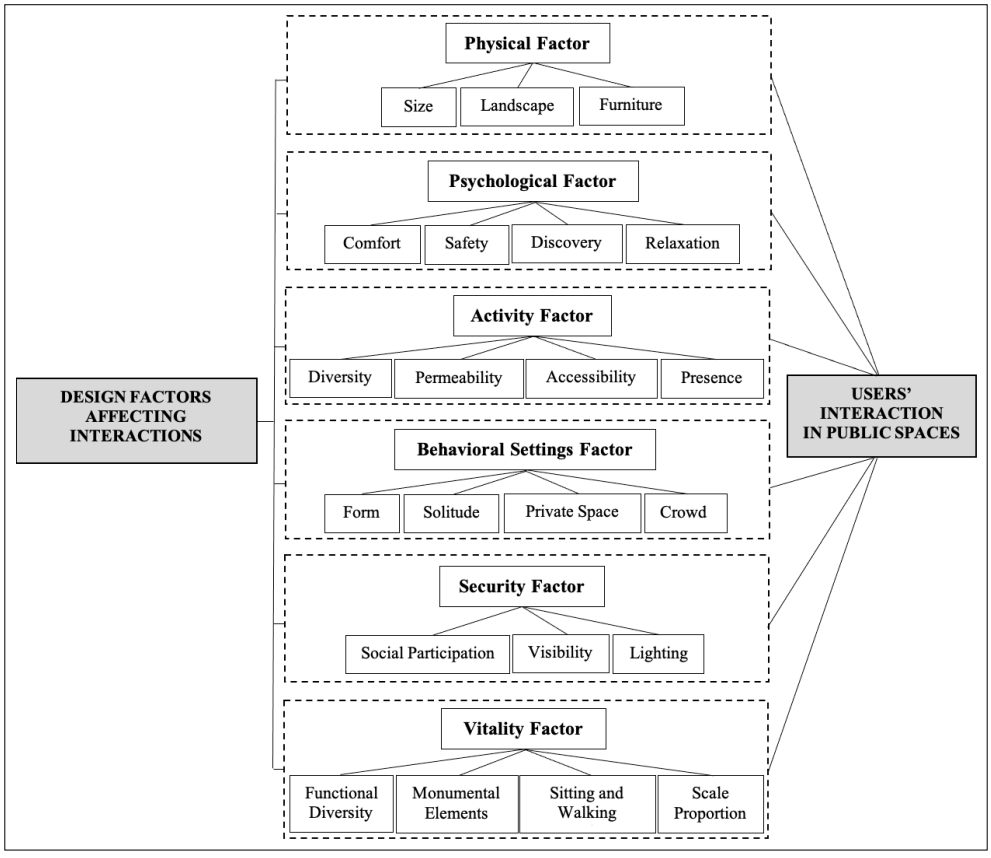

Figure 1. Conceptual model of the study.

METHODOLOGY

Since the purpose of the present study is to identify and classify the design factors that influence social interactions in public spaces, it is considered both quantitative and qualitative in terms of the nature and character of the research. This means that one part of the study should be descriptive (qualitative) and the other analytical (quantitative). Therefore, it seems necessary to apply a mixed descriptive-analytical method. Descriptive studies focus on the investigation of particular themes or situations. In this context, drawing on previous studies and a review of the literature, the factors and variables influencing the research topic are identified and presented. Analytical studies examine the relationship between variables and the desired outcomes and discover scientific relationships (studies such as the forthcoming article, case-control studies, and questionnaires). In this study, a descriptive field study was used to review the literature and the studies conducted, and to identify design factors that impact social interactions in public spaces. The relevant variables were extracted and presented in the form of the study's conceptual model (Figure 1). To test the corresponding model and categorize its factors according to their effectiveness, the analytical method was applied, i.e., data were collected by physical presence at the selected site, and through field observations and questionnaires. In this context, 268 residents (133 males and 135 females; mean age = 38.65) of the Sorkhab neighborhood in Tabriz City, East Azerbaijan Province, Iran, were randomly selected for participation. The corresponding questionnaire comprised 6 factors and 22 measurements, which were recorded on a five-point Likert scale (strongly disagree = 1 to strongly agree = 5).

Questions 1 to 3 addressed the 3 variables of the physical factor: Size (the presence of suitable facilities and the appropriate size of the park provided a sense of comfort and the opportunity to participate in social activities); Landscape (the park's surroundings, its views, green spaces, beautiful scenery, and natural diversity as effective factors encourage me to be present and interact in the park); Furniture (the design, placement, quality, variety, and comfort of the furniture used in the park encourage me to sit down, make new friends, and spend time). Questions 4 to 7 pertained to the 4 variables of the psychological factor: Comfort (the park's facilities, such as the diverse vegetation and trees, have purified the air and created a pleasant thermal condition that makes me feel comfortable); Safety (the presence of safety facilities such as surveillance cameras, adequate lighting, proximity to help and information centers gives me a sense of security); Discovery (the entertaining, monumental, and historical elements of the park arouse my curiosity to discover the surroundings); Relaxation (the sounds I hear are not disturbing, and the spaces of this park offer me the opportunity to get away from disturbing noises, and I feel calm and peaceful). Questions 8 to 11 were for the 4 variables of the activity factor: Diversity (How do you rate the diversity of plant life and its impact on your stay in the park?); Permeability (The physical environment of the park is clear and recognizable, and this makes me feel safe and able to spend time in the park); Accessibility (I often come to this park because it is easy to reach in the city and because it is also easy to navigate within the park and between spaces); Presence (when I am tired, I prefer to walk through the spatial diversity of the park and feel comfortable). Questions 12 to 15 examined the 4 variables of the behavioral factor: Form (The physical and natural elements in the park are pleasant, coordinated, and do not cloud my mind with inconsistency); Solitude (I can easily observe and follow the current activities in the park, and it is possible to see different areas of the park); Private space (To what extent do the park's spaces and facilities offer the opportunity to sit alone or in pairs); Crowd (The presence of a large crowd in the park may encourage me to participate in group activities). Questions 16 to 18 inquired about the 3 variables of the safety factor: Social participation (The park's facilities and environmental qualities motivate me to participate in social activities and improve my sociability); Visibility (The landscape and natural perspectives of the park allow me to disconnect from everyday life, and I feel relaxed, refreshed, and calm); Lighting (The lighting systems used give me a sense of calm and serenity). Questions 19 to 22 related to the 4 variables of the vitality factor: Functional diversity (The forms used in the park appeal to me and evoke positive feelings); Monumental elements (The shapes of the objects attract my attention; they are memorable and appear warm and inviting); Sitting and walking (The different areas of the park in terms of sitting, eating, walking, etc., have sufficient capacity to meet our needs); Scale proportion (I enjoy walking on a continuous path that passes by water, plants, and trees).

The questionnaire was conducted during the week, at different times of the day, and completed through personal visits. The validity of the questionnaire was confirmed by a pilot study with 38 users of the Sorkhab neighborhood park (Shahriyar Park). The reliability of the questionnaire was determined to be 0.852 using Cronbach's alpha test. LISREL software was used to analyze the data, and confirmatory factor analysis was performed using structural equation modeling. This method is a complex mathematical and statistical combination of factor analysis, multivariate regression, and path analysis, which are combined into a comprehensive system to analyze the effects of different factors and to measure multivariate phenomena such as this study. The role of each question in the reliability of the whole scale was examined. The coefficient of determination of the items was considered acceptable for values over 0.3. The validity of the results was measured using confirmatory factor analysis separately for each of the design factors. Figure 2 represents the summery of Research steps.

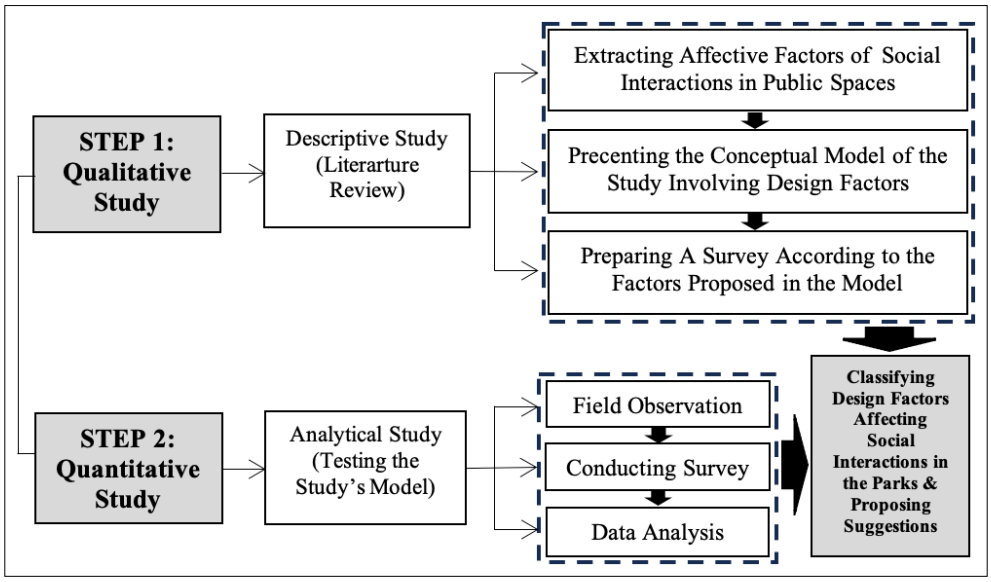

Figure 2. Procedure handled in the methodology.

STUDY AREA

Since this study aims to evaluate the effect of design factors on social interactions in public spaces, it was necessary to select an area that reflects people's cultural and social values, thereby creating a meaningful connection between the built environment and social interactions due to the presence of humans in these spaces. Therefore, Shahriyar Park, located in the old Sorkhab neighborhood of Tabriz, was chosen for the study as it is in proximity to the city's historical context and monuments (Figure 3). Tabriz is considered one of the most renowned cities in Iran and the capital of East Azerbaijan province. Known as the largest Turkish city in Iran, Tabriz serves as an administrative, commercial, political, cultural, and military hub. The city's geographical location has made it a crossroads of ancient civilizations throughout history, and it is one of the cities along the Silk Road. The old Sorkhab neighborhood, situated in the north of Tabriz, is recognized as one of the most important historical-tourist zones in the city, due to its numerous historical houses and its closeness to the historical complex of Shahriyar Park.

The cemetery known as Maqbareh Al-Shoara in the Surkhab district has been the burial place of many great Azerbaijani poets, such as Khaqani, Zaheer, Qatran, Asadi Tousi, and others, since ancient times. In 1967, it was decided to build a tomb for poets and create a park in the then-abandoned cemetery of Sorkhab. In 1970, a decision was made to erect a monument to poets. Concurrent with this event, the first steps were taken to design the park. Following the construction of the monument and its proximity to the historic mosque and the shrine of Seyyed Hamzah, officials began to develop green areas for the expansion and design of the cemetery. The green area of this complex underwent several transformations until the current park, Shahriyar Park, was designed and constructed in 1993 with the assistance of the Municipality of Tabriz District 1. The park covers an area of 35,000 m² and is bordered to the west by Seg Al-Islam Street, to the north by Arif Street, to the south by Shahid Paydar Street, and to the east by an 8-meter-long avenue. Significant features within the park that enhance

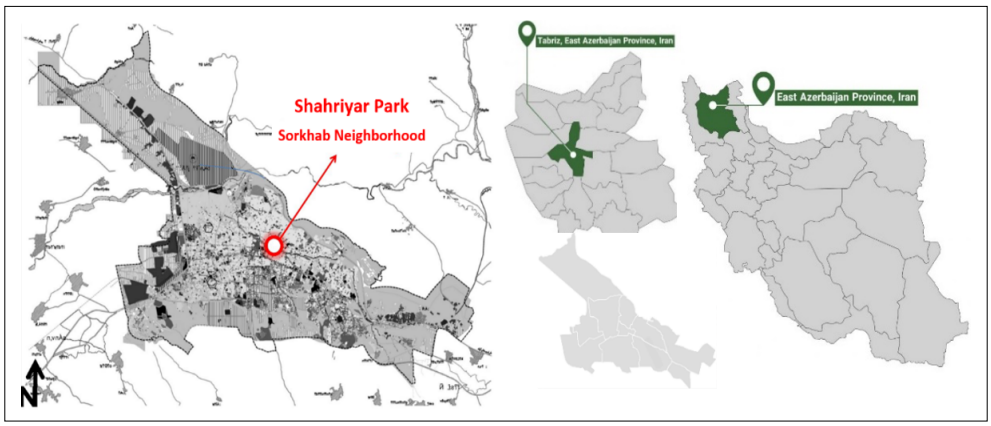

Figure 3. The urban location of the case area.

its importance for people's presence and visits include the Monument of Poets, Tombs of Ancient Poets, Seyyed Hamzah Mosque and Shrine, Behtouni Museum, Tabriz Poetry Association, Amphitheatre, and a library housing exquisite historical books and documents. Surrounding the park are vital facilities such as a pathological laboratory, schools, a children's hospital, pharmacies, sports halls, commercial complexes, residential complexes, and the organization of industries and mines, which contribute to the park being frequented by a large number of people on a daily basis (Figure 4).

Since the park has undergone various changes after restoration works, and given that it serves not only as an urban green space but also as the burial site for historical poets, writers, and philosophers of Iran, as well as the most renowned poet of the contemporary Turkish language, namely Shahriar (Maqbareh Al-Shoara Monument), along with other important architectural elements like the historical Seyyed Hamzah Mosque and Shrine, the museum, the library, an athenaeum, an amphitheater, and the monument of the poets, it has consistently been one of the most frequented centers in the city of Tabriz (Figure 5). It serves as a daily gathering place for numerous locals and tourists. Moreover, the presence of several significant structures such as hospitals, clinics, daily markets, cab and bus stations around the park further underscores its importance as an urban space, rendering it an attractive case study for investigating the influence of design and architectural factors on social interactions among users.

FINDINGS

To determine the effective design factors for user interaction in public spaces, establishing the reliability of the questions in the factor analysis was necessary. Therefore, the role of each question concerning the reliability of the entire scale was initially examined. In this context, items with coefficients of determination less than 0.3 were excluded. The results of the reliability test, using the confirmatory factor analysis method, are presented in a tabulated form for each design factor affecting interactions. Additionally, the factor loading of each index was analyzed in conjunction with its corresponding factor.

Table 1 displays the outcomes of the confirmatory factor analysis for the variables related to the physical factors. As indicated, the factor loadings for all variables exceed 0.3 and demonstrate acceptable reliability. Within this context, the variable 'landscape' (M=3.97) with a factor loading of 0.83 and the variable 'furniture' (M=3.17) with a factor loading of 0.71 exert the most significant influence on the physical factor.

The results of the confirmatory factor analysis for the variables related to the psychological factor are presented in Table 2. It is evident that all variables pertinent to reliability have factor loadings exceeding 0.3. The variables 'comfort' (M=4.33) and 'discovery' (M=4.17) are shown to have the most substantial impact on the psychological factor, with factor loadings of 0.72 and 0.66, respectively.

Based on the results obtained for the activity factor, the variables 'accessibility' (M=4.67) and 'diversity' (M=4.12) have the most significant influence on the corresponding factor, with factor loadings of 0.78 and 0.69, respectively, as shown in Table 3.

The consideration of private spaces has led to changes in the spatial behavior of users, an increase in vitality and sense of belonging, and the development of social interactions in the park. Table 4 indicates that the variables 'private spaces' (M=4.31) and 'form' (M=4.00) have the highest average values with factor loadings of 0.81 and 0.69, respectively. This reflects the quality of the corresponding variable that has contributed to the strengthening of collective space behavior.

Personal and social security in public spaces is one of the fundamental principles that contribute to their attractiveness for the population. Security in public spaces is essential for quality of life and serves as a prerequisite for

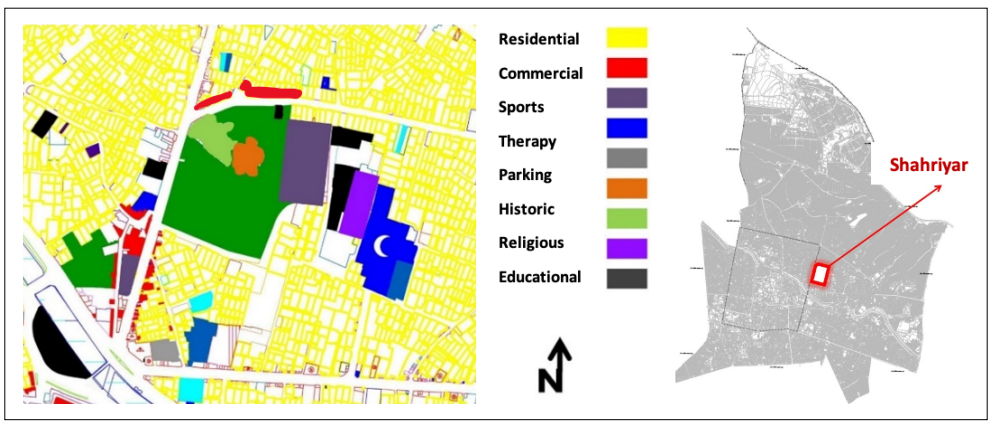

Figure 4. The locations and land-use pattern of the case area.

Figure 5. The accessibilities and various uses of the case area.

maintaining and enhancing people's well-being and health. Furthermore, security enhances the potential for cohesion and the occurrence of social interactions in collective spaces. Table 5 indicates that the variable 'visibility' (M=4.72) has the highest average value with a factor loading of 0.84 in the evaluation of the security factor.

Regarding the vitality factor, as seen in Table 6, 'sitting and walking' (M=4.19) was evaluated as the most effective variable for user interaction. Paths define continuity, transition, and movement between places. The creation of

Table 1. The results of confirmatory factor analysis of physical factors

Variable	M	SD	t	Loading Factor	Prob. Level
Size	2.14	0.39	7.93	0.31	0.000
Landscape	3.97	0.64	19.45	0.76	0.000
Furniture	3.17	0.60	17.76	0.62	0.000

Table 2. The results of confirmatory factor analysis of psychological factors

Variable	M	SD	t	Loading Factor	Prob. Level
Comfort	4.33	0.73	22.47	0.51	0.000
Safety	2.97	0.36	15.45	0.36	0.000
Discovery	4.17	0.66	19.76	0.62	0.000
Relaxation	2.23	0.34	15.15	0.32	0.000

Table 3. The results of confirmatory factor analysis of activity factors

Variable	M	SD	t	Loading Factor	Prob. Level
Diversity	4.12	0.69	19.32	0.63	0.000
Permeability	2.01	0.30	14.13	0.31	0.000
Accessibility	4.67	0.74	21.74	0.78	0.000
Presence	2.99	0.32	14.89	0.36	0.000

Table 4. The behavioral setting factors

Variable	M	SD	t	Loading Factor	Prob. Level
Form	4.00	0.63	18.79	0.69	0.000
Solitude	3.98	0.57	17.41	0.63	0.000
Private Space	4.31	0.66	19.23	0.81	0.000
Crowd	1.11	0.22	10.03	0.24	0.000

Table 5. The results of confirmatory factor analysis of the security factors

Variable	M	SD	t	Loading Factor	Prob. Level
Social Participation	3.26	0.51	16.72	0.42	0.000
Visibility	4.72	0.72	20.25	0.64	0.000
Lighting	2.81	0.29	14.50	0.31	0.000

Table 6. The results of confirmatory factor analysis of the vitality factors

Variable	M	SD	t	Loading Factor	Prob. Level
Functional Diversity	4.09	0.64	17.82	0.49	0.000
Monumental Elements	4.01	0.61	17.29	0.59	0.000
Sitting & Walking	4.19	0.71	18.67	0.74	0.000
Scale & Proportion	1.74	0.31	10.03	0.20	0.000

sequential spaces and the design of suitable views, along with the variety of materials, furniture, colors, shapes, directions, and dimensions of the path, are considered ecological capabilities of different paths. Additionally, 'functional diversity' (M=4.09) and 'monumental elements' (M=4.01) are identified as other variables that have a positive effect on social interaction. Overall, the functional-spatial structure of the park, which includes the poet's monument, the mosque, the shrine, the library, the museum, the literary club, and the green areas, enhances the legibility of the spaces and creates a coherent spatial structure, thereby multiplying the choices available to users.

In this study, internal consistency was assessed using Cronbach's alpha coefficient, which indicated high reliability of the measurement tool. Table 7 presents the results of the

Table 7. The reliability of the tool for measuring design factors affecting social interactions in public spaces

Variables	Cronbach's alpha	Factors	Cronbach's alpha
Design Factors	0.852	Physical Factor	0.702
		Psychological Factor	0.712
		Behavioral Setting Factor	0.726
		Activity Factor	0.754
		Security Factor	0.806
		Vitality	0.781

confirmatory factor analysis regarding the design factors that affect social interactions in public spaces. It reveals that each of these factors has a high factor loading. Notably, the security factor exerts the greatest influence with a factor loading of 0.806, while the physical factor has the least influence with a factor loading of 0.702.

To confirm the significance test of each design factor's contribution to social interactions in public spaces, confirmatory factor analysis was conducted. The t-value test was employed to assess the significance of the relationship between variables. Significance was determined at an error level of 0.05. Factor loadings indicated by a t-value test of less than 1.91 were not considered to signify a significant relationship. A factor loading of less than 0.3 was deemed a weak relationship, while a factor loading between 0.3 and 0.6 was considered acceptable. Table 8 presents the results of the confirmatory factor analysis regarding the design factors affecting social interactions in Shahriyar Park's public space. It demonstrates that each of the factors possesses a high factor loading. Notably, safety has the highest impact with a factor loading of 0.93, followed by vitality, activity, psychology, behavioral setting, and physical factors, with factor loadings of 0.85, 0.82, 0.81, 0.79, and 0.74, respectively (Figure 6).

Table 8. Confirmatory factor analysis of design factors affecting social interactions in the Shahriyar Park

Design Factors	T Statistic	Loading Factor	Prob.Level
Physical Factor	12.57	0.74	0.000
Psychological Factor	16.13	0.81	0.000
Behavioral Setting Factor	13.41	0.79	0.000
Activity Factor	16.63	0.82	0.000
Security Factor	19.84	0.93	0.000
Vitality Factor	17.52	0.85	0.000

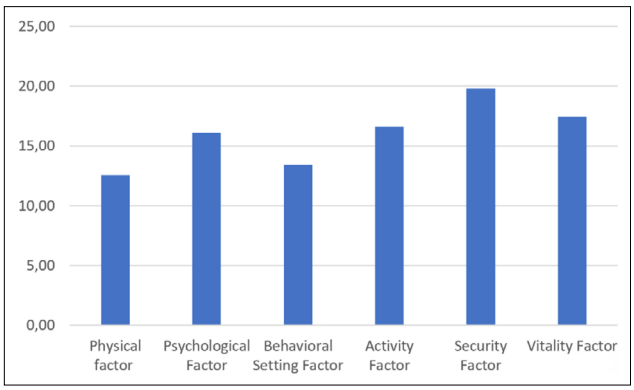

Figure 6. Impact factor of design factors affecting social interactions in the Shahriyar Park.

DISCUSSION

By examining the effects of the design factors and their components through a questionnaire completed by the users of the case area, it was found that the security factor (t=19.84, L.F. = 0.93) was identified as the most influential in fostering social interactions within the public spaces of Shahriyar Park. Given the park's accessibility from four sides, it offers opportunities for visual visibility, thereby facilitating surveillance and social safety (Figure 7). The park's proximity to important facilities such as the medical center, along with easy access from all four sides, and the row of stores on the north and south sides (Figure 4), as well as the mosque and the shrine (Figure 5), have enhanced security and social oversight. The three sides of the park that are bordered by apartment blocks, most with more than four stories, provide an excellent vantage point for overlooking the park. This has improved overall surveillance, enabling residents to use the park daily with ease, which, in turn, has led to an increase in both social interactions and a sense of security. Furthermore, observations indicate that people often traverse the park on their way back from visiting the shrine to rest, eat, relax, or pray at the mosque, and they regularly engage with both the park and the shrine. As a result, the park is consistently well-observed. Additionally, the frequent visitors to the library, the museum, and the poet's monument contribute to the human presence in the public space, enhancing controllability and security.

Figure 7. Importance of accessibility and surrounding buildings in enhancing the sense of control and security.

In this context, it is concluded that visibility, as the most effective variable, significantly contributes to creating psychological and physical security by positioning the park in proximity to high-traffic areas such as the neighborhood's main roads, public service facilities (bus station, stores, medical center), residential blocks, and historical-religious (mosque, shrine), monumental (poet's tomb), and cultural (library, museum) establishments.

Vitality was regarded as the second most influential factor (t=17.52, L.F. = 0.85), such that variables including seating and walking facilities (flower beds, paths, furniture, etc.), functional diversity (cultural and green spaces), and monumental elements (sculptures, statue-like elements, etc.) draw individuals, foster vitality, reinforce spatial legibility, and have a positive impact on the social interactions of users. In the park under study, a considerable diversity of paths and spatial sequences contributes to the space's attractiveness. The walkways vary in materials, colors, dimensions, and level differences, satisfying users with their resulting quality. Providing social cohesion through a place fosters a sense of belonging. By cultivating social relationships, the place engenders and reinforces group affiliation, thereby increasing the density of personal connections. In this park, various types of furniture, ranging from stairs and fountains to benches and statues, are utilized in the design of the diverse paths in accordance with the site's topography, attracting different age groups and infusing vibrancy, a sense of place, and interaction within an urban public space.

In Shahriyar Park, the monument dedicated to the poet stands as the focal point of the site. With its distinctive shape and proper proportions, it is visible from distant points within the city. Adjacent to this structure, the brick dome and minaret of the Seyyed Hamzah shrine are prominently featured. The juxtaposition of these two structures is intriguing, both in terms of their construction periods and their architectural styles and techniques (Figure 8). The significance of these two features in augmenting the quality of the park spaces must be acknowledged, as they are compelling elements in terms of form and symbolism as well as function, contributing to the reinforcement of social interactions. It is also essential to highlight that these structures aid in the orientation and wayfinding of visitors, offering a variety of vistas and visual sequences through movement and changes in direction within the park. Moreover, they have enhanced the physical-social identity of the urban public space in a symbolic manner.

Activity was identified as the third factor (t=16.63, L.F. = 0.82) influencing social interactions in Shahriyar Park. Regarding the activity factor, variables such as accessibility and diversity significantly encouraged users' interactions. The park's accessibility from the neighborhood's arteries on all four sides led people to frequent the park for various functions and social gatherings (Figure 9). Shahriyar Park's integration into the urban accessibility network from these four sides enhances its potential to attract more visitors, offering access to diverse features such as green spaces, furniture, and historical, cultural, and religious elements, thereby increasing social interactions. The proximity of the cab and bus stations, medical center, local market, and schools enhances the park's potential to draw individuals and facilitate access to the activities within the area. The park's main entrance is strategically located opposite the medical center (pathology laboratory), encouraging visitors to this facility to utilize the park for rest and waiting. Furthermore, the park's main wall, adjacent to the main road (Seg Al-Islam St.), plays a pivotal role in drawing residents and tourists visiting the Tombs of the Poets (Maqbareh Al-Shoara). Notably, the park's proximity to the Seyyed Hamzah Shrine Mosque and the presence of numerous merchants along this wall are key factors in

Figure 8. Diverse functions in the park and their impacts on users' vitality and interactions.

Figure 9. Attractive walls and sides of the study area.

attracting more visitors. The array of stores and residential units on the north side (Arif Street) also draws additional foot traffic to the park. Significantly, the dome and minaret of the shrine mosque, and the monument at the poet's tomb, serve as prominent landmarks and attractions on this side of the park.

The psychological factor was acknowledged as the fourth factor (t=16.13, L.F. = 0.81) influencing social interactions in Shahriyar Park. The variables of comfort and discovery were determined to have the most significant impact on users' interactions, as the quality of the landscape and green areas, combined with the park's orientation in relation to the sun's path and prevailing winds, provided optimal thermal comfort (Figure 10). Furthermore, the incorporation of diverse functions (entertainment spaces, monumental, and historical features) creates attractive perspectives and enhances visual appeal, making public spaces welcoming and enjoyable. In terms of comfort, the selection of vegetation, including elm, willow, and alder trees, has contributed to air purification and the establishment of a favorable thermal environment. The strategic orientation of the park maximizes comfort and meets ecological requirements. Moreover, the park stimulates visitors' curiosity and sense of discovery, with its entertainment (green spaces), monumental (the poet's tomb and monument), and historical components (ancient mosque and shrine). As these elements are framed by the trees and shrubbery, various perspectives and visual effects emerge, capturing users' interest and fostering social interactions. Apart from the west side and the entrance facing the main road, the remainder of the park offers a serene environment, relatively free from noise and odors, with the vegetation playing a crucial role in mitigating unpleasant smells and sounds.

Behavioral attitudes (t=13.41, L.F. = 0.79) and physical factors (t=12.57, L.F. = 0.74) are the fifth and sixth factors influencing sociability in the case study, respectively. Private spaces and form have been identified as the most effective behavioral settings that enhance social interactions in parks. Private spaces contribute to the reinforcement of individual or group spatial behavior and the development of social interactions by providing opportunities to sit alone or with others, utilizing divergent or convergent geometries, and creating pleasing views and plantings. The high average variable of private spaces is attributed to their positive response to the individual (solitude) and collective (interaction) needs of users, offering conditions suitable for solitary or paired seating, optimal geometry, vegetation, and vistas.

In terms of formal characteristics and acknowledging that the factors of activity and place are instrumental in creating a behavioral setting that leads to spatial functions, it can be asserted that the Poets' Monument in Shahriyar Park serves multiple roles. In addition to its commemorative function and housing the graves of renowned poets, it functions as a museum and exhibition, thereby constituting a unique behavioral setting. Moreover, this structure facilitates conversation and social interaction within, outside, and around its base. It also stands as a symbolic form, and its proximity to the sanctuary has fostered an inviting environment where people can gather, communicate, and interact (Figure 11).

Furthermore, the results of this study indicate that monumental and symbolic elements, such as the poet's monument, possess various conceptual and cultural attributes that serve as significant features, drawing people and enhancing sociability. The findings also reveal that defining spaces with physical elements—historic buildings and monuments, trees, statues, natural elements, seating areas, and walkways—contributes

Figure 10. Controlled noise and air condition providing comfort.

Figure 11. The behavioral settings of Shahriyar Park.

positively to the prolonged presence of people in public spaces by fostering a sense of security among users. The park in question has provided physical efficiency and visual appeal through its diverse vegetation, trees, and historical components. Moreover, physical qualities like monuments, stairs, fountains, and sculptures are acknowledged by visitors as influential factors that encourage presence and interaction in the space, thereby enriching the physical attributes of the park's public areas (Figure 12).

CONCLUSION

Urban public spaces, such as parks, are recognized as one of the most crucial environments for fostering the social interactions of citizens. The enhancement of social interactions in urban public spaces reflects their responsiveness to collective behavior and their capacity to contribute to vitality and a stronger sense of community. This study aimed to examine the impact of design factors

Figure 12. Various physical elements of Shahriyar Park.

on user interactions within these spaces. A review of theories and research on social interactions in public spaces highlighted physical, psychological, activity-related, and behavioral attitudes, as well as security and vitality as influential design components. The findings suggest that an accessible public space, like a park, is where diverse activities take place and where numerous opportunities for participation are available. Such spaces should be universally accessible, both physically and socially, to enrich the quality of life and interactions in an urban setting. Moreover, the aesthetics of a public space play a pivotal role in enhancing sociability, with the quality of activities and aesthetic considerations emerging as key variables in assessing the space's appeal. This study determined that factors such as accessibility, topography, material variety, planting, and the presence of amenities like furniture make a park more inviting and stimulate user interaction. It was observed that psychological and physical security in the park, influenced by visibility, visual permeability, and legibility, promote and sustain the presence of people. Aesthetic elements, historical and monumental features draw individuals and encourage social engagement. Recognizing that public spaces are instrumental in building trust and fostering solidarity within the urban community, the functional diversity of the park—including features like the poet's monument, mosque, shrine, museum, and library—plays a significant role in facilitating communication and sociability. Additionally, elements such as monuments, stairs, fountains, forms, materials, and planting are acknowledged as impactful in enhancing the physical quality of public spaces and in motivating people to gather and interact.

For future studies, it is recommended to evaluate the effectiveness of public spaces by their ability to offer accessibility, safety, and a welcoming atmosphere that encourages people to stay longer. Successful spaces prioritize comfort, provide aesthetically pleasing views, and serve as social hubs for users to forge and strengthen relationships. Furthermore, the results suggest a direct correlation between park usage and its central neighborhood location, which simplifies transportation and access; thus, the inclusivity of disabled individuals should be considered in all areas. The park's legibility, achieved through various features such as monuments, religious buildings, diverse furnishings, trees, and walls, contributes positively to its occupancy by offering a sense of security. Design considerations should include seating, edges, and low walls in green spaces and parks to enhance user comfort and encourage longer stays. Protection from the elements through vegetation or structures addresses physical needs and promotes longer visits, thus stimulating interactions. Various amenities like lighting, benches, trash bins, fences, statues, and special lighting should be incorporated to evoke a welcoming atmosphere, reinforce local identity, and attract users. The research indicates that visible and open spaces, as opposed to secluded areas, generate a sense of safety, which is key to attracting people. Creating social interactions through organized activities such as festivals and performances, as well as providing opportunities for people-watching, are recommended. The presence of colors and lighting that spark discovery and curiosity are also significant factors in drawing people. Lastly, considering the diversity of users and their needs, offering a range of uses and activities tailored to different groups—women, men, children, youth, the elderly, etc. - can enhance the park's appeal and visitation rates. The addition of food and beverage services like cafes and restaurants, along with commercial amenities such as stalls and kiosks, can further facilitate social interactions.

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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

Determination of urban regeneration project conflict causes for the Turkish construction industry

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ABSTRACT

Urban regeneration projects come into prominence for various reasons such as the economic development of cities, earthquakes, urban decay, and lack of land for expansion. Due to the complexity of urban regeneration projects and the participation of multiple stakeholders, conflicts, which impede the successful implementation of projects, among stakeholders are unavoidable. There is limited knowledge about urban regeneration conflict causes in the literature. Existing studies have employed case study methodology and determined project-specific conflict causes. According to the literature review analysis, there has not been a single study to establish the priority orders of urban regeneration conflict causes based on risk severity, risk occurrences, and risk impact in urban regeneration projects. Therefore, this study aimed to identify and determine the urban regeneration conflict causes specific to Türkiye. In the article, the authors detected 69 urban regeneration conflict causes after a focus group discussion. The identified conflict causes were analyzed with the fuzzy TOPSIS methodology by considering the conflict causes' impacts on project cost overruns, delays in the project schedule, and project quality. The analysis showed that "Construction abandonment by a construction company" and "Bankruptcy of a construction company" are the most significant conflict causes for urban regeneration projects, respectively. The "Imperfect platform for appeal expression and public participation" conflict cause was found to be the least important conflict specific to Türkiye. Practitioners can use the study results to develop urban regeneration strategies and policy formulation, prevent conflicts, or mitigate tension among stakeholders.

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INTRODUCTION

Capital cities and cities play a crucial role in the economic development and growth of developing countries. Moreover, cities are the driving forces behind innovation. However, cities and their living conditions are under pressure due to rising real estate prices and rents, traffic congestion, land use conflicts, and environmental quality (Knippschild & Zöllter, 2021). In addition, fierce competition among cities is increasing to attract capital, investment, trade, and high-skilled labor (Kuyucu, 2022). In the face of positive economic development requirements, urban

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decline is highly possible and is already occurring due to economic decline, high unemployment, and deteriorating infrastructures. Furthermore, migration from cities to rural or village areas is increasing due to depopulation and aging issues. Vacant buildings are proliferating as the population in cities decreases due to migration from city to village (Jang, 2020; Knippschild & Zöllter, 2021). Therefore, urban regeneration projects are one of the significant parts of the economic transformation of cities.

Moreover, the lack of land for the expansion of cities plays a crucial role in turning their attention to existing building stock lands (Wang & Xiang, 2019). Thus, regeneration projects gain importance not only for the transformation of building stocks but also for enabling efficiency in terms of infrastructure, life quality, and use. From another perspective, urban regeneration projects gain momentum due to the increase in land income corresponding to the compensation mechanism of floor area ratio (Huang, 2023).

Urban regeneration projects aim to foster the change and development of the physical, socio-economic, and cultural aspects (Kim et al., 2023a). In other words, regenerated buildings, cities, or regions help to convert physical and social conditions into a more livable and robust economy (Erbey & Erbas, 2017). Additionally, Yu & Lee (2012) stated that urban regeneration projects involve a series of actions that enhance the economic, physical, social, and environmental conditions in the urban regeneration area. However, urban regeneration is not an effortless process for both residents and the public. It is challenging to address regional issues since urban regeneration projects involve "project planning, land expropriation, housing demolition, and resettlement of owners" (Wang & Xiang, 2019). The study findings indicated that most conflicts in urban regeneration projects are related to "self-immolations, violent demolitions, banner protests, and nail households" (Wang & Xiang, 2019).

In Türkiye, urban regeneration is one of the most complex and problematic project types. Urban regeneration projects have gained momentum after 2004. In that year, the Justice and Development Party participated in developing the first comprehensive law regulating urban regeneration. The government initiated and funded many urban regeneration projects, improving housing quality, infrastructure, living conditions, and economic development. Foreign capital has subsidized the Turkish market (Kuyucu, 2022). In urban regeneration, Istanbul has been a leading force as a city. Although numerous projects began between 2004 and 2019, the projects were either suspended or terminated due to illegality or conflicts (Kuyucu, 2022). However, renewed building projects are handled not only within the scope of urban regeneration but also the rebuilding of individual buildings is extensively used (Kuyucu, 2022). Evin (2021) & Genc (2008) noted that while landowners and contractors agree to conduct small-scale building regenerations (on vacant land and private property), central or local governments undertake large-scale urban regeneration projects involving higher risk and cultural assets. In other words, in Türkiye, the public, cooperative, and private sectors play a joint role in urban regeneration practices (Yolcu, 2021).

According to Genç (2008), urban regeneration projects are extensively carried out in urban conservation areas, illegal and urban areas with a poor quality of life, prestigious new central business districts, exhibition centers, shopping and entertainment centers, international resorts, and golf courses in Türkiye. Moreover, urban regeneration has been implemented in both brownfield areas and historical urban environments in Türkiye (Erbey & Erbas, 2017). In other words, conflicts arise between economic redevelopment and the preservation of historical or cultural heritage, as seen in the case of Türkiye (Kim et al., 2023a). The central and city governments have endeavored to enhance cities to make them more resilient to earthquakes, availability of many depressed areas, fierce competition, and economic challenges (Erbey & Erbas, 2017). Following the Kahramanmaraş earthquakes in 2023, urban regeneration projects have gained increased momentum, and it is expected that urban regeneration will attract more attention going forward.

Urban regeneration projects are distinguished from other construction projects by their complexity and uncertainty (Yu & Lee, 2012). Conflict management is one of the most critical success criteria for the successful completion of urban regeneration projects (Yu & Lee, 2012). In these projects, disputes between developers, property owners, and the government are common. Such disputes pose significant challenges to sustainable urban regeneration efforts as well (Huang, 2023). In this context, Kuyucu (2022) noted that urban regeneration projects involve challenging tasks and risks that lead to conflicts among stakeholders. These conflicts result in delays, cost overruns, and reduced profitability (Yu & Lee, 2012). Additionally, conflicts exert "increased pressure on the government to maintain stability, increased costs to developers, and a reduced willingness among property owners to participate" (Wang & Xiang, 2019). The authors also observed that these types of conflicts have negative social impacts on the public. Therefore, identifying conflicts and facilitating their management before they occur is essential to prevent them. The literature review revealed that there is no comprehensive study identifying conflicts occurring during the execution of urban regeneration projects specific to the Türkiye case. Urban regeneration studies in Türkiye have used case study methodologies to elucidate conflicts during the project execution process. The only study employing a qualitative method, such as a multi-criteria decision-making method, was conducted specifically for South Korea. Consequently,

this study aims to identify the causes of urban regeneration conflict and determine the priority order of urban regeneration conflicts for Türkiye. The analysis of this study revealed that the reasons for urban regeneration conflicts specific to the Türkiye case differ from those in the Hong Kong case.

RESEARCH METHODOLOGY

This research aims to identify conflict causes in urban regeneration projects and determine their ranking orders. To achieve the research objectives, the research flowchart followed in this study is depicted in Figure 1. The authors conducted a literature review to identify the conflict causes that arise in urban regeneration projects. The outcomes of the literature review were utilized in a focus group discussion to finalize the list of conflict causes for urban regeneration projects. Subsequently, the fuzzy TOPSIS method was employed to rank the priority orders of conflict causes specific to the Türkiye case.

Literature Review and Identification of Urban Regeneration Conflict Causes

The term 'old city area' represents a building stock that was constructed between the 1960s and 1980s. These buildings had low construction standards, limited public service facilities, and lacked modern amenities (Huang, 2023). Therefore, numerous urban regeneration projects have been conducted worldwide to increase prosperity and improve living standards. Although there are many studies on urban regeneration in the literature, there are few studies on conflict causes in these projects.

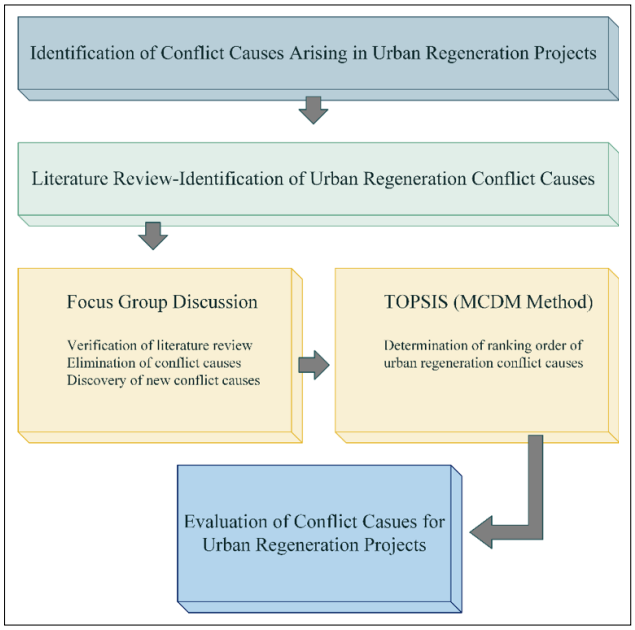

Figure 1. Research Flowchart.

Historical places often feature in urban regeneration projects. Many conflicts occur due to preservation regulations. In this context, Kim et al. (2023a) aimed to discover conflicts in urban regeneration projects conducted in historical districts using a case study methodology and proposed a framework. Another study by Huang (2023) investigated the process and core problems of the urban regeneration project in the old city of Shenzhen, focusing on explaining conflicts during project implementation. This study also combined a case study and literature review to determine urban regeneration problems. Knippschild & Zöllter (2021) developed a decision support tool to prioritize urban regeneration projects or buildings, considering the conflict between cultural heritage preservation and urban regeneration. Yung & Yu (2018) examined the urban regeneration process in Nga Tsin Wai old village through group meetings and interviews to explore challenges and processes.

Additionally, conflicts between stakeholders in urban regeneration projects are a common issue. Kim et al. (2023b) noted that stakeholder conflicts are a significant hindrance in urban regeneration projects in Korea and analyzed perception-related conflicts. Wang & Xiang (2019) investigated stakeholder-related conflicts using the Structural Equation Model for analysis. Urban regeneration projects can also cause tension between stakeholders due to conflicting interests. Jang (2020) looked into the role of universities in urban regeneration and the conflict between university students and residents caused by a decrease in rental income due to these projects. Conflicts between stakeholders often stem from differences in perception. Waite (2020) analyzed the displacement of tenants and their perceptions in urban regeneration projects using a case study methodology. Zhang et al. (2021) studied perception differences among local governments, residents, merchants, and all participants in urban regeneration projects.

Specific to Türkiye, many urban regeneration studies have been performed, but none focus solely on conflicts in urban regeneration. Generally, conflicts are mentioned in case studies. Erbay & Erbaş (2017) analyzed urban regeneration projects in Fener Balat, Türkiye, using technical expertise reports and theses from over ten years. Kuyucu (2022) investigated the reasons behind the unsuccessful urban regeneration projects of the government in Istanbul, Türkiye, attributing the reasons to poorly designed legal/institutional infrastructure and conflictual relations between stakeholders, based on a case study.

In the literature, only one study utilizes the Multi-Criteria Decision Making (MCDM) method, aiming to propose a conflict-risk assessment model for urban regeneration projects (Yu & Lee, 2012). The risk model was created based on the Fuzzy-Failure Mode and Effect Analysis, a well-known risk management concept. The authors identified leading causes of conflicts as the implementation

of urban regeneration projects in developing areas, a variety of construction works, the consideration of cultural and historical values, and the unawareness or misunderstandings of public bodies. However, this study was specific to South Korea, and the results showed many differences in conflict types between South Korea and Türkiye. Additionally, the study by Yu & Lee considered a limited number of conflict causes, and there are differences in institutional and urban regeneration processes between Türkiye and South Korea.

Urban regeneration conflict causes were identified following a literature review. For this review, the Scopus scientific search engine was chosen due to its comprehensiveness and reliability in comparison to the Web of Science search engine. It has been noted in the literature that although Google Scholar contains a more extensive collection of scientific documents, it is prone to errors owing to indexing issues. Hence, Google Scholar is not favored over its two competitors (Franceschini et al., 2016).

The keywords "urban regeneration," "conflict," "urban regeneration," and "dispute" were utilized for the literature review in the Scopus search engine. According to the analysis results, studies related to "dispute" and "urban regeneration" were not found to be of interest. However, 45 studies related to the keywords "urban regeneration" and "conflict" were discovered. Out of these, 16 studies were selected for an in-depth analysis to identify urban regeneration conflict causes. A total of 97 urban regeneration conflict causes were initially identified. These identified conflict causes were then consolidated and refined following a focus group discussion.

Focus Group Discussion Technique for the Verification of Identified Urban Regeneration Conflict Causes

The Focus Group Discussion (FGD) technique was employed to validate the urban regeneration conflict causes identified from the literature review. FGD is a widely-used technique for rapid evaluation. It allows for structured, semi-structured, and unstructured forms of data collection. Selected or purposively chosen experts discuss the key themes pinpointed by researchers. FGD is a qualitative method that often yields more comprehensible data compared to quantitative techniques (Escalada & Heong, 2007).

Originating from the field of sociology, conflicts between stakeholders in urban regeneration projects are closely linked with social behaviors. The number of FGD participants varies according to the study's scope and the availability of experts. As found in the literature review, a range of expert group sizes can be effective: two experts (dyad), three experts (triad), four to six experts (mini-group), seven to ten experts (small group), or eleven to twenty experts (super-group). However, to gather valuable insights, it is crucial that the invited experts have diverse backgrounds and experiences (Yu & Leung, 2015). In this context, the profiles of the invited experts are summarized in Table 1. Experts were selected from public institutions, universities, and the private sector to ensure a comprehensive evaluation.

The FGD aims to foster an environment where experts can share their perceptions, feelings, and experiences. To avoid moderator bias and the dominance of certain voices during FGD sessions, moderators must facilitate discussions that yield valuable knowledge (Yu & Leung, 2015). To this end, moderators first outlined the study's objectives to the experts. Then, they presented the urban regeneration conflict causes for evaluation, using a 1-5 Likert scale where 1 signifies "no importance" and 5 indicates "very important." Experts were also asked if they wished to introduce new conflict causes. However, rather than adding new causes, experts chose to amalgamate some of them. Conflict causes with an average rating below 3 were subsequently discarded.

Following the FGD analysis, 20 urban regeneration conflict causes that scored under 3 were removed. The eliminated conflict causes include "Conflict between economic redevelopment and historical or cultural preservation, Increase in additional charges of cooperative (Project developer) members, Delay in general meeting for the permit of management disposition plan, Controversy of permission process for management disposition plan, Impact of urban regeneration projects on views, Inadequate protection of historical heritage, Imperfect construction of public facilities, Controversy of permission process for cooperative/commission establishment, Claim of cooperative regarding legal regulation relaxation (such as business regulation so on), Opposition of other local/

Table 1. The expert profiles in the FGD session

Expert ID	Personal profession	Institution	Education	Years of experience
E1	Architect	Municipality	Architect (MSc degree)	CI: 10 years. UR: 10 years.
E2	Project manager	Private sector	Civil Engineer (MSc degree)	CI: 15 years. UR: 8 years.
E3	Project manager	Private sector	Civil Engineer (MSc degree)	CI: 20 years. UR: 12 years.
E4	Project manager	Private sector	Civil Engineer (MSc degree)	CI: 14 years. UR: 8 years.
E5	Academician	University	Architect (Ph.D. degree)	CI: 15 years. UR: Not applicable.
E6	Civil Engineer	Municipality	Civil Engineer	CI: 5 years. UR: 5 years.

CI: Construction Industry; UR: Urban Regeneration.

district government regarding the designation of urban regeneration district, Claim regarding legal regulation relaxation (related to construction), Lack of preferential policies (special consideration apart from the rest of society), Irregular democratic procedures, Non-standard procedure of administrative operation, Transparency issues, Volume rate changes dramatically, Lack of timely publication of information, Imperfect emergency mechanism, Large-scale demolition (civil society protests), and Disintegration of owners' social space and culture." After this process, 69 urban regeneration conflict causes remained as a result of the analysis and merging. The final list of urban regeneration conflict causes is presented in Table 2.

Determination of Ranking Order of Urban Regeneration Conflict Causes—Fuzzy TOPSIS

Another objective of this study is to determine the ranking order of urban regeneration conflict causes. In the literature, conflict causes are typically identified through qualitative studies, such as case studies, which are specific to each case. Consequently, generalizing conflicts to develop solutions for the most probable conflicts during urban regeneration projects is challenging. This study also aims to bridge this gap using quantitative techniques such as Multi-Criteria Decision Making (MCDM) methods. Bridging the gap will aid in predicting the most probable challenges in urban regeneration projects.

MCDM methods are applicable in various domains, including the economy, social sciences, and engineering. In an MCDM approach, the research problem consists of multiple alternatives and criteria that may be in conflict. The ranking order of alternatives is determined based on the weight of each criterion (Nădăban et al., 2016). Decision-makers, while evaluating the problem, face constraints and ambiguities. To address these issues, fuzzy set theory was introduced, accommodating constraints and incomplete or uncertain information. Furthermore, decision-makers typically employ precise numbers in non-fuzzy approaches. In this context, linguistic variables represented by fuzzy numbers can overcome the disadvantages of non-fuzzy approaches, such as definite meaning and incomplete or uncertain knowledge (Nădăban et al., 2016).

Fuzzy set theory has been integrated with various MCDM methods in the literature. One such method is the fuzzy Technique for Order Preference by Similarity to Ideal Solution (TOPSIS). The fuzzy TOPSIS method possesses several advantages: there are no limitations on the number of criteria and options, it can accommodate both negative and positive criteria, it allows for the simultaneous consideration of qualitative and quantitative criteria, and it is an easy and faster problem-solving method (Maghsoodi & Khalilzadeh, 2018). The fuzzy TOPSIS method operates on the principle of "minimizing the distance from the ideal solution and maximizing the distance from the negative ideal solution" (Maghsoodi & Khalilzadeh, 2018). A group of seven or more experts can conduct the fuzzy TOPSIS method (Taylan et al., 2014). Table 3 outlines the expert profiles involved in the fuzzy TOPSIS analysis.

The TOPSIS technique was first introduced by Hwang and Yoon in 1981. This method has since been enhanced through the integration of fuzzy set theory. The steps for implementing the fuzzy TOPSIS methodology are outlined below, as summarized by Maghsoodi and Khalilzadeh (2018):

Step 1: The first step involves determining the weights of the evaluation criteria before analyzing the ranks of alternatives. Various methods are available in the literature to ascertain the weights of criteria, such as the Analytic Hierarchy Process (AHP) methodology, the TOPSIS method, or other Multi-Criteria Decision Making (MCDM) methods.

Step 2: A fuzzy decision matrix is constructed using the fuzzy triangular numbers corresponding to the verbal values provided in Table 4.

Each element of the created matrix given in Eq. 12 corresponds to (x_ij)=(l_ij,m_ij,u_ij). As stated above, these values are taken from Table 4.

$$\widetilde{D} = \begin{bmatrix} \widetilde{x_{11}} & \cdots & \widetilde{x_{1n}} \\ \vdots & \ddots & \vdots \\ \widetilde{x_{m1}} & \cdots & \widetilde{x_{mm}} \end{bmatrix}$$

Step 3: Normalization of the fuzzy decision matrix is created by using Eq. 2-3.

$$r_{ij} = \frac{l_{ij}}{u_j^*}, \frac{m_{ij}}{u_j^*}, \frac{u_{ij}}{u_j^*} \text{ and } u_j^* = \max_i u_{ij}$$

$$r_{ij} = \frac{l_j^-}{u_{ij}}, \frac{l_j^-}{m_{ij}}, \frac{l_j^-}{l_{ij}} \text{ and } l_j^- = \max_i l_{ij}$$

Step 4: Normalized decision matrix is multiplied with weights of criteria obtained in step 1.

$$v_{ij} = w_j r_{ij}$$

Where w_j represents the weights of the j^{th} criterion.

Step 5: The positive ideal and negative ideal solutions are determined by using Eq. 5 and 6.

$$A^* = \{v_1^*, \cdots, v_n^*\}$$

$$A^- = \{v_1^-, \cdots, v_n^-\}$$

Step 6: The negative and positive distance values are calculated by using Eq. 7-8, respectively.

$$d_i^+ = \sum_{j=1}^{n} d(v_{ij}, v_{ij}^+)$$

$$d_i^- = \sum_{j=1}^{n} d(v_{ij}, v_{ij}^-)$$

Step 7: Defuzzification of distance values is performed with Eq. 9.

$$d(v_1, v_2) = \sqrt{\frac{1}{3}[(l_1 - l_1)^2 + (m_1 - m_2)^{jj\ n\ 2} + (u_1 - u_2)^2]}$$

Step 8: The relative closeness to the ideal solution is calculated by using Eq. 10;

$$CCi = \frac{d_i^-}{d_i^+ + d_i^-}$$

Table 2. Urban Regeneration Conflict Causes

Conflict Causes	References
Disagreement between the cooperative and constructor about the general sale price	Yu and Lee (2012)
Bankruptcy of construction company	Yu and Lee (2012)
Deliberate sales delay by the construction company	Yu and Lee (2012)
Increase in construction unit costs	Yu and Lee (2012)
Disagreement about indemnification for tenants and measures for an emigration plan	Yu and Lee (2012)
Owners' income reduction	Wang and Xiang (2019)
Owners' living costs increased dramatically	Wang and Xiang (2019)
Excessive extra cost/Rising transaction costs during the urban regeneration project execution	Wang and Xiang (2019), Kuyucu (2022)
Unreasonable financing scheme	Wang and Xiang (2019)
Uncertain future returns of urban regeneration projects	Kuyucu (2022)
Environmental contamination (Claim regarding generated noise and dirt during construction)	Kim et al. (2023a), Yu and Lee (2012)
Owners' employment difficulties	Wang and Xiang (2019)
Forced evictions/Nail households' problem	Kim et al. (2023a), Can (2020), Huang (2023)
Forced demolition	Can (2020), Huang (2023)
Violence to coerce them to sign the contract	Can (2020), Huang (2023)
Die of old tenants	Huang (2023)
The Claim of Project developers regarding legal regulation relaxation (such as a business regulation)	Yu and Lee (2012)
Lawsuits of Sale Claim/Unreasonable compensation standard/ fair treatment in housing pricing	Yu and Lee (2012), Wang and Xiang (2019), Can (2020), Yung and Yu (2018)
Disagreement on transferring free-based facilities	Yu and Lee (2012)
Delay in purchasing national/public land	Yu and Lee (2012)
Controversy of permission process for project implementation plan	Yu and Lee (2012)
Lawsuit about disposition method (sales or adjusted amounts)	Yu and Lee (2012)
Lawsuits of trust registration	Yu and Lee (2012)
Tenants' emigration refusal/ Claim regarding legal measures for Tenants' emigration	Yu and Lee (2012)
Unable to continue the performance of the contract	Wang and Xiang (2019)
Obvious loopholes in the contract	Wang and Xiang (2019)
Illegal housing stock	Kocabas (2010), Waite (2020)
Strong policy change	Huang (2023)
Conflicts due to planning scheme (unclear change and improvement)	Huang (2023)
The opposition of landowners to the designation of urban regeneration district	Yu and Lee (2012), Kuyucu (2022)
The claim of landowners to the designation of urban regeneration district	Yu and Lee (2012)
Imperfect laws and regulations (ill-designed legal/institutional infrastructure) / Inconsistency with policy planning, unavailability of policy, and unavailability of guideline	Wang and Xiang (2019), Kuyucu (2022), Can (2020), Erbey and Erbas (2017), Yung and Yu (2018), Islam and Esa Abrar Khan (2017)
Political pressures	Ball and Maginn (2005)
Institutional clashes	Kuyucu (2022), Erbey and Erbas (2017), Yung and Yu (2018)
Excessive requirements	Huang (2023)
A claim regarding construction defects	Yu and Lee (2012)
Construction abandonment of the construction company	Yu and Lee (2012)

Table 2. Urban Regeneration Conflict Causes (Cont.)

Conflict Causes	References
Immature project management / Uncertainty of management subject	Wang and Xiang (2019)
Imperfect accountability mechanism	Wang and Xiang (2019)
Frequent adjustment of planning	Wang and Xiang (2019)
Violation of approval procedures	Wang and Xiang (2019)
Serious delays in demolition progress	Wang and Xiang (2019)
Unreasonable implementation plan	Wang and Xiang (2019)
Insufficient competence of managers	Wang and Xiang (2019)
Plan ambiguousness / Conflicts with spatial plans	Kuyucu (2022), Erbey and Erbas (2017)
Consideration of a sense of community	Kim et al. (2023a), Waite (2020)
Resettlement is not in place (including tenants)	Wang and Xiang (2019), Huang (2023)
The imperfect platform of appeal expression and public participation	Wang and Xiang (2019), Waite (2020)
Deterioration of public order	Wang and Xiang (2019)
Reduction of resources related to owners' education and healthcare	Wang and Xiang (2019)
Increase in migrant population	Wang and Xiang (2019)
Urban regeneration project acceptance by the community	Jang (2020)
Failure to improve living conditions in regenerated projects	Yung and Yu (2018)
Stakeholder collaborations, communication, and coordination issues conflicts between stakeholders	Kim et al. (2023a), Wang and Xiang (2019), Kuyucu (2022), Huang (2023), Waite (2020), Kim et al. (2023b), Zhang et al. (2021)
The interest pursuit (incompatible interests)	Huang (2023), Wang and Xiang (2019), Kuyucu (2022), Yung and Yu (2018)
Internal conflicts and contradictions among owners	Huang (2023)
Disorderly establishment of the tentative committee	Yu and Lee (2012)
Different opinions during the selection process of a contractor	Yu and Lee (2012)
Leadership disputes between members and representatives in the committee	Yu and Lee (2012)
Disagreement among property owners regarding project/ committee establishment/cooperative establishment	Yu and Lee (2012)
Controversy regarding legal validity during the selection process of subcontractor	Yu and Lee (2012)
Disagreement among cooperative/commission members regarding the project implementation plan	Yu and Lee (2012)
Delay in the general meeting for permit of the project implementation plan	Yu and Lee (2012)
Disagreement among members of the cooperative regarding equity ratio after a real estate appraisal	Yu and Lee (2012)
Insufficient capacity of developers	Wang and Xiang (2019)
Owners' loss of housing	Wang and Xiang (2019)
Participation of many NGOs	Can (2020), Waite (2020)
Excessive power of developers on owners	Yung and Yu (2018)
Relocation of settlers	Waite (2020), Islam and Esa Abrar Khan (2017)

According to the explanation of the fuzzy TOPSIS steps, data were analyzed. The analysis results are summarized in Table 5.

In the discussion section, the four most significant urban regeneration conflict causes will be analyzed.

DISCUSSION

Urban regeneration projects are designed to revitalize brownfields and areas that have deteriorated. These projects encompass a range of activities aimed at enhancing

Table 3. The expert profiles participated in the fuzzy TOPSIS analysis

Expert ID	Personal profession	Institution	Education	Years of experience
E1	Architect	Municipality	Architect (MSc degree)	CI: 10 years. UR: 8 years.
E2	Project Manager	Private sector	Civil Engineer (MSc degree)	CI: 15 years. UR: 8 years.
E3	Project Manager	Private sector	Civil Engineer (Ph.D. degree)	CI: 20 years. UR: 12 years.
E4	Project Manager	Private sector	Civil Engineer (MSc degree)	CI: 14 years. UR: 8 years.
E5	Academician	University	Architect (Ph.D. degree)	CI: 15 years. UR: Not applicable.
E6	Civil Engineer	Municipality	Civil Engineer	CI: 5 years. UR: 5 years.
E7	Project Manager	Private sector	Civil Engineer	CI: 8 years. UR: 4 years.
E8	Planning Engineer	Private sector	Civil Engineer (MSc degree)	CI: 10 years. UR: 6 years.
E9	Civil Engineer	Municipality	Civil Engineer	CI: 7 years. UR: 4 years.
E10	Project Manager	Private sector	Architect (MSc degree)	CI: 9 years. UR: 4 years.
E11	Owner	Private sector	Civil Engineer	CI: 16 years. UR: 10 years.
E12	Project Manager	Private sector	Civil Engineer (MSc degree)	CI: 12 years. UR: 7 years.

CI: Construction Industry, UR: Urban Regeneration.

Table 4. "The Membership Functions of Fuzzy Triangular Numbers" (Maghsoodi and Khalilzadeh 2018)

Verbal Value	Triangular fuzzy number of the weight variable	Triangular fuzzy number of priorities
Too low	(0, 0.1, 0.3)	(0, 1, 3)
Low	(0.1, 0.3, 0.5)	(1, 3, 5)
Average	(0.3, 0.5, 0.7)	(3, 5, 7)
Important	(0.5, 0.7, 0.9)	(5, 7, 9)
Very important	(0.7, 0.9, 1)	(7, 9, 10)

the physical, socio-economic, and cultural dimensions, involving multiple stakeholders. However, conflicting interests among these stakeholders, financial constraints, land scarcity, complex and protracted processes, and various other challenges often give rise to conflicts. These conflicts may result in project suspension or termination, as well as common issues like delays and cost overruns. Hence, this study focuses on identifying the causes of conflicts in urban regeneration and establishing their priority orders specific to Türkiye.

The fuzzy TOPSIS analysis revealed that "Construction abandonment by the construction company" and "Bankruptcy of the construction company" are the most influential and frequent causes of conflict in urban regeneration, respectively. In Türkiye, since 2019, high interest rates and a decline in house sales have signaled the financial crisis's effects on the construction industry. The Turkish government has tried to counter these challenges by reducing VAT, promoting housing mobilization, and offering low-interest loans for housing through public banks (Yeşilbağ, 2020). Nevertheless, these measures have not led to price stability. Furthermore, the rise in construction material costs has had a direct impact on residential housing prices (Çetin C, 2021). Consequently, construction companies face significant pressure to sustain or complete projects. Urban regeneration projects are particularly complex, increasing the likelihood of construction abandonment. Although there are guaranteed rates applied to urban regeneration projects, these rates should be reevaluated and potentially increased to address this issue. Additionally, construction project abandonment is prevalent in the construction industry, which is considered one of the most fraud-prone industries globally. This is often attributed to unethical practices such as overpricing, bid cutting, late or insufficient payments, unfair treatment during tender or final account negotiations, exaggeration of capacity, and falsification of experience and qualifications (Adnan et al., 2012; Kuoribo et al., 2023). Therefore, a meticulous tendering process is crucial to mitigate ethical issues and prevent the abandonment of construction projects.

Furthermore, the unethical practices mentioned earlier significantly contribute to the bankruptcy of construction companies. Companies that go bankrupt typically exhibit a high debt ratio, lower labor and asset productivity, negative profitability, and diminished cash liquidity (Spicka, 2013).

Table 5. Fuzzy TOPSIS Analysis Results

Conflict Causes	Fuzzy TOPSIS Results	General Rank
Disagreement between the cooperative and constructor about the general sale price	0,478	15
Bankruptcy of construction company	0,538	2
Deliberate sales delay by the construction company	0,444	30
Increase in construction unit costs	0,512	3
Disagreement about indemnification for tenants and measures for an emigration plan	0,451	28
Owners' income reduction	0,433	37
Owners' living costs increased dramatically	0,438	34
Excessive extra cost / Rising transaction costs during the urban regeneration project execution	0,473	19
Unreasonable financing scheme	0,488	10
Uncertain future returns of urban regeneration projects	0,445	29
Environmental contamination (Claim regarding generated noise and dirt during construction)	0,377	59
Owners' employment difficulties	0,399	50
Forced evictions/Nail household problems	0,457	24
Forced demolition	0,464	22
Violence to coerce them to sign the contract	0,426	38
Die of old tenants	0,384	57
The claim of Project developers regarding legal regulation relaxation (such as a business regulation)	0,386	54
Lawsuits of Sale Claim/Unreasonable compensation standard/ fair treatment in housing pricing	0,425	39
Disagreement about the transfer of free-based facilities	0,405	46
Delay in purchasing national/public land	0,451	27
Controversy of permission process for project implementation plan	0,477	17
Lawsuit about disposition method (sales or adjusted amounts)	0,421	43
Lawsuits of trust registration	0,401	49
Tenants' emigration refusal/ Claim regarding legal measures for Tenants' emigration	0,438	35
Unable to continue the performance of the contract	0,496	7
Obvious loopholes in the contract	0,485	12
Illegal housing stock	0,443	31
Strong policy change	0,424	41
Conflicts due to planning scheme (unclear change and improvement)	0,437	36
The opposition of landowners to the designation of urban regeneration district	0,440	32
The claim of landowners to the designation of urban regeneration district	0,407	45
Imperfect laws and regulations (ill-designed legal/institutional infrastructure) / Inconsistency with policy planning, unavailability of policy and guideline	0,486	11
Political pressures	0,473	18
Institutional clashes	0,472	20
Excessive requirements	0,455	25
The claim regarding the construction defects	0,481	13
Construction abandonment of the construction company	0,545	1
Immature project management / Uncertainty of management subject	0,494	8
Imperfect accountability mechanism	0,384	56

Table 5. Fuzzy TOPSIS Analysis Results (Cont.)

Conflict Causes	Fuzzy TOPSIS Results	General Rank
Frequent adjustment of planning	0,478	14
Violation of approval procedures	0,477	16
Serious delays in demolition progress	0,508	4
Unreasonable implementation plan	0,502	5
Insufficient competence of managers	0,497	6
Plan ambiguousness / Conflicts with spatial plans	0,494	9
Consideration of sense of a community	0,365	62
Resettlement is not in place (including tenants)	0,352	66
The Imperfect platform of appeal expression and public participation	0,308	69
Deterioration of public order	0,361	63
Reduction of resources related to owners' education and healthcare	0,386	55
Increase in migrant population	0,345	67
Urban regeneration project acceptance by the community	0,374	60
Failure to improve living conditions in regenerated projects	0,342	68
Stakeholder collaborations, communication, and coordination issues conflicts between stakeholders	0,463	23
The interest pursuit (incompatible interests)	0,440	33
Internal conflicts and contradictions among owners	0,452	26
Disorderly establishment of a tentative committee	0,388	53
Different opinions during the selection process of a contractor	0,469	21
Leadership disputes between members and representatives in the committee	0,372	61
Disagreement among property owners regarding project/ committee establishment/cooperative establishment	0,392	51
Controversy regarding legal validity during the selection process of subcontractor	0,404	47
Disagreement among cooperative/commission members regarding the project implementation plan	0,403	48
Delay in the general meeting for permit of the project implementation plan	0,425	40
Disagreement among members of the cooperative regarding equity ratio after a real estate appraisal	0,415	44
Insufficient capacity of developers	0,422	42
Owners' loss of housing	0,357	64
Participation of many NGOs	0,390	52
Excessive power of developers on owners	0,352	65
Relocation of settlers	0,381	58

During procurement, falsification of experience and qualifications, as well as overstated capacities, can lead to reduced labor productivity, profitability, and liquidity, making bankruptcy almost inevitable for some construction companies.

"Increase in construction unit costs" emerged as the third most critical conflict cause in urban regeneration projects. Since a substantial portion of resources in urban regeneration projects is directed towards construction, the investment in construction is considered a risk factor. The intricate nature of urban regeneration projects, coupled with conflicts, makes cost increases an expected outcome, as these projects typically span longer durations than new constructions. Apollo and Miszewska-Urbańska (2015) observed an average cost increase of 15% in the refurbishment of 29 residential buildings, attributed to unexpected additional works such as stabilizing walls, foundation reinforcement, and earthworks. They also found that these cost hikes often stem from contractors who submit the lowest bids, leading to unforeseen issues during the planning stage.

"Serious delays in demolition progress" is the fourth most significant cause of conflict in urban regeneration. Delays in demolition pose a significant barrier to construction activities and can severely affect urban regeneration projects through cost escalations, safety hazards, increased crime rates, and community dissatisfaction. Wang and Xiang (2019) noted that developers might delay building demolitions to minimize resettlement compensation, causing conflicts and dissatisfaction among developers and property owners.

The fuzzy TOPSIS analysis also indicated that project and economy-related conflicts are the most likely causes of conflict in urban regeneration projects in Türkiye. Furthermore, the findings suggest that "Imperfect platform of appeal expression and public participation" and "Failure to improve living conditions in regenerated projects" are the least influential causes of conflict. This implies that social-based conflicts are less prevalent than other types. This could be due to the predominance of concerns related to feasibility and economic viability in urban regeneration projects.

CONCLUSION

Urban regeneration projects are increasingly significant in Türkiye, driven by urban decay and earthquakes, and they are drawing more investors to spur economic development. Yet, such projects entail intricate and extensive interactions among stakeholders, where conflicts stemming from their differing interests are a common occurrence. Prior research has established the priority orders of urban conflict causes with a focus on South Korea, particularly from the perspective of risk management using Failure Mode and Effects Analysis (FMEA). This study identified 34 conflict causes. Research specifically on Türkiye has been limited to case studies, with conflict causes identified on a per-case basis. Thus, this study set out to identify urban regeneration conflict causes and establish their priority orders.

A three-phase approach was implemented to meet the study's objectives. The initial phase involved a literature review that uncovered 63 new conflict causes. The second phase saw experts evaluate 97 conflict causes, leading to the validation of 69 by the experts. The final phase involved analyzing the 69 confirmed conflict causes using the fuzzy TOPSIS method, incorporating evaluations from 12 experts. The analysis concluded that "Construction abandonment of construction company," "Bankruptcy of construction company," and "Increase in construction unit costs" rank as the most significant conflict causes in Türkiye, with economic and project-related conflicts being the most prevalent.

The findings of this study are valuable for both practical and academic pursuits. Practically, developers of urban regeneration projects can craft effective strategies and plans to address these conflict causes, aiming to prevent or reduce stakeholder tension. Academically, the study contributes to a field where research on conflict causes in urban regeneration is limited, enriching the knowledge base and providing insights into the causes of conflict in Turkish urban regeneration projects. The analysis results can also inform policy-making. Future research will examine dispute factors in urban regeneration more closely and develop resolutions.

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Article

Climate-responsive daylight system design for primary schools in Türkiye

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ABSTRACT

Passive systems are currently the preferred method in architectural design for enhancing energy efficiency in buildings. Utilizing daylight as the primary light source in buildings meets the visual, psychological, and physiological needs of users while avoiding the negative effects of direct sunlight. Therefore, passive systems are widely favored in architectural design to promote energy efficiency. It is essential to use natural lighting as a passive system to reduce a building's energy needs for lighting. Additionally, it creates an appealing visual atmosphere while maintaining comfort requirements.

The daylight criteria for providing sufficient daylight in educational buildings were evaluated in this study related to the TS EN 17037+A1 standard. The study aimed to establish an optimal approach for determining direction, obstruction, and façade design parameters that will ensure sufficient daylight in primary school classrooms in different climatic regions of Türkiye. The study's main focus was to develop a framework for classroom design in educational buildings that takes into account the provision of adequate daylight while avoiding discomfort glare.

"The Minimum Design Guide for Educational Buildings" is a guidebook for constructing educational buildings in Türkiye. However, it lacks detailed specifications for dynamic variables of the environment and interior components. To address this issue, the guide should be improved according to the latest standard of TS-EN 17037-A1, which provides guidelines for daylight design in buildings.

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INTRODUCTION

From the early beginning of building design in history, the aim of utilizing daylight has played an active role in settlement decisions, building shaping, and facade design. In today's world, it has become an accepted fact that conscious consumption is essential due to the depletion of energy resources. Therefore, today's architecture prioritizes the efficient use of daylight and reducing lighting energy consumption as one of its main purposes (Mardaljevic, Heschong, & Lee, 2009).

For an efficient lighting application, in addition to the required illuminance level, it is essential to meet the qualitative needs (Kocagil, 2022), (Türk Standardları Enstitüsü, 2021). Additionally, adequate daylight provision is the primary objective of natural lighting systems.. Achieving the proper distribution of daylight is crucial to fulfill the user's visual performance as well as their psychological and physiological needs, while avoiding the negative consequences of direct sunlight (Illuminating Engineering Society, 2013). Architectural design is

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significantly influenced by climatic conditions, from the urban to the building scale. Climate-responsive design is an increasingly important consideration in today's architecture (Littlefair, 2011). Presently, passive systems are predominantly favored in the architectural design of buildings to enhance energy efficiency. One of the most prominent passive systems employed is daylighting, which is the primary lighting system for all buildings with daylight openings. Utilizing natural lighting as a passive system is crucial in reducing the building's energy requirements for lighting and creating a desirable visual environment while ensuring comfort requirements (Illuminating Engineering Society, 2013). Furthermore, learning spaces where students spend much of their early life play a crucial role in their cognitive, physiological, and social development (Duyan & Ünver, 2022). Additionally, access to natural daylight benefits human well-being, both physiologically and psychologically, as it positively impacts human health and environmental conditions (Turan, Chegut, Fink, & Reinhart, 2020).

It is highlighted in the TS-EN 17037-A1 standard that giving priority to natural lighting as a passive system is crucial for reducing the energy needed for building lighting, establishing an inviting visual atmosphere, and ensuring comfort. Spaces should be illuminated by daylight for a considerable part of the annual daylight hours (Türk Standartları Enstitüsü, 2022).

The 'TS-EN 17037-A1: Daylight in Buildings' standard, approved by CEN on 29 July 2018 and last updated on 2 March 2022, is a comprehensive and up-to-date guide for evaluating daylight in indoor areas. The standard takes into account various environmental and climatic factors that affect daylight performance. It outlines four main criteria for assessing daylight in interior spaces: 'daylight provision, view out, exposure to sunlight, and protection from glare' (Türk Standartları Enstitüsü, 2022). Additionally, the standard recommends a classification for daylight assessments in three levels: 'minimum, medium, and high'. Moreover, the recommendations for these assessments are mentioned in Table 1.

In this study, the criteria for providing daylight in educational buildings were examined in accordance with the TS-EN 17037-A1 standard. The main purpose was to develop an approach to determine the optimum values of direction, obstruction, and façade design parameters for different climatic regions of Türkiye in the context of providing sufficient daylight in the classroom design of primary school buildings.

Türkiye is located in a wide geography that has a variety of five different climate zones. This article focuses on the optimal conditions for two of these climate zones, with representative provinces of Istanbul and Antalya. Variable scenarios of direction, façade design, and obstruction were assessed according to the criteria of daylight provision and protection from glare recommended in TS-EN 17037-A1. The aim is to create a comprehensive design proposal

Table 1. Assessment of Daylight Performance for indoor areas as defined in TS-EN 17037-A1

Daylight Assessments			**Recommended Levels**		
			Minimum	**Medium**	**High**
	% area	**% Daylight Hours**			
Daylight Provision					
Target Illuminance (lx)	50%	50%	300lx	500lx	750lx
Minimum Target Illuminance (lx)	95%	50%	100lx	300lx	500lx
View Out					
Horizontal sight angle			≥14°	≥28°	≥54°
Outside distance of the view			≥6 m	≥20 m	≥50 m
Number of layers to be seen from at least 75% of utilized area			1 (Landscape)	2 layer	All layers
Exposure to sunlight					
Recommended number of hours (h) for a given reference day (between February 1st - March 21st) that a space should receive sunlight			1.5 h	3 h	4 h
Protection from glare					
DGP-value, that is not exceeded in more than 5 % of the occupation time			0,45	0,4	0,35

that takes into account the climatic conditions and design variables for educational buildings to be built in Türkiye, which will be used from the early beginning of the design process.

METHOD

The classroom model created for this purpose was designed according to the criteria specified for primary school classrooms in the 'Educational Buildings Design Standards Guide', which was prepared by the Ministry of National Education (MEB) for educational buildings in 2013 and revised in 2015 (MEB, 2015).

In order to make an accurate comparison, it is necessary to determine variable and invariable assumptions for analysis. The steps of the method improved within the scope of the study are outlined in Figure 1.

The first step involves making preliminary decisions by identifying design variables and constants. After determining these parameters, a number of 200 classroom models are created and evaluated based on the daylight criteria of daylight provision and protection from glare as recommended in TS-EN 17037-A1. Finally, the optimal combinations of climatic conditions, direction, obstruction, and façade design are determined in order to contribute to the design guide for educational buildings to be built in Türkiye.

Preliminary Design Decisions

The generated model to be analyzed is a primary school classroom designed with optimum dimensions based on the criteria specified for primary school classrooms in the 'Minimum Design Standards Guide' published by the Ministry of National Education (MEB, 2015), which was published in 2013 for educational buildings and revised in 2015.

Based on the specifications outlined in the guide, the classroom model that has been generated possesses a capacity of 30 pupils. The classroom design is intended to provide each student with a minimum of 1.60 square meters of usage area. Additionally, in the 'mechanical installation standards' section of the guide, the internal air quality standard states that the breathable air volume per student in primary education buildings is at least 5m^3 (MEB, 2015). Accordingly, the estimated amount of breathable air per student in a classroom with a total volume of 201.6 m^3 is 6.72 m^3, which exceeds the requirement.

Dimensions of the classroom are 7m x 8m with a height of 3.6 meters. The window is positioned on one side and furnishing of the classroom generated in order to allow daylight to reach the students from the left side. According to the guidelines outlined in the manual, the window area of the generated classroom model has been designed with the recommendations with a minimum transparency ratio (window area/wall area) of 50%. However, alternative design scenarios need to be considered since the current

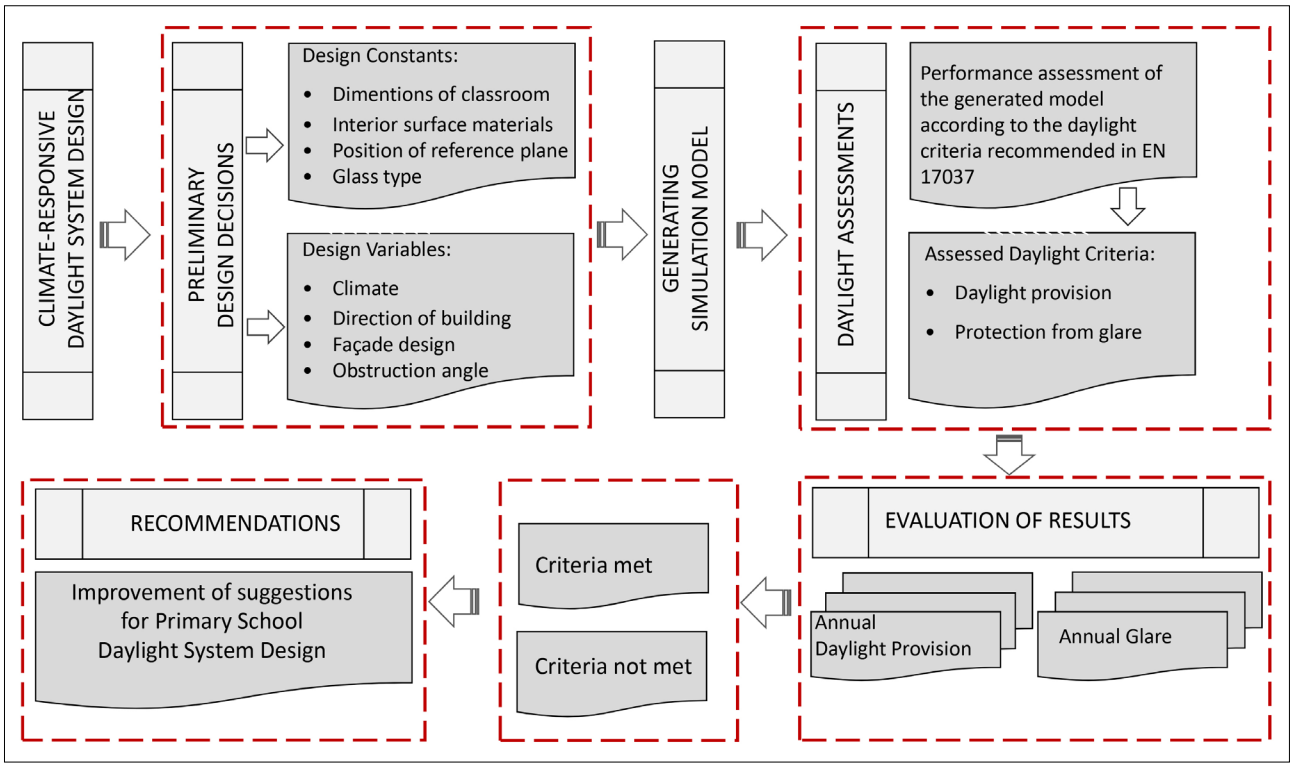


Figure 1. Method of the Study.

guidelines do not provide specific transparency ratios that would be responsive to the variables. Transparency ratios of 40% and 30% were generated to account for different requirements in current calculation methods, which consider variables such as direction, climate characteristics, and obstacle conditions. In addition, a total of 5 façade scenarios were created with attached and separate layout alternatives for 30% and 40% transparency ratios. The detailed window specifications of the classroom model with alternative façade designs appear in Figure 2.

The values of constant design parameters are listed below:

Constant Parameters of Indoor Workspace:

- Number of users of the classroom: 30 pupils
- Dimensions of classroom: 8m length, 7m width, 3.6 m height
- Window location: One side-long wall
- Glazing: 5.8mm - 12.7mm - 5.7mm (outside to inside)
- U value of glazing: 1.81 W/m²K
- Visible transmittance value of glazing (TVIS): 0.804
- Reflectance of interior surfaces: ceiling:0.7, interior walls:0.51, floor: 0.23
- Reference plane: 0.75m from the floor, 0.50m offset from walls

Constant Factors of Exterior Workspace:

- Reflectance of exterior surfaces: exterior walls:0.29, exterior ground: 0.21

Variable Parameters:

- Location: İstanbul (temperate humid climate), Antalya (hot humid climate zone)
- Direction of window opening: South, North, East, West
- Transparency ratio: 50%, 40%, 30%
- Window orientation: attached, separated
- Obstruction angle: 0°, 20°, 30°, 40°, 50°

A total of 200 simulations were conducted to explore alternative scenarios for variables such as climate, direction, façade design, and obstruction angle.

Because the study aims to produce a guide that takes into consideration different climatic conditions, 2 different cities are chosen for daylight performance assessment. For this purpose, the optimum conditions for Istanbul (temperate humid climate), located on a latitude of 41°00'49"N and longitude of 28°57'18"E; and Antalya (hot humid climate), on a latitude of 36°53'15"N and longitude of 30°42'27"E provinces, are compared. It is aimed to create a design proposal for educational buildings to be built or renovated in Türkiye.

The classroom model was developed with consideration of various orientations: north, south, east, and west. Moreover, 5 different façade designs, which include alternative transparency ratios of 50%, 40%, and 30% in addition to separated and attached arrangements of 40% and 30% alternatives, were considered. It is assumed that the

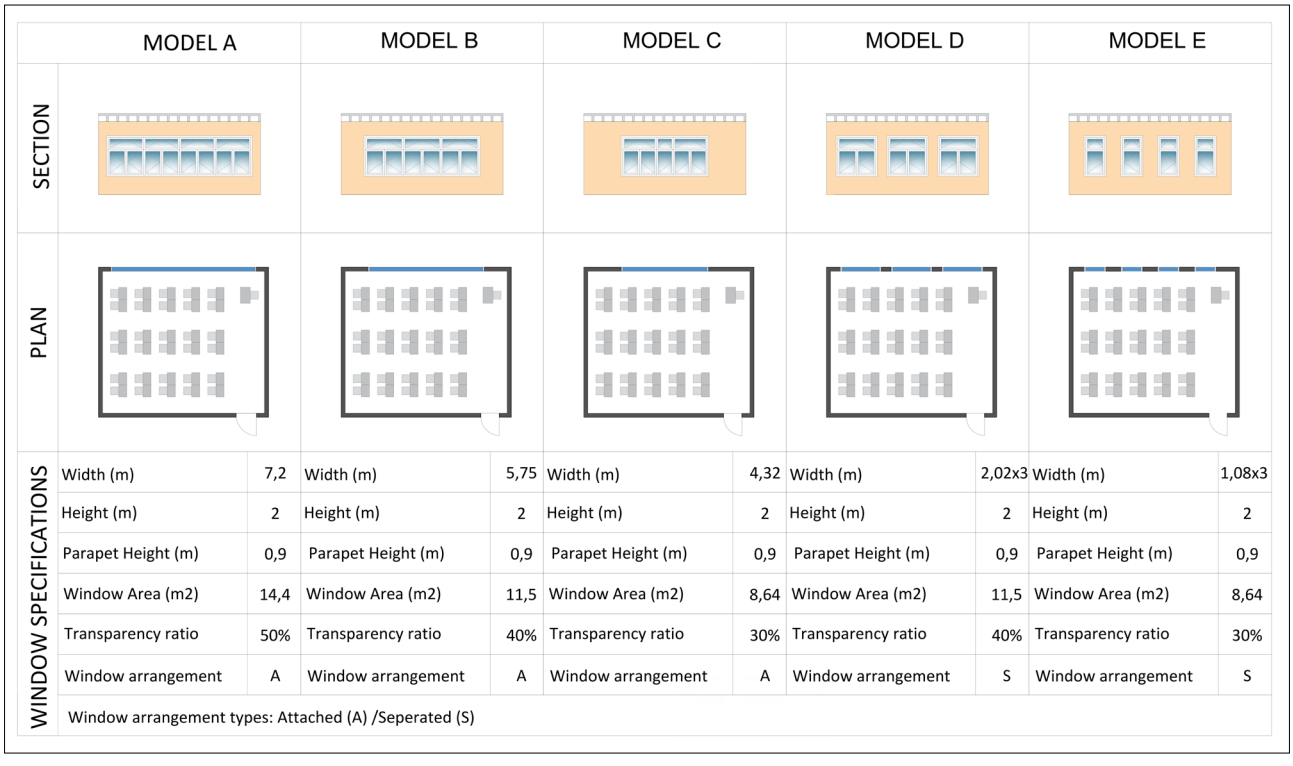


Figure 2. Classroom plan - section with varied façade designs.

Table 2. Interrelation Between Permitted Road Width and Floor Numbers of Obstacle Buildings According to 'Building Bylaws' published in 2017

Type	Road width (RW) acc. to Building Bylaws	Maximum number of floors allowed	Approximate Obstruction Angle
1	RW ≤ 7.00 m	2	20°
2	7.00m < RW ≤ 10.00 m	30°	30°
3	10.00m < RW ≤ 12.00 m	4	30°
4	12.00m < RW ≤ 15.00 m	5	35°
5	15.00m < RW ≤ 20.00 m	6	40°
6	20.00m < RW ≤ 25.00 m	8	40°
7	25.00m < RW ≤ 35.00 m	10	45°
8	35.00m < RW ≤ 50.00 m	14	50°
9	50.00m < RW	18	55°

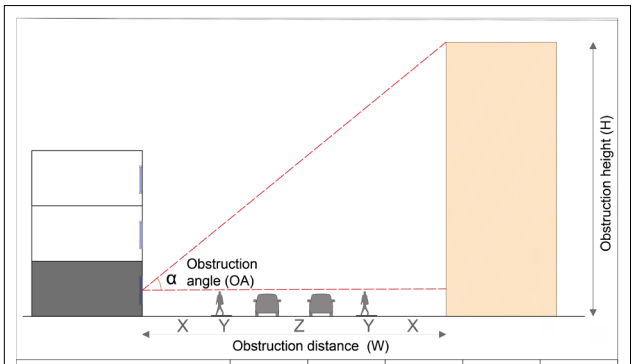
classrooms are located on the ground floor as recommended in the Minimum Design Guide for Educational Buildings, and calculations were made for the ground floor, which is the most negative situation in the simulations. Thereby, a total of 200 alternative classroom models generated according to the parameters mentioned were evaluated according to the criteria of daylight provision and protection from glare.

The building height is determined as 12 meters (3 floors) based on the maximum number of floors allowed for primary education buildings in the 'Educational Buildings Minimum Design Standards Guide' (MEB, 2015). The criteria in the Building Bylaws were accepted as a basis when determining obstruction distances and building heights of obstacles (Resmi Gazete, 2017). Additionally, it is accepted that all obstacles are permanent. The interrelation between permitted road width and the number of floors is given in Table 2.

Within the scope of the study, the scenarios created relating to the interrelation between permitted road width and number of floors according to obstruction angle alternatives of 0°, 20°, 30°, 40°, and 50° were evaluated. For the created classroom models, representative scenarios for obstructions are generated based on the road width - number of floors relationship specified in the 'Building Bylaws Regulation for Planned Areas', which was last published in the Official Journal of Türkiye in 2017. Road width and building height interrelation are represented as type 2 for a 30° obstruction angle, and type 5 for a 40° obstruction angle as mentioned in the Building Bylaws. According to Building Bylaws regulations, an obstruction angle of 0° assumes there are no obstacles in front of the building (Resmi Gazete, 2017). Obstruction angle scenarios to be applied in alternative scenarios are presented in Figure 3.

Daylight Assessment

As stated in the daylight provision criteria, daylight illumination must be provided for a significant part of the year for daylight hours. The daylight illumination provided depends primarily on the climatic conditions, then on the neighboring structures surrounding the building, building openings, surrounding building elements, and the configuration of indoor spaces (Türk Standartları Enstitüsü, 2022). In order to provide the required daylight illumination within the indoor space, the target illuminance level (ET) should be provided with daylight for 50% of the space and at least half of the annual daylight hours, while the minimum target illuminance level is desired to be achieved with daylight for at least half of the annual daylight hours in 95% of the space (Türk Standartları Enstitüsü, 2022), (Mardaljevic & Christoffersen, 2017). The standard also recommends that the reference plane height should be taken as 0.85m unless otherwise specified. As the study focuses on elementary school classrooms, the reference plane is taken to be at a height of 0.75m, which is due to the desk height suitable for primary school students.



Obstruction angle (OA)	50°	40°	30°	20°	0°
Obstruction distance (W)	39m	29m	24m	16m	-
Obstruction height (H)	56m	24m	16m	8m	-
H/W	1,43	0,82	0,66	0,5	
X distance	5m	5m	5m	3m	-
Y distance	1,5m	1,5m	1,5m	1,5m	-
Z distance	26m	16m	11m	7m	-

Figure 3. Obstruction angle scenarios.

In this article, two criteria for daylight are assessed, which are daylight provision and protection from glare. Table 1 provides a classification of these criteria. The target illuminance level was accepted as 300 lux, which is the recommended threshold level for primary school classrooms (MEB, 2015). A minimum illumination level of 100 lx is needed to ensure optimal visual comfort for students.

Calculation Method

The classroom was modeled with the 'Rhino 7' software, and daylight simulations were conducted using Climate Studio, which is a plug-in that employs validated simulation engines Energy Plus and Radiance to assess dynamic visual performance parameters. Additionally, the created models are assessed in terms of annual daylight performance using daylight criteria according to the TS EN 17037 standard included in the software. The daylight performances throughout the year have been determined by means of the daylight autonomy method. The daylight autonomy method was utilized to compute the potential of achieving the desired illuminance levels for half of the daylight hours in a year (Reinhart, Mardaljevic, & Rogers, 2013). The calculations were based on the climate data of Istanbul and Antalya provinces gathered from Energy Plus.

CALCULATION RESULTS

A total of 200 simulations were conducted for the alternative scenarios for climate, direction, façade design, and obstruction angle variables. The results are assessed according to two of the assessments mentioned in the TS-EN 17037 standard: daylight provision and protection from glare. The results are evaluated under subheadings of direction, façade design, obstruction angle, and climate.

Assessments for Daylight Availability

The main objective of the study is to determine the optimum visual performance parameters for the user to maintain their work tasks and activities in classrooms. For this purpose, evaluations for the sufficiency of daylight are completed for variations of climate, direction, façade design, transparency ratio, and obstruction angle in order to prepare a detailed guide for the daylight design of primary schools in Türkiye. Rhino 7 was used to create classroom models, which were then analyzed using 'Climate Studio' software. The simulation results were generated using the EN 17037 workflow within the Climate Studio plug-in.

An annual climate-based simulation is used to calculate compliance for interior illuminance distributions (IES Daylight Metrics Committee, 2012). The criteria for compliance measure the percentage of the floor area that achieves minimum and target illuminance level thresholds for each hour of the year. To meet compliance, the target illuminance of 300 lux should be achieved over 50% of the floor area for at least 50% of daylight hours, while the minimum illuminance of 100 lux should be met over 95% of the floor area for at least 50% of daylight hours (Mardaljevic & Christoffersen, 2017). Daylight hours are defined as 4380 hours, and the climatic data of locations are taken from Energy Plus.

For daylight provision assessments according to the TS-EN 17037 standard, the alternative scenarios classified as medium and high also meet the requirement of the minimum level. Because of providing a minimum level of 300 lux illumination for at least 50% of daylight hours over 50% of the reference plane, which is sufficient for primary school classrooms, all three classifications were taken as having passed the requirement. The same acceptance is valid for meeting minimum illuminance requirements which is sufficient for assessments, as the classroom can achieve compliance with medium and high levels by satisfying higher illuminance thresholds. For the evaluation of alternative scenarios, the ones that meet the requirement of providing target and minimum target illumination levels for defined hours of the year and percentage of the floor area are both accepted as prevalent conditions.

- **Direction**

Based on the assessments conducted on the direction parameter, it has been observed that the south and east directions exhibit superior daylight performance compared to the other directions. Despite the common expectation that the South direction would offer better daylight sufficiency in all circumstances, the East direction is found to have higher annual daylight performance in some alternative scenarios. Upon analyzing the relationship between direction and façade design, it can be concluded that changing the direction does not have a significant impact on achieving the target illuminance for at least 50% of the floor area for 50% of the time. However, there is a significant difference in providing the minimum target illuminance for 95% of the floor area for 50% of the time. Figure 4 illustrates the correlation between direction and façade model through a graph for the fraction of daylight hours (Ftime,%). The graph displays the percentage of daylight hours that provide target illuminance of at least 50% of the floor area and minimum target illuminance in at least 95% of the floor area separately, based on changes in direction and façade model. According to the assessments, the values obtained from the east and west directions in most of the options appear to be quite similar.

The D and E models, which are separated window layout alternatives for different transparency ratios, show a sharper change according to the direction change. Especially for the north orientation, daylight performance has a sharp decrease in daylight illuminance.

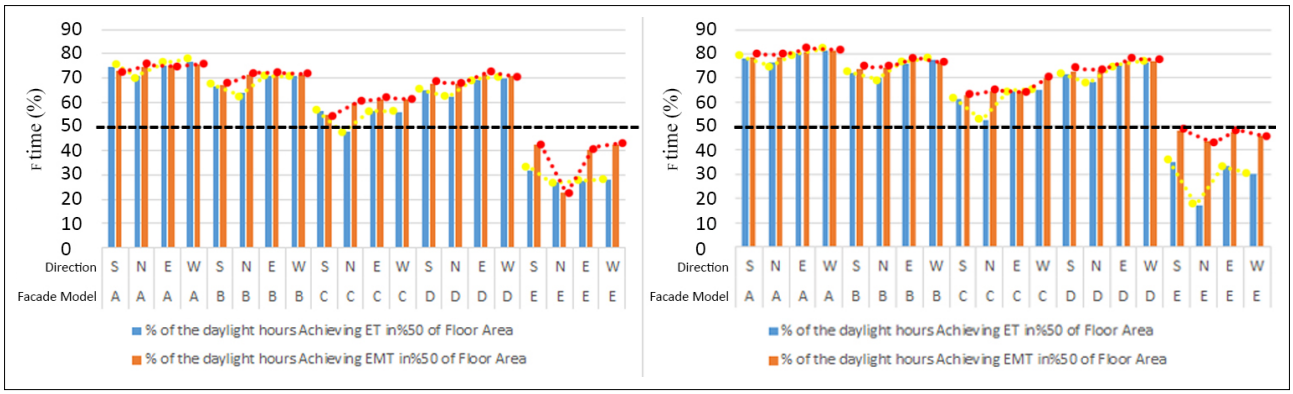


Figure 4. Daylight Provision Changes by Direction Variables for Alternative Façade Designs of 20° Obstruction Angle for Istanbul (Left) and Antalya (Right).

Additionally, for higher obstruction angles, it is observed that buildings with facades facing east and west exhibit better daylight efficiency in comparison to the south direction. Furthermore, it can be understood that Model E cannot provide the criteria for a 20° obstruction angle in any direction variables in Istanbul, while Antalya provides the criteria for South orientation.

• **Façade Design**

The Educational Buildings Design Guide has a description of the transparent area-to-floor area ratio suggestion that is approximately equal to a transparency ratio of 50%. There is no other description for alternative façade designs responsive to interior and exterior environmental parameters. The alternative transparency ratios of 30%, 40%, and 50%, and window layout variables of separated and attached arrangement for 30% and 40% transparency ratios are evaluated as Model A, B, C, D, and E facades, which are displayed in Figure 2.

The required daylight illuminance for all façade models can be provided if the obstruction angle remains below 20°, except for façade model E. Furthermore, for obstacle angles of 20° and below, it can be observed from the scenarios that both the minimum target illuminance level and the target illuminance level criteria are fulfilled for all window direction variables. After analyzing the simulation outcomes of options featuring a 30° obstacle angle, it appears that facades models A, B, and D satisfy the target illuminance level and minimum target illuminance level. However, the C and E models do not meet the required criteria for all directions. The graphics presented in Figure 5 indicate the fraction of time that meets the target and minimum target illuminance requirements. These graphics are generated for the façade variations with the constant direction of the south window orientation. In Istanbul and Antalya provinces, the transparency ratio has a linear effect on daylight performance, as shown in the separate graphics created for each province. It can be observed that the increase in performance is smoother for obstruction angles of 20° or less, while the increase becomes more pronounced as the obstruction angle increases. Upon closer examination of the graphic, it becomes evident that the percentage of increase becomes sharper as the obstruction angle increases.

The Model B facades in the attached window arrangement with 40% transparency, and the Model D facades in the separate layout with obstruction angles of 0°, 20°, and 30 degrees, all fulfill the daylight requirement. However, the Model C alternative with a 30% transparency ratio in the

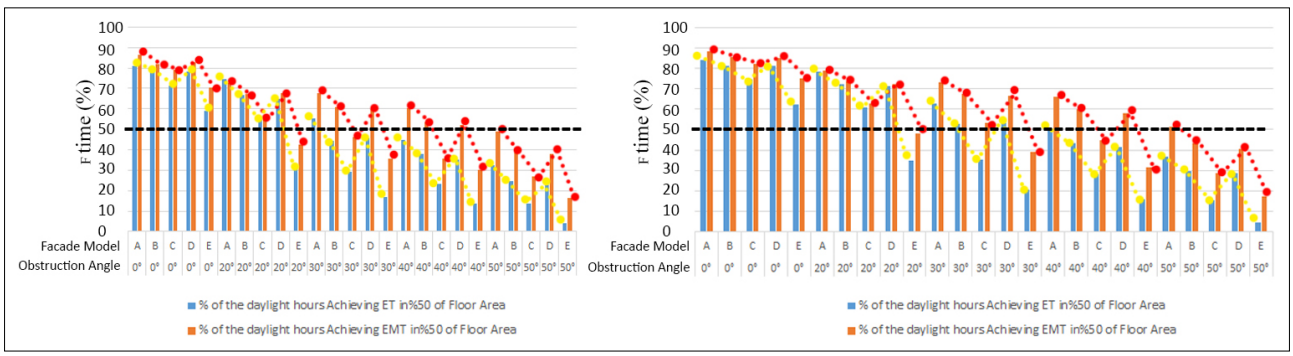


Figure 5. Daylight Provision Graphic for Façade Design Variables for Provinces of Istanbul (left) and Antalya (right) for South Orientation.

attached facade shows better daylight performance than the separated Model E. In the attached window arrangement with 30% transparency, 0° and 20° obstruction angles demonstrate positive daylight performance. Nevertheless, the daylight criteria are not met except for the south facade with a 0° obstruction angle in the separated layout. According to the graph, the attached window orientation has a positive effect on daylight performance. The difference between attached and separated window orientations is significant, leading to a direct decrease in performance, primarily for a 30% transparency ratio. This indicates that window configuration changes have a more significant impact on daylight performance as the transparency ratio drops.

• **Obstruction Angle**

Upon analyzing all the alternative scenarios, it becomes apparent that the alternatives with lower obstruction angles perform better in terms of daylight provision. As the obstruction angle increases to 30° and beyond, it becomes impossible to meet the daylight provision criterion, particularly at 40% and 30% transparency rates. Especially in Istanbul, it is evident that the daylight criteria cannot be met except for some direction alternatives when the obstruction angle exceeds 40°. It is observed that Antalya province receives an adequate amount of daylight, even with the highest obstruction angle, particularly in the option with a 50% transparency ratio. On the other hand, the option with 40% transparency and a 40° obstruction angle does not offer enough daylight for Istanbul, but it is sufficient for Antalya province. Furthermore, Antalya cannot receive sufficient daylight when the obstruction angle goes beyond 40°. When the façade design has 30% transparency, it produces unfavorable outcomes for both climate zones when the obstacle angle is above 20°. However, the sensitivity to the obstruction angle is less significant in Antalya province, which represents hot and humid climates. Figure 6 displays a graphic that shows the obstruction angle variables for the provinces of Istanbul and Antalya for the south orientation changes by façade models. As per the graph, there is a significant decrease between changes in the obstruction angle. It can be inferred that obstruction angle variables have a greater impact on achieving the required target illuminance level performance throughout the year compared to the minimum target illuminance level.

• **Climate**

Istanbul and Antalya were taken as representative provinces from the temperate humid and hot humid climate regions evaluated in the study. Within the scope of the variables evaluated in the study, it can be said that the hot humid climate region allows more flexible designs in terms of window design, building orientation, and obstacle status.

For instance, it has been observed that a 50% transparent façade may not offer adequate daylight for Istanbul when the obstruction angle exceeds 40°. However, a required illuminance level of 300 lux is achieved in at least 50% of the space and daylight hours, while a minimum illumination level of 100 lux is achieved in over 95% of the space and more than 50% of the daylight hours in Antalya province. It was also established that the comparable scenario was applicable for the option with a transparency ratio of 40%. However, for a 30% transparency ratio, sufficient daylight cannot be provided in both climate zones when the obstruction angle exceeds 30° or more.

After evaluating the daylight performance of various scenarios created for Istanbul and Antalya based on direction, façade model, and obstacle variables, it has been observed that 49 out of 100 scenarios created for Istanbul, and 69 out of 100 scenarios created for Antalya meet the required illuminance level criteria. These scenarios fulfilled both the target illuminance level and minimum illuminance level criteria. Thus, it can be concluded that Antalya has a more favorable daylight performance as compared to Istanbul. Based on all the findings, it is determined that

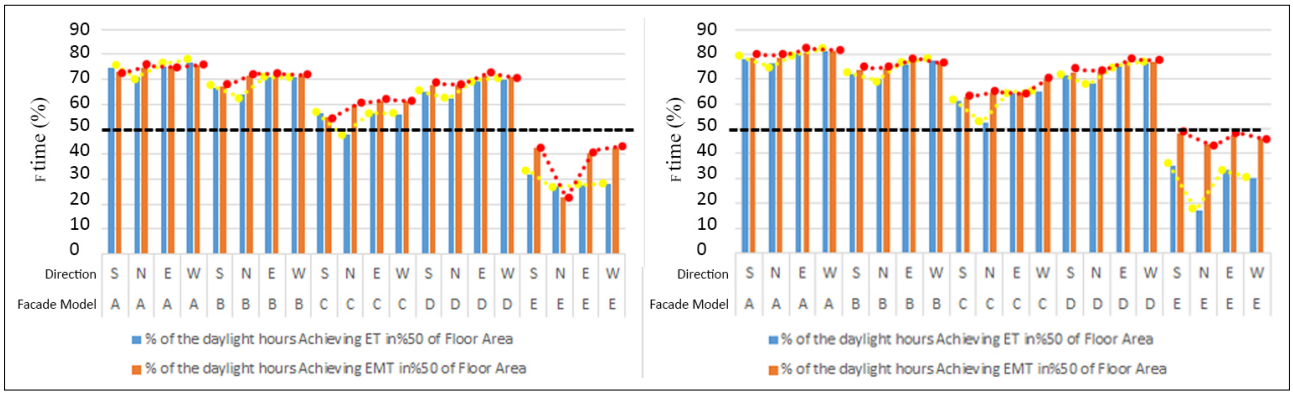


Figure 6. Daylight Provision Graphic for Obstruction Angle Variables for Provinces of Istanbul (left) and Antalya (right) for South Orientation.

having the highest level of transparency and the least amount of obstruction is positive for daylight provision. However, it is important to consider the protection against glare as well, which is one of the daylight criteria mentioned in EN 17037 (Türk Standartları Enstitüsü, 2022), (Walkenhorst, Luther, Reinhart, & Timmer, 2002). During the study, the most favorable scenarios were those where the area received enough natural light, and glare protection was provided.

Assessment of Protection From Glare

Glare can happen due to several design factors, such as the optical properties of the material, the location, the direction of view, the orientation of the façade, the transparency ratio of the façade, the glazing transmittance, and the user's distance from the window.

To evaluate daylight glare, one must consider the complex luminance distribution within the field of view as well as the size, intensity, and location of the glare sources in relation to the line of sight (Türk Standartları Enstitüsü, 2022), (Sepúlveda, Luca, Varjas, & Kurnitski, 2022).

Daylight Glare Probability (DGP) is a dynamic metric used to assess the level of protection from glare in spaces where activities like reading, writing, or using display devices take place. DGP is particularly important in cases where occupants have limited ability to choose their position or viewing direction (Türk Standartları Enstitüsü, 2022). It is important to ensure that the FDGP exceed, which represents a certain fraction of the reference usage time, does not surpass the DGP-threshold values (Türk Standartları Enstitüsü, 2022).

Spatial Disturbing Glare (sDG) refers to the percentage of occupied hours where at least 5% of views across the regularly occupied floor area experience Disturbing or Intolerable Glare (Solemma, 2020).

In this part, alternatives of direction; façade model, and obstruction angle are evaluated for annual glare by means of the sDG (spatial disturbing glare) metric. The number of 200 models evaluated with a reference plane with 0.5m distance from the wall and 1.20m height off the finish floor, which represents the eye level of the seated observer. Additionally, according to TS-EN 17037-A1, the maximum grid size of reference for calculation is evaluated as 1.8m. However, for a more accurate assessment, the grid size is determined as 0.8m (Türk Standartları Enstitüsü, 2022). The frequency of glare is displayed with eight directional pie slices for view nodes on the reference plane, which are color-coded to indicate frequency from intolerable to tolerable glare.

TS-EN 17037 states that in situations where there are multiple potential locations for activities, it is suggested to investigate the position with the worst expected outcome. These positions are defined as near the building's façade or where there is a possibility of a low sun position.

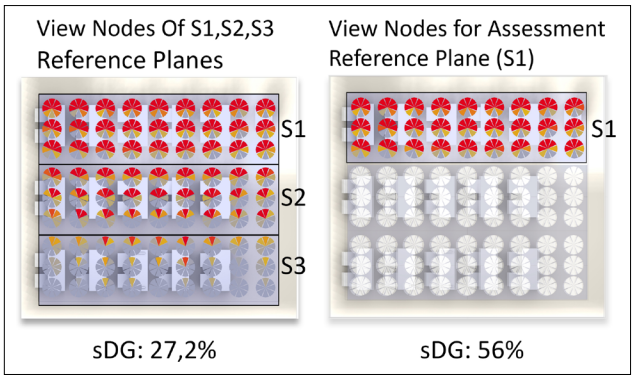


Figure 7. The Reference plane displays view pie slices for the entire classroom (left) and calculation area (right).

Moreover, if the glare requirements are met for the worst-case positions within a given space, then they are also accepted to meet throughout the entire occupied area (Türk Standartları Enstitüsü, 2022). According to this admission; in order to make a sensitive evaluation, the calculation points are determined for this study as the area occupied by the group of desks through the window. Figure 7 shows the sDG values for the entire area (left) and the calculation area to be used for evaluation (right). Based on Figure 7, it can be inferred that the desks aligned near the window pose the highest risk of glare. Therefore, evaluating the entire classroom area for the entire year would not be a realistic approach. This is why for this study, annual evaluations for glare are conducted specifically for the desks aligned with the window, as illustrated in Figure 7 as S1.

Direction

Based on the simulation results, it has been determined that the highest probability of glare occurs when a building is oriented toward the South. The East and West directions follow this trend. However, there is no risk of glare from the North direction for any building model or obstruction angle alternatives. The facades of models A, B, and C pose no risk of glare in any direction when the obstruction angle is 50°. For models C and D, with an obstruction angle of 40°, there is no probability of glare in the North, East, and West directions. As for model E, there is no risk of glare in any direction for obstruction angles of 20°, 30°, 40°, and 50°, except for the South direction at a 20° obstruction angle. Figure 8 represents sDG (%) values for alternative scenarios of directions for Istanbul and Antalya provinces, changing by façade and obstruction angle variables.

Based on the graph, it can be inferred that the South orientation poses the highest glare risk in all circumstances. On the other hand, the North orientation has no glare risk. It is recommended to take glare control precautions for buildings facing South, East, and West, particularly when the obstruction angle is 30° or more.

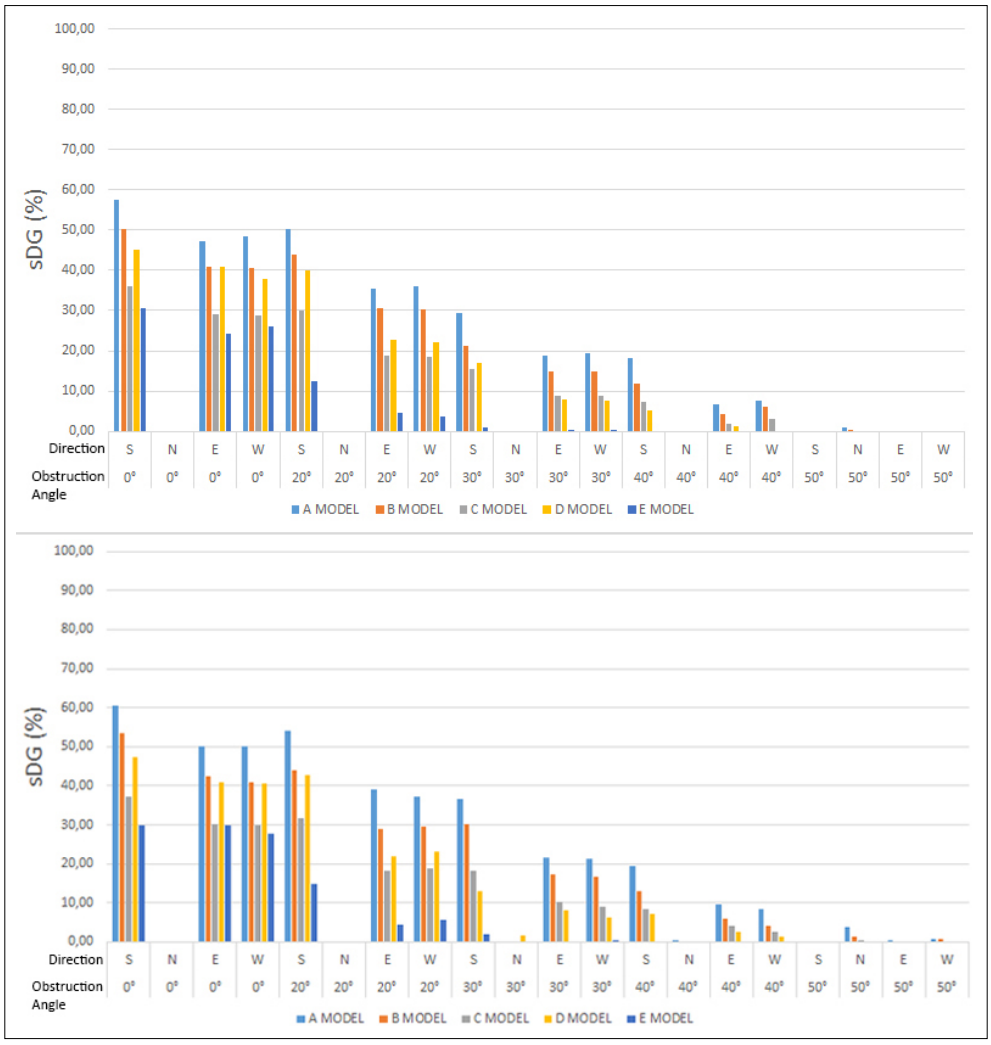


Figure 8. Graphics for sDG (%) value for alternative scenarios of Directions for Istanbul (up) and Antalya (down).

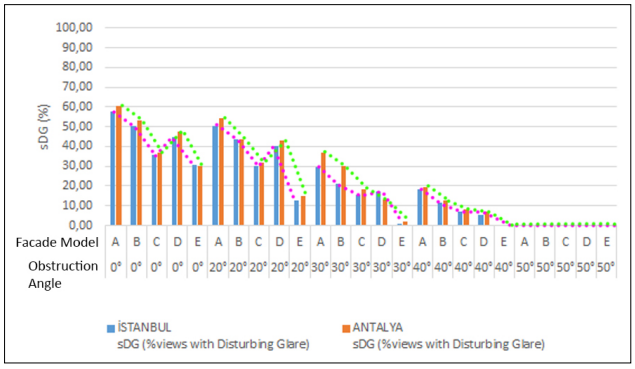


Figure 9. Graphics for sDG (%) value according to Façade Model in South orientation for provinces of Istanbul and Antalya.

Façade Design

The design of a building's façade should be carefully considered as it can significantly affect the occurrence of glare. Upon closer examination, it has been noticed that façade models A and B do not cause any glare issues except for a 50° obstruction angle in both provinces. However, models C and D have a risk of causing glare for 40° and 50° obstruction angles. Finally, model E has no risk of glare, except for an obstruction angle of 0. Figure 9 displays sDG (%) values according to Façade Model in the South orientation for the provinces of Istanbul and Antalya. It can be said that Models A, B, and C exhibit a linear decrease in effect with changes in transparency ratio, while Models D and E exhibit the same ratio of decrease in comparison.

Obstruction Angle

Glare can be significantly affected by obstruction. Among all the façade models assessed, those with 0° and 20° obstruction angles are at the highest risk of glare. As the angle of obstruction increases, the risk of glare also increases in a linear manner. It is especially important to take precautions against glare for façade models A, B, and D with obstruction angles of 0° and 20°. Figure 10 shows the

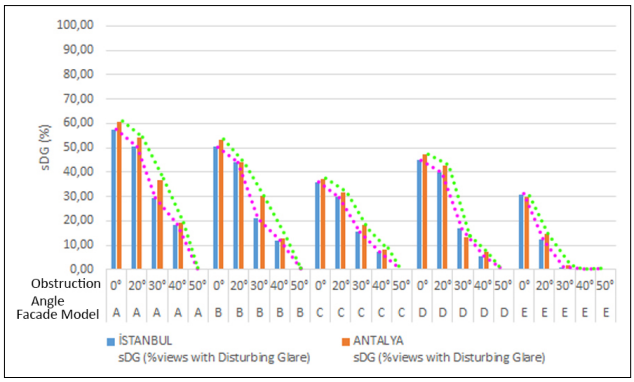


Figure 10. Graphics for sDG (%) Value Change According to Obstruction Angle Alternatives in South orientation for provinces of Istanbul and Antalya.

change in sDG (%) values according to obstruction angle alternatives in the South orientation for the provinces of Istanbul and Antalya.

Climate

The role of climate is crucial in protecting against glare. However, the Design Guides for educational buildings in Türkiye lack detailed alternative façade scenarios for different climate zones. Figure 11 shows the changes in sDG (%) values for the Model A façade in the Istanbul and Antalya provinces.

It is important to note that the Antalya province is at a higher risk of glare than Istanbul under all circumstances. Precautions against glare are particularly important for south-facing buildings. Additionally, glare protection should be considered for buildings facing east and west with obstruction angles of 30° or greater. A closer look reveals that the Istanbul province has more flexible design alternatives when it comes to façade models and obstruction angles compared to Antalya. Therefore, it is recommended to use solar control components when there is a high possibility of glare during the necessary days and hours of the year.

DISCUSSION

As displayed on the flow chart in Figure 1, several alternative scenarios varying climate, direction of the building, façade design, and obstruction angle parameters have been generated in order to assess the daylight performance of primary school buildings in Türkiye regarding the recommendations outlined in TS-EN 17037-A1 standard. The generated models were assessed according to the daylight provision and protection from glare criteria as explained in the standard. Out of the total number of 200 models, those that met and those that did not meet the criteria were determined. According to these outputs: recommendations were generated in order to improve primary school daylight system design.

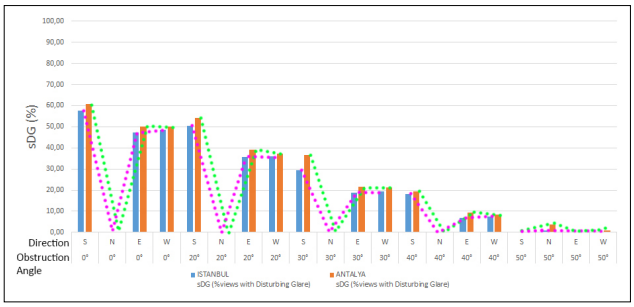


Figure 11. Graphics for sDG (%) Value Changes of Istanbul and Antalya Provinces for Model A Façade.

In the first part of the study, daylight provision was assessed according to the criteria given in TS-EN 17037. From the number of 200 alternative scenarios, 110 of them provided the target illuminance of 300 lux in 50% of daylight hours at least for 50% of floor area and 100 lux of minimum target illuminance in 50% of daylight hours minimum for 95% of the daylit area both. Antalya has a total of 61 models that meet the criteria, whereas Istanbul only has 49 models available. It's important to have plenty of natural light in a space, but it's also crucial to limit the possibility of glare, which is caused by higher illuminance levels.

Glare assessments indicate that the risk of glare is higher for smaller obstruction angles, which emphasizes the need for solar control components. Additionally, for higher transparency ratios, specific times of the year may require glare control more than other options. Furthermore, a south-facing orientation carries the highest risk of glare. Designers are advised to use solar control elements integrated into façade design or, in some cases, if they are not sufficient, user-controlled systems such as curtains, roller blinds, and blinds, to protect against glare in negative alternatives. Within the 200 alternative models analyzed, 31 models pose a risk of disturbing glare, and 94 models have a probability of causing glare throughout the year. Glare protection precautions should be implemented from the initial design phase, especially for the 31 models that cause a decline in visual performance.

When assessing alternatives based on both daylight provision and protection from glare, models that meet target and minimum illuminance levels in identified circumstances while avoiding disturbing glare are considered positive. Out of 200 models evaluated for meeting the criteria of providing adequate daylight and avoiding glare, 79 models were found to have efficient daylight performance.

CONCLUSION

Passive systems are preferred in building design to enhance energy efficiency and visual comfort. Natural lighting is a crucial passive system for reducing a building's energy

requirements for lighting while creating a desirable visual environment and ensuring comfort requirements (Kocagil & Oral, , 2021). For educational buildings, a natural lighting system is vital for students' visual comfort and performance (Çelik & Ünver, 2019). Furthermore, variables such as climate, direction, and façade design significantly affect daylight performance. Therefore, to design an effective daylight system for educational buildings, it is necessary to make suggestions that are sensitive to environmental and physical parameters.

The purpose of the study is to create a detailed design guide for primary school classrooms in educational buildings by determining positive scenarios according to the façade model, obstruction angle, and direction variables for different climate regions. For that purpose, alternative scenarios are considered positive when daylight provision requirements are met while avoiding glare according to criteria described in TS-EN 17037-A1. In addition, the study can be improved by investigating the effect of solar control elements on daylight performance (Bian, Dai, & Yuan Ma, 2020).

It is necessary to develop a design guide that takes into account the impact of variables on daylight performance in order to create a sensitive artificial environment design. The currently available guidance does not offer detailed alternative scenarios based on environmental and physical variables. The output of the study can be used for the construction or renovation of educational buildings.

In conclusion, the study indicates that it would be beneficial to improve the Minimum Design Guide for Educational Buildings in accordance with the recommendations to create an efficient environment for students. The effect of environmental and interior design parameters should be considered from the early beginning of the building design phase.

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