Thermal Comfort in Social Housing: A Case Study from Türkiye's Hot and Dry Region

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Abstract

This study examines thermal comfort and satisfaction in TOKI Etiler, a social housing project in Gaziantep constructed by the Turkish Mass Housing Administration (TOKI). Focusing on six high-rise blocks in this project, the research evaluates the current state of social housing in hot and dry climate conditions. Thermal comfort is identified as a critical factor in improving residents' quality of life. Utilizing a mixed-methods approach, the study incorporates in-depth interviews with residents, unit observations, thermal imaging, and statistical analysis using SPSS. The findings underscore significant thermal discomfort, particularly in top-floor units of the 12-story buildings, with dissatisfaction peaking at 45.9% in August. Thermal comfort perceptions also varied based on household size, highlighting the need for tailored solutions. To improve thermal performance, the study proposes strategies such as minimizing excessive heat gain, implementing passive systems like shading devices, and harnessing solar energy. Inspired by the region's vernacular architecture, incorporating water features in outdoor spaces is also recommended to enhance evaporation and cooling. Furthermore, the study identifies thermal bridges in building envelopes and calls for better insulation alongside environmentally friendly alternatives to synthetic and petroleum-based construction materials, which pose risks to both human health and the environment. By analyzing the unique climatic challenges of Gaziantep and residents' adaptive behaviors, this research offers a comprehensive evaluation of indoor environmental conditions in the TOKI Etiler project. The findings contribute valuable insights into climate-responsive housing solutions for hot and dry regions.

Keywords: *Thermal comfort, hot and dry climate, POE, occupant satisfaction, social housing,* Türkiye*.*

1. Introduction

In recent years, there has been a growing interest among researchers in indoor environmental quality and thermal comfort, particularly concerning health and occupant well-being. Enhancing indoor environments to improve these aspects has become a key focus, with numerous studies examining the complex relationship between climate, urban design, and user satisfaction. Research by Erell *et al.* (2011) highlighted the connection between the outdoor conditions of a settlement and its sustainability performance. Indeed, the microclimates shaped by urban design choices influence user satisfaction and behaviors within them. While many studies have addressed the impact of outdoor climate on indoor comfort (Chen *et al.,* 2003), the unique contribution of this study lies in its focus on the interaction between local climatic conditions and residential spaces in Gaziantep, Türkiye, particularly in social housing. By examining how traditional passive cooling strategies have been overlooked in modern designs, this research aims to bridge the gap in existing knowledge on the importance of climate-responsive design in Türkiye's hot and dry climate.

A critical component of enhancing indoor environmental quality is thermal comfort, which is a key metric for both building performance and occupant well-being. Defined by ASHRAE Standard 55, thermal comfort refers to the condition of mind that represents satisfaction with the thermal environment and needs subjective evaluation. A thermal environment is considered satisfactory when 80% or more of occupants within a space find it acceptable (ASHRAE 55, 2013), as the term "acceptability" is used for "satisfaction" in thermal comfort-related research (de Dear and Brager, 2002).

As climate change remains one of the most pressing challenges of the 21st century, numerous studies have focused on evaluating thermal comfort worldwide. In particular, growing awareness of the impact of indoor environmental conditions on well-being has significantly accelerated research aimed at improving thermal quality in residential spaces (Spetic et al., 2008). Thermal comfort studies in multi-unit residential buildings identify several significant parameters affecting comfort. For example, smaller dwelling sizes and lower occupancy levels result in reduced heat gains and less interaction with building control systems (Roetzel et al., 2014; Ioannidis et al., 2016). A thermal performance parametric study on window type, size, orientation, and shadowing presented that north orientation in Portugal has better thermal performance than northwest and northeast orientation (Amaral et al, 2016). Other studies have focused on the effects of building height and the stack effect. During cold periods, the overheated upper levels cause thermal discomfort for occupants, while drafts become a concern for those on lower floors due to the infiltration of cold air (Mijorski and Cammelli, 2016; Jo et al., 2007).

Research conducted in Seville examined the benefits of courtyards, including users' thermal perceptions. Findings revealed that an efficient passive cooling system in Mediterranean social housing could enhance energy efficiency by up to 20.5% (Diz-Mellado et al., 2023). Similarly, Perez-Fargollo et al. (2018) analyzed improvements in the thermal envelopes of social housing in Chile, evaluating the economic benefits of reducing costs associated with these upgrades using the adaptive thermal comfort model. Another adaptive comfort study in Chile discussed the issue of energy poverty, where homes fail to maintain minimum thermal comfort standards. Results showed that one-third of participants could not maintain a comfortable indoor environment for at least 80% of the time, while over 20% struggled to do so for 65% of the time (Porras-Salazar et al., 2020).

Similarly, research conducted in other regions also explores the effects of thermal comfort in social housing. In Toronto, a year-long study analyzed 70 social housing units across seven buildings, focusing on summer overheating, which led to significant discomfort. The study identified discrepancies between survey responses and monitoring data (Patiño et al., 2018). Another study critically analyzed interventions in social housing in Porto under the Improvement Plan, which enabled the rapid construction of many dwellings. Despite these efforts, challenges persist regarding comfort parameters. This study explored the impact of current measures on interior comfort, existing issues, and alternative approaches to balancing energy efficiency and thermal comfort (Rocha et al., 2023).

Recent research (Ghaddar et al., 2024) has also addressed sustainable cooling technologies, particularly for vulnerable populations facing excessive heat events affecting cities globally, from the south to the north. This study underscores that passive adaptation strategies, including cool and green roofs, radiative coatings, high-R and low-emissivity windows, as well as trees and vegetation, play a crucial role in mitigating extreme heat effects on building surfaces. However, their effectiveness varies depending on building typology and climatic conditions, making a standardized approach unfeasible. Therefore, comprehensive design assessments and impact analyses are essential to develop tailored, climate-responsive solutions for each specific context.

Increasingly frequent extreme climate events and rising global temperatures play a critical role in shaping energy retrofit strategies, highlighting the importance of accounting for future climate scenarios. The study by Iskandar et al. (2025) examined the effectiveness of natural ventilation as a passive cooling strategy for low-thermal-mass buildings in hot and humid climates, assessing its performance under both present and projected weather conditions throughout the century. The results emphasized the necessity of adaptive retrofit solutions, such as optimizing existing systems, modifying operational practices, and incorporating shading devices to minimize heat gain. These findings reinforce the need for integrating passive strategies into building design, particularly in regions with extreme climate conditions (Iskandar et al., 2025).

Traditional vernacular architecture in Türkiye offers valuable insights into passive cooling strategies that are well-adapted to local climatic conditions. In hot and dry regions like Gaziantep, natural ventilation techniques have historically played a significant role in shaping building design, either through spatial configurations such as courtyards or through enclosure elements like solar collectors, shading devices, and operable architectural features. These design strategies demonstrate how traditional dwellings have effectively filtered extreme climatic forces throughout the year, ensuring indoor comfort. Building surfaces function as a medium for climate regulation, with strategically designed openings facilitating passive cooling. The impact of climatic variables on residential buildings is particularly evident in the widespread use of courtyards and stone construction, both of which serve as defining elements of the region’s architectural identity. While many of these low-rise courtyard houses have been demolished or repurposed into hotels, they once dominated the residential landscape in Gaziantep.

Courtyards provide naturally ventilated, habitable open spaces, while the thermal mass of locally sourced stone helps maintain indoor temperatures during the hot season. Additionally, landscape features such as gardens and water ponds contribute to microclimate regulation while enhancing the visual and environmental quality of the built environment. As Taleghani (2014) highlights, courtyards function as natural cooling systems by storing cool air at night, which is absorbed by surrounding surfaces and released gradually throughout the day. As temperatures rise, thick walls slow heat penetration, while convection-driven ventilation helps maintain thermal balance indoors (Taleghani, 2014).

Despite these traditional strategies, modern social housing developments in Türkiye often fail to integrate climate-responsive design, leading to significant thermal comfort challenges. While passive systems have been widely studied in warm climates, there remains a gap in research on their application in social housing projects, particularly regarding microclimatic influences and resident perceptions. For instance, Suta and Zencirkan (2024) evaluated user satisfaction in social housing in Edirne, Türkiye during the COVID-19 era, emphasizing that thermal comfort positively influences overall satisfaction. Despite these studies covering various climate zones, the lack of experimental research and data on thermal comfort in arid and hyper-arid regions complicates decisions between passive or active heating and cooling systems (Sakhri et al., 2022).

While the energy efficiency of passive systems in warm climates has been extensively analyzed, research addressing the conditions in social housing projects, including the influence of their microclimates and residents’ perceptions, remains insufficient. Additionally, the limited number of thermal comfort studies in Turkish social housing underscores the need for further research in this area. This research contributes to understanding the local climatic conditions of Gaziantep, their impact on residents, and the behavioral patterns adopted to adapt to the complexities of Türkiye's hot and dry climate. It offers a scientific assessment of indoor environmental conditions in TOKI residential projects, emphasizing the importance of appropriate orientation and layout in optimizing natural ventilation for energy efficiency and improved thermal comfort.

This study aims to highlight the importance of passive cooling and thermal comfort in identifying pathways for sustainable development in hot and dry regions. By experimenting with a social housing typology in Türkiye, the study will address the following questions related to the thermal comfort of residents living in the selected social housing:

- Does the thermal comfort and satisfaction of occupants in social housing in Gaziantep fall within acceptable ranges as defined by established standards?
- Are there any thermal-related differences that residents experience in different units? If yes, what are the reasons for discomfort?

Studies into human thermal comfort have generated comfort models that predict a statistical population averaging neutral temperature. These include the Physiological Comfort Model and Adaptive Comfort Model. It is important to understand the heat balance mechanism in the human body and also the factors affecting thermal comfort. Personal and environmental variables are used when defining conditions of thermal comfort: metabolic rate and clothing insulation as personal factors and air temperature, radiant temperature, air velocity, and humidity as environmental factors (ASHRAE, 2010).

There is a strong connection between thermal comfort sensation and heat balance. The human body needs to maintain a heat balance to operate properly. Being warm-blooded, it tries to maintain a core body temperature of about 37°C and a skin temperature of about 33°C. If the body heats up or cools down too much, it can impair its functionality. For instance, at approximately 42°C, individuals may experience fainting due to potential brain damage, and at about 44°C, severe consequences like passing out can occur. Similarly, shaking begins at 35°C, while serious damage that is irrecoverable starts to occur at 15°C (La Roche, 2012). So, our body employs several regulatory mechanisms to maintain optimum operating conditions.

To prevent overheating, subcutaneous blood vessels expand and increase the amount of blood to the skin and skin temperature. Thus, it enhances heat dissipation. If this is insufficient, the body initiates sweating for evaporative cooling. However, if evaporative heat loss fails to restore equilibrium, hyperthermia ensues. On the other hand, the human body reduces blood circulation to the skin to prevent excessive cooling. This process lowers skin temperature and decreases the rate of heat dissipation and surface evaporation. The metabolic rate increases through shivering. If heat loss cannot be sufficiently mitigated, this condition progresses, inevitably leading to hypothermia. Our body employs several regulatory mechanisms to maintain optimum operating conditions.

1.1. Variables Affecting Thermal Comfort

Fanger (1970) combined four environmental variables; air temperature, humidity, radiation, and airspeed, and two personal variables; metabolic rate and clothing level, into a deterministic model that can be used to determine a predicted mean vote and predicted percentage dissatisfied (Spagnolo & de Dear 2003).

- Among two personal variables, metabolic rate refers to the heat produced by the human body. It is associated with two kinds of activities: Basal metabolism which are continuous or nonconscious biological process and muscular metabolism.
- The clothing insulation unit is clo which ranges from 0 (for a body without clothes) to 3 or 4 (for clothing for very cold temperatures like in polar regions). In this regard, 1clo=0.155°C/W. Also, it can be measured in the same units of thermal transmittance (U-value) W/m^2K.
- Air temperature is one of the most important environmental factors that affect thermal comfort. With air movement, air temperature affects the rate of convective dissipation.
- Radiant temperature exchanges between the body and the surfaces that surround it affect thermal comfort. Also, the view angle between the body and the surface has an impact. For

instance, a larger angle of exposure increases radiant exchange. This parameter is indicated by the mean radiant temperature (MRT).

- Air movement affects the evaporation of moisture from the skin. Especially in hot climates, air movement is a useful method to cool the body. It is measured in meters per second (m/s) or feet per minute (ft/min).
- Relative humidity affects the evaporation rate from the skin. A humidity level between 30% and 60% is considered acceptable since it does not have a great effect on thermal comfort.

1.2. Thermal Comfort Model

To assess indoor thermal comfort, Fanger's model was used as the most commonly used method (Fanger, 1970). This heat balance model is a mathematical representation of the thermodynamic equilibrium of the human body. It states that all individuals are alike physiologically, and their comfort can be explained through a physiological perspective. Furthermore, it acknowledges that the comfort zone remains consistent for individuals regardless of location and adaptation (La Roche, 2012). Establishing a numerical system, Fanger introduced two metrics for assessing thermal comfort. First, the Predicted Mean Vote (PMV) is an index that calculates the average value of thermal sensation options on a 7-point scale. This system is based on the heat balance of the human body.

The predicted mean vote is defined as an index that predicts the mean value of the thermal sensation votes of people on a sensation scale (ASHRAE 55, 2013). This scale ranges between -3 to +3 where 0 symbolizes ideal thermal comfort. PMV Scale is expressed via a seven-point thermal scale representing the categories "cold", "cool", "slightly cool", "neutral", "slightly warm", "warm", and "hot". Acceptability is associated with thermal sensations of "slightly warm", "neutral", and "slightly cool" (de Dear & Brager 2002). The PMV value between -0.5 and +0.5 is for typical metrics for thermal comfort (Figure 1). It corresponds to a Percentage of people dissatisfied of <10% (IES-VE, 2018).

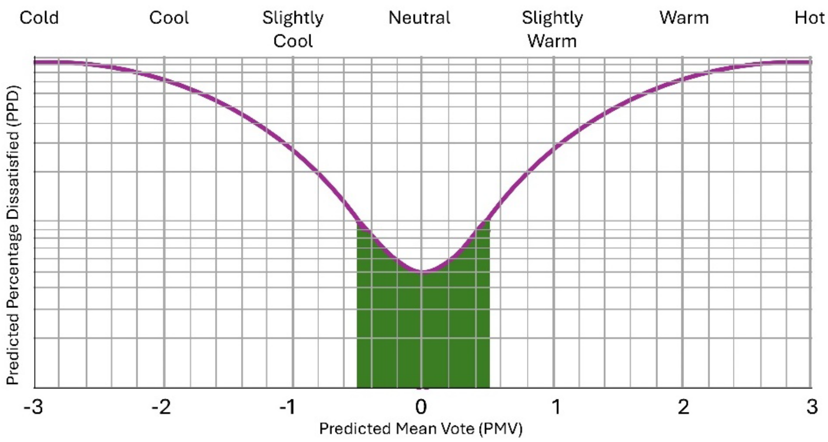

Figure 1. Predicted Mean Vote (IES-VE)

Additionally, Fanger introduced the concept of the Predicted Percentage of Dissatisfied (PPD), which forecasts the average thermal sensation opinions of a large group of people exposed to the same environment. The adaptive method, on the other hand, suggests that occupants can adjust to varying temperatures by interacting with their surroundings, such as by adjusting insulating (clothing) or opening windows. These methodologies for evaluating thermal comfort have become the basis for contemporary international standards, including the ASHRAE Standard 55 (ASHRAE. 2013), ISO 7730 ISO 7730 (ISO, 2005), and EN 15,251 (CEN, 2007). PPD offers a quantitative estimate of the percentage of individuals dissatisfied with their thermal environment, derived from PMV (ASHRAE 55, 2013). PPD is influenced by various environmental conditions including the average air temperature and the mean radiant temperature (Hacker & Holmes, 2007).

1.3. Outdoor Conditions for Thermal Comfort

Studies indicate that outdoor human comfort in urban climates is influenced by a diverse array of human and weather-related factors. Factors such as air velocity, air temperature, relative humidity, and solar radiation play significant roles in determining human preference and overall comfort. Nicolopoulou *et al.* (2001) discuss how characteristics of microclimates impact outdoor urban spaces and influence user behavior regarding comfort. Especially the emphasis on the psychological adjustment of users was identified as a significant aspect.

Stathopoulos (2009) explains the profound correlation between temperature, humidity, and wind conditions. Temperature and relative humidity impact on human comfort is explained through the connection between the heat balance of the human body and sensation. This equilibrium is shaped by metabolic processes and mechanisms of heat dissipation such as conduction, convection, radiation, and evaporation. Heat losses by convection and evaporation are linked to wind conditions, which affect temperature and humidity. In hot regions, the human body requires increased heat loss to maintain thermal comfort. Adjusting the insulation value of clothing and sweating facilitates heat losses associated with the latent heat of evaporation. Since wind speed increases the efficiency of evaporation, wind is a significant parameter in hot climates. Conversely, increased relative humidity diminishes this efficiency (Stathopoulos, 2009).

The effectiveness of cooling via natural ventilation depends on various factors such as peak interior temperatures, humidity, solar radiation, and wind directions. Typically, air temperatures are below the human body's average temperature of 36.5ºC. Cooling occurs in different ways according to wind patterns. If air is still, the heat loss occurs via convection from exposed body parts like the hands and head. Conversely, in breezy conditions, heat loss occurs through conduction, and evaporation also contributes to cooling. The intensity of the wind influences the rate of cooling (Krautheim, 2014). Occupant satisfaction rises when they have control over their surroundings, particularly through operable windows in naturally cooled and ventilated environments (Jones & West, 2001).

A simulation study by Yucekaya and Uslu (2020) examined meteorological parameters in Gaziantep, including air temperature, wind speed, relative humidity, and mean radiant temperature. The findings indicate that during the overheated period, relative humidity remains relatively stable, with no significant differences between the hottest and coldest hours, fluctuating between 45–55%. Furthermore, urban planning decisions directly influence wind dynamics; construction aligned with optimal wind directions can enhance airflow, whereas multi-story buildings reduce wind speed and intensify temperature stress due to the canyon effect (Yucekaya and Uslu, 2020). As stated by several studies (Perini & Magliocco, 2014; Song & Park, 2015; Ali-Toudert & Mayer, 2007; Wania et al., 2012), multi-storey buildings reduce wind speed and increase temperature stress by increasing the canyon effect. It is seen that the hardscapes, such as roads, carparks, and walkways have negative effects on bioclimatic comfort.

2. Methods

The methodology employed in this study is depicted in Figure 2 and schematically described as follows. A case study approach was adopted to examine a social housing project located in a hot and dry climate region of Türkiye. Following a literature review on thermal comfort, indicators for the research were identified. Subsequently, a thermal comfort analysis was conducted to gain insights into the real-world conditions of the selected project in the city of Gaziantep. To comprehensively evaluate thermal comfort in the TOKI Etiler housing project, a mixed-methods approach was employed, combining resident surveys, thermal imaging, and energy analysis. The responses collected from 143 residents through detailed questionnaires provided insights into their behavioural patterns and thermal comfort perceptions during the cooling period. These behavioural characteristics were instrumental in understanding how residents adapted to seasonal temperature fluctuations.

Thermal imaging was conducted during representative summer and winter months to capture temperature variations across the building envelope and identify areas of missing or inadequate insulation. This step was crucial in pinpointing thermal bridges and evaluating the overall effectiveness of the building's insulation systems. Furthermore, energy simulations were performed using the IESVE software, focusing on the thermal performance of individual floors over six months. This analysis quantified the dissatisfaction levels experienced by residents based on Predicted Percentage of Dissatisfied (PPD) metrics, revealing significant variations in comfort levels across different floors. For instance, upper floors demonstrated higher thermal discomfort during peak summer months due to excessive heat gain.

The integration of survey responses, thermal imaging results, and energy analysis allowed for a comprehensive and realistic evaluation of thermal comfort. The combined use of statistical and energy modelling approaches ensured a robust comparison of resident feedback with simulated data, validating the accuracy of the findings. This methodology not only highlights key thermal comfort challenges within the case study but also offers actionable insights for improving the design and performance of social housing projects in similar climatic contexts.

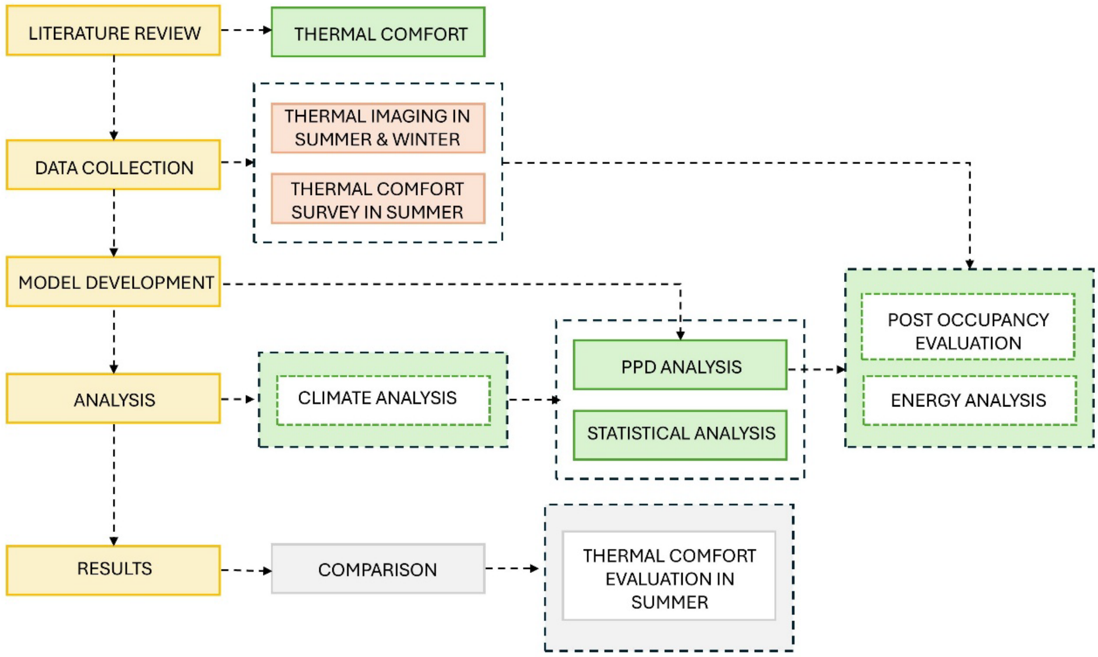

Figure 2. Applied methodology

2.1. Case Study

2.1.1. Location and Climate

Situated in the southeastern Anatolia region of Türkiye, Gaziantep serves as a typical representation of the challenges associated with cooling in hot and dry climatic conditions. The city's topography within a 3-kilometer radius exhibits various elevations, with a maximum difference of 135 meters and an average elevation above sea level of 860 meters. Approximately 52% of Gaziantep's total area comprises mountains, while 27% consists of plains. This topographical diversity engenders a blend of continental climate effects in the north and Mediterranean climate characteristics in the south.

Summers are characterized by heat and dryness, whereas winters are marked by cold and rainfall. Gaziantep has a hot-summer Mediterranean climate with influences of a continental climate. This entails hot, dry summers and cool, wet winters, occasionally accompanied by snowfall (The Köppen-Geiger Climate Classification). Despite low relative humidity levels in the region, the evaporation rate is high during the summer months. Figure 3 illustrates the variation in dry-bulb temperature, external relative humidity, and wind speeds across different seasons. Values increase from blue to red on the key for all parameters. While the highest relative humidity values are observed during the winter months, wind speeds peak in the summer period, particularly in July. A prevailing southwest wind dominates the city's wind conditions. During the summer, the high temperatures are mitigated by breezes that provide a cooling effect. These breezes are of moderate intensity, with an average wind speed of 3 m/s.

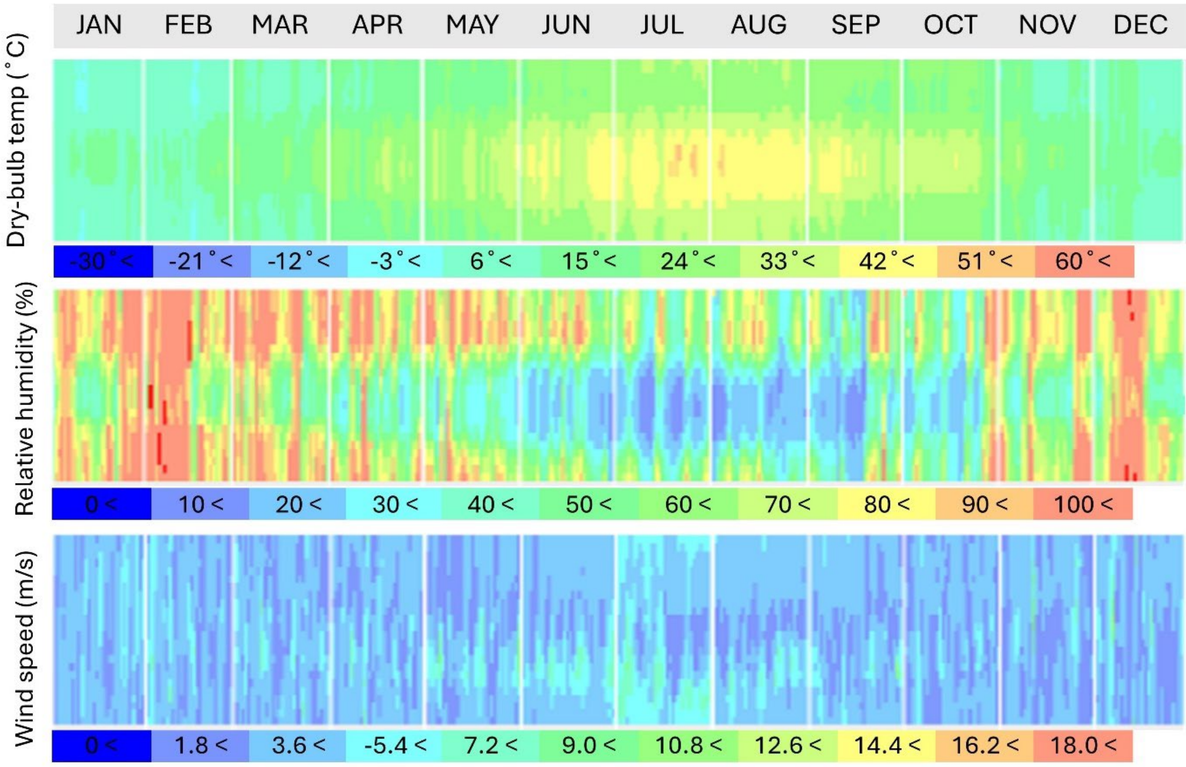

Figure 3. Diagrams for three climate variables in Gaziantep (IES VE)

Based on five-year real-time weather observations from Gaziantep weather stations spanning 2013 to 2018 (Figure 4), this climate is characterized by hot and dry summers with average temperatures exceeding 30°C and lasting up to six months. Conversely, January marks the coldest month with an average temperature of 3.7 °C (Turkish State Meteorological Service). The annual average temperature is 16.4°C. Although May and October are considered 'comfortable' in terms of thermal conditions in the city, daytime temperatures can still climb to 28°C and 24°C, respectively. The temperature differences between day and nighttime bring a cooler and more pleasant sensation during the summer nights. However, heat stress remains a significant thermal issue.

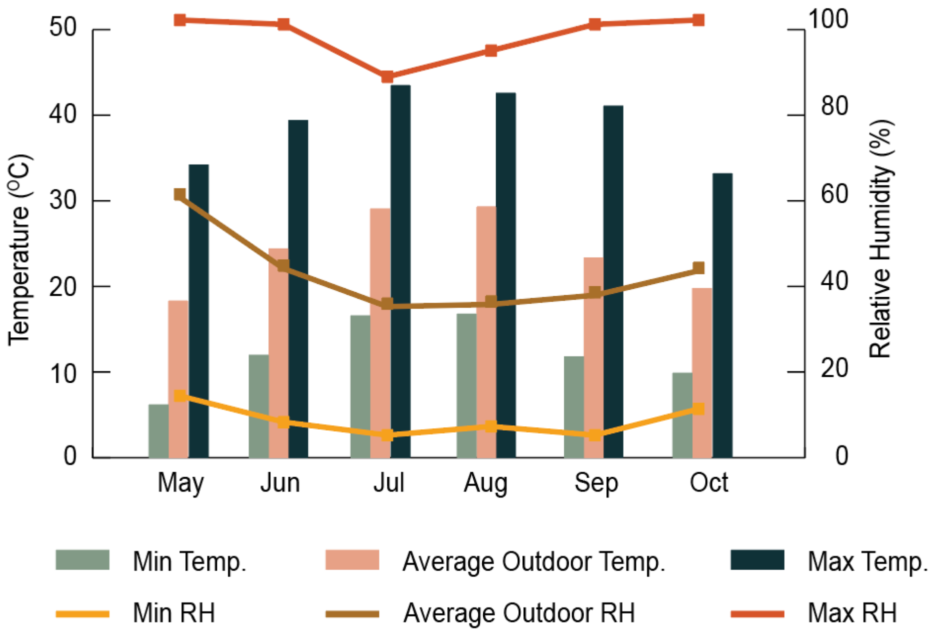

Figure 4. Minimum, maximum, and mean outdoor values during the warmer period in Gaziantep

2.1.2. Population and Social Housing in Gaziantep

The TOKI Etiler project was considered a typical model of TOKI mass housing initiatives for low-income groups in Gaziantep. This city has experienced rapid urbanization and significant population growth over the past decades. In the 1970s, its population stood at around 120,000 people. However, by 2018, the population had surged to over 2.02 million, with an annual growth rate of 4.25% (TUIK). This urbanization has occurred in a largely unplanned manner, leading to haphazard development. Projections indicate that the population will grow to an estimated 3 million in the next 20 years. By 2000, Istanbul had become the largest city with over 10 million inhabitants, followed by Ankara, Izmir, Bursa, Adana, and Gaziantep. Today, these numbers show an increment in these cities between 20-40% and just with Gaziantep reaching 56% growth in the last two decades (Table 1).

Table 1. Gaziantep Population 1990-2018 (Turkish Statistical Institute 2019)

Name	Population 2000	Population 2010	Population 2018	Growth 2000-2018 %
Istanbul	11.076.840	13.255.685	15.067.724	36
Ankara	3.889.199	4.771.716	5.503.985	41
Izmir	3.431.204	3.948.848	4.320.519	25
Bursa	2.150.571	2.605.495	2.994.521	39
Adana	1.879.695	2.085.225	2.220.125	18
Gaziantep	1.292.817	1.700.763	2.028.563	56

Despite this substantial growth, urban planning measures in Gaziantep have been limited. The most recent city growth plan dates back to 1974. As a result, local municipalities have relied primarily on zonal plans as a means of controlling urban expansion (ECA Sustainable Cities Report, 2013).

Figure 5. Growth along the Southern border of Gaziantep, 2009 (top) -2019 (bottom) (GoogleEarth)

The rapid expansion of Gaziantep places considerable strain on land markets, housing markets, and public service infrastructure. This unplanned growth also contributes to energy efficiency shortcomings, particularly due to the emergence of new developments without proper planning. Like many other major Turkish cities, Gaziantep has witnessed the rise of informal settlements on available land to accommodate both domestic and incoming populations. Additionally, high gasoline prices in Türkiye discourage outward expansion and suburban-type developments (Figure 5). Consequently, the city's developed area has reached a population density of approximately 3,750 people per square kilometer (ECA Sustainable Cities Report, 2013).

Considering the European Commission's (Florczyk et al., 2019) description of high-density urban centers worldwide as areas characterized by at least 1,500 inhabitants per km² of land or a built-up surface covering at least 50% per km² (including roads and infrastructure), with a total population of at least 50,000, Gaziantep's population density is relatively high. By 2017, the number of these residences in Gaziantep has reached 25,000 due to the need for accommodation for former informal housing residents (TOKI). Since the great numbers of the same housing typology produced by the Mass Housing Administration in Türkiye, the Etiler Project in Figure 6, serves as a representative model of the multifamily buildings TOKI produces.

Figure 6. TOKI Etiler project during and after construction. [Photos by Aydın Insaat, n.d (top) and Bay-Şahin, 2019 (bottom)].

2.1.3. Building Description

The selected TOKI Project, constructed in 2012, aimed to accommodate low-income families displaced during the '*gecekondu* (informal housing in Turkish) clearance' phase of an urban renewal program. (Gaziantep27, 2017). The selection of residents was conducted jointly by the TOKI agency and local municipalities, based on criteria such as economic status and demographic details of the families. The Etiler project comprises six residential blocks distributed randomly on an irregular plot (Figure 7). The project consists of 12 story blocks with a total of 48 identical units. Like many social housing projects in Türkiye, it prioritizes less dense land utilization and offers larger outdoor spaces. However, concerns regarding pedestrian discomfort because of the harsh summer conditions resulted in limited usage of these outdoor areas.

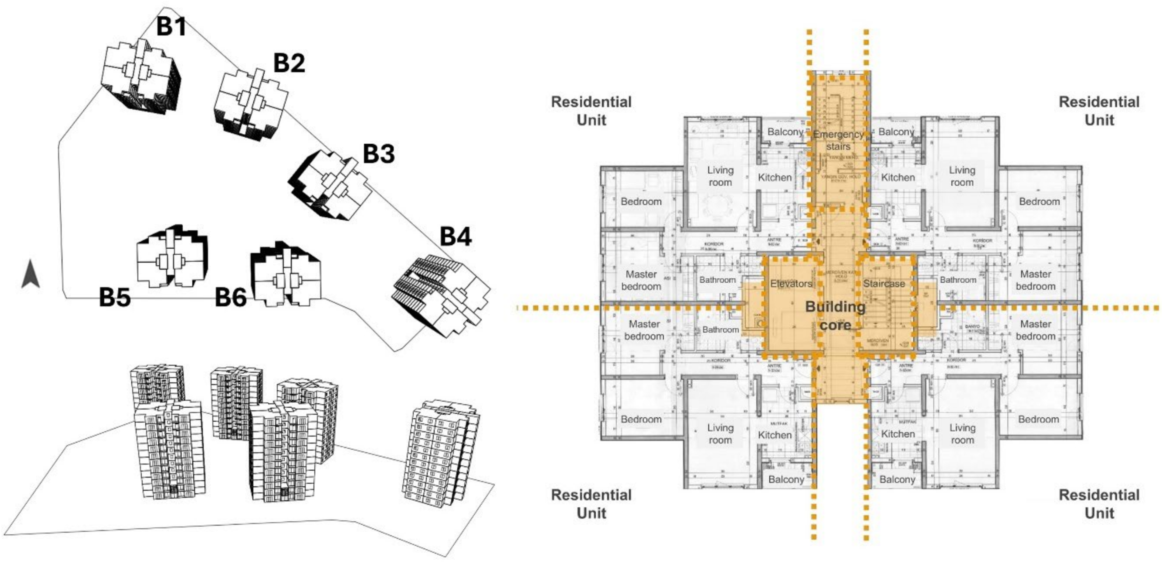

Figure 7. TOKI Etiler project and a typical floor plan

The Etiler Project, within a site spanning 18.506,63m², features two different block types that have 296 identical housing units. Two blocks, each with twelve stories and a basement, were complemented by an additional basement floor in the other four blocks, accommodating two extra units. Each floor has a plate area of 346m² with the ground floor slightly larger (359.2m²) due to the entrance. The building follows a residential unit prototype with a central core developed by TOKI. Each apartment unit, with a volume of 232m³, has an average of 67m² enclosure area facing the exterior (Table 2). These units incorporate naturally conditioned spaces, allowing residents to regulate thermal conditions. The window-to-wall ratio is obtained as 0.14. The units in the Etiler project include side-hung and fixed windows. Since each opening is divided into flow and non-flow regions, the openable area is 80% after accounting for the removal of the window frame. Each floor comprises eight thermal zones including four residential units along with a staircase, an elevator, a corridor, and emergency stairs. The floor-to-floor height is 2.9m.

Table 2. TOKI Etiler Building specifications

a) Unit dimensions		b) Specifications of windows	
Floor area (m²)	80.32		Openable area (%)
Volume (m³)	232	Side hung window	80
Ext wall area (m²)	67		
WWR	0.14	Fixed window	0
c) Specification of the building envelope			
Building components	Material	Thickness (m)	U-value (W/m²K)
Exterior walls	Cast concrete (C30/37)	0.28	0.433
Interior walls	Cast concrete	0.10	1.099
Floor	Concrete	0.2	0.453
Roof	Concrete	0.1	0.263
d) Specification of the building openings			
Windows (Double- glazed, clear float with air-filled cavity)	SHGC	Visible light normal transmittance	U-value (W/m²K)
	0.75	0.8	3

In contrast to most mass housing examples, these blocks lack a centralized area designated for communal services (Givoni, 1991). However, the project features limited collective spaces concentrated at the center of the project except a playground for children and benches for socializing. There are 148 parking spaces located along the perimeter streets and within the inner part of the site. This allocation translated to one parking space per two dwellings within the 296-unit project.

Access to the units is provided through the core on each floor. Within the core, two elevators are centrally positioned while the main staircase and emergency staircase are situated on opposite edges of the floor. The project does not offer various types of housing; instead, each unit is uniform, featuring two bedrooms, one living room, one kitchen, and one bathroom. Additionally, units have a balcony. Although the first level mirrors the layout of other floors, except the building entrance, four units on this floor do not have direct access to the street level.

2.1.4. Thermal Comfort Survey and Statistical Analysis

To comprehend the factors influencing residents' thermal preferences, a survey was conducted in August 2019 within the TOKI Etiler Project. The sample surveyed was obtained through voluntary participation during the field study. The demographic characteristics of the interviewed residents were assessed for correlation with information related to thermal related questions and opinions on natural ventilation. Therefore, data on gender, age, first occupancy, and ownership status were collected. At the time the questionnaires were administered, the majority of participants were adult women with over half being 'first occupants' and 'owners' of their units.

In the data analysis aimed at understanding the dynamics of thermal comfort, the proportion between women (125) and men (18) and the 'age range' were taken into account (Figure 8). Additionally, information related to 'clothing values' and 'metabolic activities' was also observed. Within the sample, the predominant group falls within the age range of 18 to 50 years old.

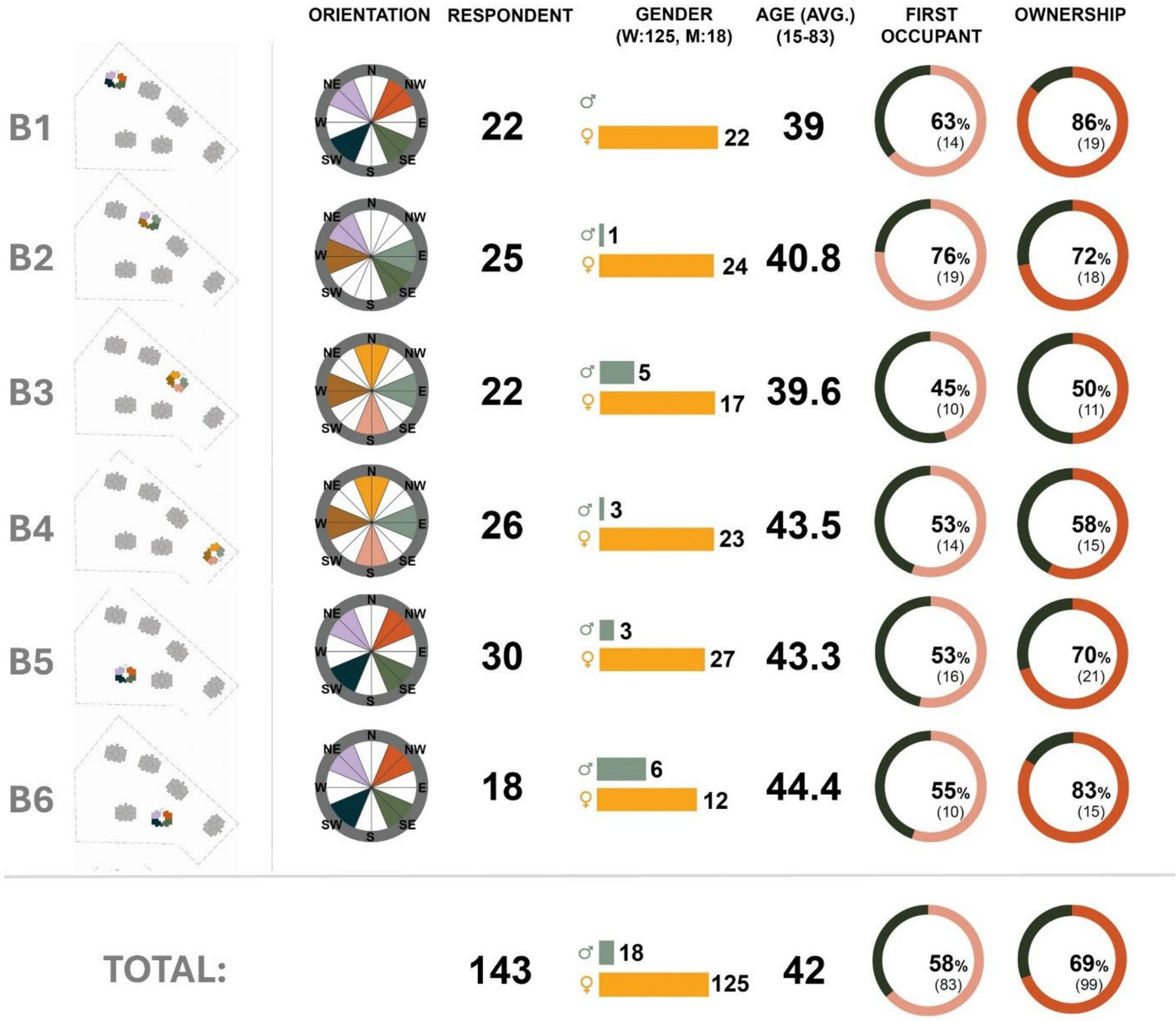

Figure 8. Residents' demographic and unit information

The questionnaire was designed according to the socioeconomic level of residents. It was translated into Turkish, as it is the primary language spoken by the residents of the TOKI Etiler project. To ensure clarity and avoid any issues related to natural ventilation and thermal comfort conditions, the questionnaires were distributed exclusively to adults aged 18 years and above. Respondents completed the questionnaires either at the central core of their floor or within their apartment unit if they permitted the researcher to enter.

Interviews were carried out between 10 am to 5 pm over two months (July and August 2019). A total of 143 respondents out of the 288 residents participated, representing their households during the study period. The questions aimed to gather comprehensive information about occupants' opinions on thermal comfort, behavioral patterns related to natural ventilation, and overall satisfaction with their living environment during the survey period. The questionnaire covered the following topics:

- Age (Also, bands arranged as 18-30, 31-40, 41-50, 51-60, 61-70, and 71+.) and family size.

- Block (B1, B2, B3, B4, B5 or B6), unit level (1 to 12), and unit orientation (N, NE, E, SE, S, SW, W, NW, N)
- Residents' information (whether the resident owns the unit and whether he/she is the first occupant of the unit)
- Type of previous dwelling (apartment unit/house) and residents' future expectation
- Indoor and outdoor Thermal Sensation Vote (TSV) according to ASHRAE 55's seven-point sensation scale (-3, -2, -1, 0, +1, +2, +3) from very dissatisfied to very satisfied
- Existing clothing preference based on ASHRAE 55 (including choices in the answer options)
- Having air conditioning in residential units or not

Following the survey, the collected data, consisting of categorical and ordinal variables, was tabulated and analyzed using the SPSS 21 software package. Findings about user profile, block location, unit level, and unit orientation were presented by calculating the frequency and percentage distribution of the coded data. A one-way analysis of variance (ANOVA) was employed to examine whether the mean values of thermal sensation, unit level, family size, and summer clothing differed significantly from each other. Furthermore, correlation analysis was conducted to assess the relationship between two normally distributed interval variables, namely airflow performance and thermal sensation.

3. Findings and Discussion

3.1. Infrared Thermography Images in TOKI Etiler Buildings

Thermal imaging was utilized as a method to observe thermal insulation within the studied residential blocks. A thermal imaging camera connected to a smartphone was used to capture surface and window temperatures both in the winter and summer seasons. The iron (FLIR) color palette was used to visualize the images. This setting displays the purples and blacks as cold areas and uses warm colors such as yellow and white to show warm areas. Thermal images taken during both the summer and winter periods were transferred to a computer and analyzed to identify significant thermal bridges and surface temperature differences.

During the thermal imaging phase of the study, a representative unit in Block 3 was selected to analyze the worst-case scenario during the summer. The availability of airflow is a key factor in the performance of natural ventilation. Given that Block 3 is centrally located among the six surrounding blocks, it experiences the most significant airflow restrictions, making it the least advantageous in terms of natural ventilation. Figure 9 shows the surface temperatures at 3:30 pm in Block 3. The selected unit has facades oriented southwest and northwest. The surface temperature of the southwest wall in the unit's balcony was recorded at 31°C, while the window temperature was approximately 35°C (Figure 9a).In the apartment layout, each bedroom and the living room are equipped with one operable window, while the kitchen lacks any windows. However, the kitchen has a glazed balcony door as the sole opening. As shown in Figure 9, it's worth highlighting that during the daytime, over 95% of families utilize the balcony door, making it the primary opening for ventilation both during the day and at night. As anticipated, bedroom windows are predominantly open during nighttime. Interestingly, they are also utilized in the mornings and afternoons by more than 65% of families (Figure 9b).

Figure 9. Surface and glazing temperatures in Block 3 units in July, a. Kitchen (SW), b.Bedroom (NW), c. Corridor, d. Living room (NW)

Figure 10 displays the thermal image of the southeast façade of Block 3 bedrooms which was taken from a residential unit in Block 4. This data related to exterior wall surface temperatures was recorded during the early afternoon. Since July is the warmest month when the highest outdoor temperatures and lowest humidity levels are seen during the cooling period in the city. As seen in Figure 10, the wall surface temperature was recorded as 41.6°C at 1 pm.

Figure 10. Exterior wall temperature on the southeast façade of Block 3 in TOKI Etiler in July

The thermal image taken in December at 5 pm shows temperature variations of the walls in Figure 11 that might be the result of gaps in insulation or insulation bridged by other building materials. Thermal bridging is a significant problem that typically occurs in the insulation area of the external construction layer. In these two thermal images taken during the winter, the brighter yellow areas at the center of the façade indicate a higher surface temperature in these places, suggesting higher local heat loss. This inconsistency in insulation installation could be attributed to gaps between the insulation batts in certain areas of the cavity or the accumulation of mortar debris (NHBC Foundation, 2020).

Figure 11. Exterior wall temperature on the southwest (left) and southeast (right) façades of Block 3 in TOKI Etiler in December

3.2. SPSS Statistical Analysis for Thermal Comfort Evaluation

To investigate the relationship between unit orientation and users' thermal perception, respondents were queried about whether they observed minor thermal-related issues (cooler conditions during warm periods) in other apartment units within six TOKI blocks of the Etiler Project. The sample of the survey comprised 143 participants from various households across different blocks, unit levels, and unit orientations within the residential project. The feedback collected was analyzed according to these variables. Also, open-ended questions encouraged residents to provide deeper, more detailed responses during one-on-one discussions.

Overall, the distribution of respondents was consistent across all six blocks of this residential project. Additionally, a similar number of households were interviewed per level. When researchers asked whether they were satisfied with their unit's orientation compared to their neighbors' units, 28% of respondents drew comparisons and complained about excessive heat gain during the warm period. They reported that other apartments were cooler than their units during the summer season. These 40 respondents included 13 residents living in southwest-facing units in Blocks 1 and 5, 9 residents living in southeast-facing units in Blocks 1, 2, and 6, and 18 residents living in south-facing units in Blocks 3 and 4.

Inside their units, it is observed that some residents undertake modifications that are related to passive strategies to adapt their living spaces to achieve thermal comfort, particularly during the hot summer months. They rely on natural ventilation methods to deal with the high temperatures during the summer months in Gaziantep.

To understand user behaviors regarding thermal adaptation during warm periods inside their units, residents were presented with multiple options for cooling methods and asked to select their preferred choices. The options included 'opening windows,' 'opening their apartment door,' 'using fans,' 'using air conditioning units,' and 'keeping windows closed.' The survey revealed that the most commonly utilized method for cooling was the operation of windows and the apartment door to enhance cross ventilation through the units. However, occupants prefer spending time in building hallways when cross ventilation is not enough to enhance their thermal comfort (Figure 12).

Figure 12. Occupants when cross ventilation is insufficient, July 2019

Our previous work (2019) showed that with a central heating system (a hot water boiler with radiators in each unit), a significant proportion of residents report a 'warm' thermal sensation during cold periods, even when wearing light clothing. During the summer months, over 60 percent of residents experience a thermal sensation above neutrality despite also wearing light clothing. Also, a 'Likert-type' scale is used to measure the attitudes of surveyed occupants (Figure 13). Through this assessment, the thermal satisfaction level of interviewed residents was recorded, with only 13.9% expressing an 'acceptable satisfaction' (above neutral) with their indoor thermal conditions. Conversely, 68.6% of residents indicated dissatisfaction/below neutral with indoor areas (13.4% very dissatisfied, 7.7% dissatisfied, 47.6% slightly dissatisfied, 17.5% neutral, 7.7% slightly satisfied, 5.6 % satisfied, and 0.6% very satisfied). Similarly, residents were asked about their overall satisfaction levels regarding their units and the outdoor environment within the TOKI Etiler Project. The results revealed that 68.6% of the total residents reported a unit satisfaction level below 'neutral.' Additionally, 57.3% of the population expressed being 'very dissatisfied' with outdoor areas in the Etiler project while 17.4% and 5.5% expressed 'dissatisfied' and 'slightly dissatisfied', respectively (Bay, 2019).

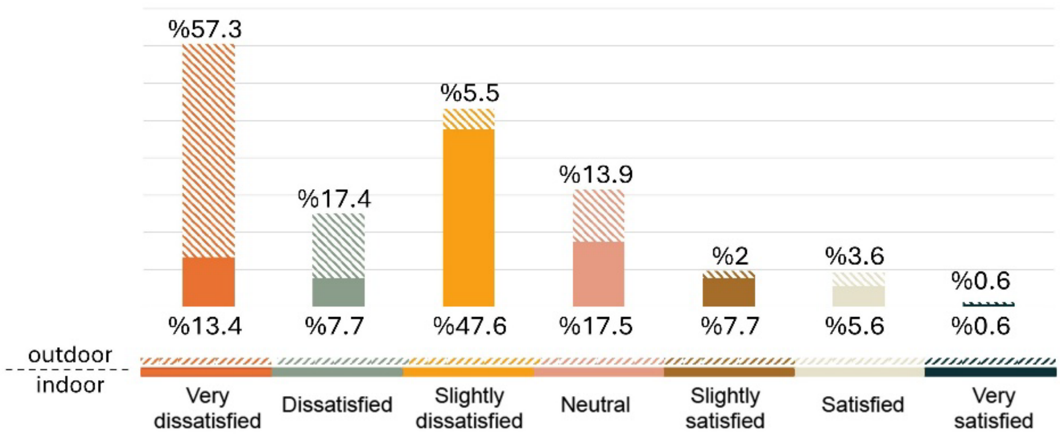

Figure 13. Likert-type scale for thermal comfort survey

Following the surveying process, the collected data (categorical and ordinal) was tabulated and analyzed using the SPSS 21 software package. In the SPSS output, the model summary section typically includes several key data points. This data includes:

- Demographic information such as age, gender, and family size;
- Homeownership details such as whether the respondent is the first occupant of the unit, previously lived in a low-rise building, or previously had a garden;
- Unit features such as the block name, unit orientation, floor, etc. Findings related to user information and unit features were derived through the calculation of frequency and percentage distributions of the coded data.

The correlation coefficient (R) indicates the strength and direction of the linear relationship between the observed and predicted values of the dependent variable. The R-square value represents the proportion of variance in the dependent variable that can be explained by the independent variables. Adjusted R-square is a modified version of R-square that adjusts for the number of predictors in the model and provides a more accurate estimate of the proportion of variance explained by the model in the population. Lastly, the standard error of the estimate quantifies the average distance between the observed and predicted values of the dependent variable.

The linear regression analysis in Figure 14 was used to interpret the relationship between air flow performance and thermal sensation. The R-square value indicates that 12.8% of the variance in the thermal sensation can be predicted from the independent variable “airflow performance”. However, the adjusted R-square provides a more reliable estimate of the R-square for the population, accounting for potential overfitting or underfitting issues in the model (UCLA - IDRE).

Independent variable — **Dependent variable**

(x) Air flow performance → **(y)** Thermal sensation

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	,357[a]	,128	,122	1,179

a. Predictors: (Constant), Nat_Vantilation

12 percent of the variance of the thermal sensation is predictable from air performance.

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	28,729	1	28,729	20,658	,000[b]
	Residual	196,082	141	1,391		
	Total	224,811	142			

a. Dependent Variable: Thermal_Comfort

b. Predictors: (Constant), Nat_Vantilation

P value < 0.01

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	2,162	,265		8,156	,000
	Nat_Vantilation	,406	,089	,357	4,545	,000

a. Dependent Variable: Thermal_Comfort

Positive relationship: If air flow performance increases, thermal comfort satisfaction also rises.

Figure 14. Linear regression analysis

In the Anova table, the sources of variance include Regression, Residual, and Total. Regression represents the variance that can be explained by the independent variables included in the model, while Residual represents the unexplained variance that remains after accounting for the independent variables. Total variance encompasses all variances in the independent variable. As shown in Figure 14, “Sig.” The column in the Anova table represents the p-value associated with the F statistics (IBM

SPSS, 2012). This p-value indicates the probability of observing the obtained F value (or a more extreme value) if the null hypothesis is true or if the independent variables do not have any effect on the dependent variable. If this value is smaller than the alpha level which is typically 0.05, it can be concluded that the independent variables reliably predict the dependent variable. If not, it means that the selected independent variables do not reliably predict the dependent variable.

Gürbüz and Şahin (2014) explain the correlation relationship levels as weak between 0 – 0.30, medium between 0.30 – 0.70, and strong between 0.70 – 1. Since R is between 0.30 and 0.70, the correlation coefficient (0.357) indicates a moderate positive relationship between air flow performance (independent variable) and thermal comfort (dependent variable). The coefficient of determination (0.128) shows that approximately 12.8% of the variation in thermal comfort is explained by air flow performance. Adjusted for the number of predictors, it is 0.122, meaning 12.2% of the variance is explained when accounting for model complexity. The F-value of 20.658 indicates that the model significantly predicts thermal comfort. The standard coefficients, or Beta, suggest that as airflow performance increases, there is a corresponding rise in thermal comfort satisfaction within this climate region (Figure 14). This can be interpreted that if air flow performance increases, the thermal comfort satisfaction level rises. The p-value (0.000) indicates that the air flow performance significantly impacts thermal comfort. Overall, the model is reliable, as indicated by the low p-value and moderate F-statistic.

Thermal sensation and **Unit level**

H1: There is a **statistical difference** between thermal sensation and unit level.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	15,881	2	7,940	5,321	,006
Within Groups	208,930	140	1,492		
Total	224,811	142			

P value < 0.01

Thermal sensation and **Family size**

H2: There is a **statistical difference** between thermal sensation and family size.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	14,013	2	7,007	4,653	,011
Within Groups	210,798	140	1,506		
Total	224,811	142			

P value < 0.05

Thermal sensation and **Summer clothing value**

H3: There is a **statistical difference** between thermal sensation and summer clothing value.

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	79,316	6	13,219	4,183	,001
Within Groups	429,802	136	3,160		
Total	509,119	142			

P value < 0.01

Figure 15. Anova test

ANOVA test was used to determine if the mean values of thermal sensation, unit level, family size, and summer clothing value are statistically different from each other. Although there was no environmental monitoring in the units, this statistical analysis helped to understand whether unit level, family size, or clothing value of residents in summer influences users' thermal sensation. For instance, upper floors typically experience more heat due to greater exposure to sunlight, while lower floors might be cooler due to shades. Variations in airflow can impact thermal comfort differently depending on the unit level. The second hypothesis indicates a statistical difference between thermal sensation and family size. It means that the perception of thermal comfort significantly varies depending on the size of the household. Larger families lead to more internal heat generation which could elevate thermal sensation levels and people feel warmer. The last hypothesis in Figure 15, suggests that the thermal sensation varies significantly based on the type or amount of clothing worn during summer since clothing plays a key role in thermal regulation. Lighter or thinner clothing allows the body to cool more efficiently, which could lead to a lower perception of heat. On the other hand, people who wear less clothing are likely to experience less thermal discomfort than those wearing more covering clothing.

Overall, the ANOVA test confirmed the hypothesis that all groups of variables are indeed statistically different from each other (Figure 15). Furthermore, both the linear regression analysis and the Anova test confirmed that the current airflow conditions in the project effectively explain the issue of overheated indoor environments.

3.3. PPD Analysis

To comprehend residents' satisfaction levels under these climatic conditions, the Predicted Percentage of Dissatisfied (PPD) values for each of the six blocks were documented over one year using energy simulations. Through a visual comparison, PPD values obtained in each block were similar, despite the varying orientations and spatial configurations across the studied plot.

For the whole-year energy analysis model, a simplified geometry was modeled following the original drawings of this residential project using IES VE simulation software. It was used in many scientific publications to conduct building performance analysis (Iskandar *et al.,* 2024; Bay *et al.* 2022; Elzeyadi & Batool, 2017; Lau *et al.*, 2016). After building the model in IES VE, different modules of the software were used to perform an energy simulation. The *Apache* as a Dynamic Simulation Module (DSM) evaluates thermal comfort performance. The required weather data for the energy simulations was obtained from the Gaziantep Airport weather station (TMY3 weather file) by IES VE.

During the cold period, the 'heating setpoint' was maintained at 21 ºC, resulting in PPD values of less than 10%. On the other hand, during the hot period, no mechanical cooling systems were utilized. In this scenario, the highest levels of dissatisfaction were observed for more than 50% of the time, particularly in July and August. The PPD values were obtained from May to October for each floor level. It was observed that the top-floor units exhibit higher dissatisfaction levels compared to the other eleven floors in the twelve-story building. The highest level of 'dissatisfaction' reaching 45.9 %, was recorded in August. The PPD values fluctuated between 5.9% to 7.1% during May and October. However, this range increases significantly from 11.7 % in September and 18.8 % in June. As the 'heat stress' rises during the two warmest months of 'July and August', the minimum number of people experiencing dissatisfaction rises to 36.7% (Table 3).

Table 3. Percentage of People Dissatisfied (PPD) values per floor (mean)

Floor	May	Jun	Jul	Aug	Sep	Oct
12	6.5	18.8	42.2	45.9	13.9	7.1
11	6.0	15.8	37.4	41.0	12.1	6.7
10	5.9	15.4	36.7	40.3	11.8	6.6
9	5.9	15.5	36.7	40.3	11.8	6.6
8	6.0	15.8	37.3	41.0	12.2	6.6
7	6.1	16.2	38.0	41.5	12.4	6.5
6	6.0	15.9	37.5	41.3	12.1	6.4
5	5.9	15.7	37.3	41.1	11.9	6.3
4	5.9	15.7	37.3	41.1	11.8	6.2
3	5.9	15.7	37.5	41.3	11.7	6.2
2	6.1	16.4	38.2	42.0	12.1	6.3
1	6.3	17.5	39.9	43.5	12.8	6.5

The majority of units in the Etiler Project face northwest and southeast, similar to the units in Blocks 1, 2, 5, and 6. Consequently, representative units located on the northwest and southeast orientations were selected for the PPD analysis. Furthermore, PPD is exemplified by two typical units located on the northwest (NW) and southeast (SE) sides on the third level on which there are thermally advantageous units between upper and lower-level apartments. During May, July, and August, residents in both NW and SE units have higher satisfaction levels during May. SE units consistently display higher PPD values across May, June, and July, primarily due to increased 'solar gains' and lack of 'shading'. Also, 'dissatisfaction' values in the SE unit peaked at 60 % in June.

4. Discussion and Conclusion

This study examines the contemporary urban dynamics of Gaziantep, a southeastern city in Türkiye, where recent migrations have led to an unprecedented demand for housing. The research employed a Thermal Comfort survey to assess the level of comfort perceived by individuals in low-income housing. The findings of the Post-Occupancy Evaluation (POE) presented in this study were derived from a high-rise residential project in Gaziantep, encompassing a total sample of 288 apartment units. The findings provided insights into the current thermal environment within these residential units. This information was gleaned from users' detailed responses regarding indoor and outdoor microclimate conditions.

The spatial and thermal needs/preferences expressed by the TOKI residents in the POE were identified as key 'environmental' objectives. Findings related to air velocity, indoor temperature, and predicted percentage of dissatisfied (PPD) were aimed at addressing the technical aspects required in a naturally ventilated building. Passive cooling strategies help alleviate thermal stress and reduce electricity consumption. Olgyay (2015) mentions that the possibility of better living conditions and improved thermal environments can be achieved at lower costs by minimizing reliance on mechanical conditioning systems. This can be accomplished by designing structures that effectively harness natural resources to mitigate undesirable stresses and create environments conducive to human comfort.

The findings highlight the significant influence of outdoor climatic conditions on residents' reported thermal sensation. During the cooling season, residents reported higher dissatisfaction with indoor temperatures, primarily due to the absence of mechanical ventilation or cooling systems. Consequently, residents rely on natural ventilation strategies, such as operable windows and doors, to regulate indoor temperatures. Incorporating resident feedback on thermal preferences and clothing values into simulation models provides a more comprehensive understanding of thermal dynamics in social housing. This holistic approach integrates outdoor conditions, occupant behaviour, their preferences, clothing choices, and adaptive strategies contributing to provide a more detailed analysis of indoor comfort.

To enhance sustainability in social housing design, architectural strategies should prioritize minimizing environmental impact while fostering a high-quality living environment. This can be achieved by incorporating collective and multifunctional spaces with diverse programs, which foster community integration with the urban fabric. A balanced approach between private dwellings and communal areas is essential, facilitated by flexible living spaces that adapt to residents' evolving needs. Additionally, building shapes and compactness should be carefully considered in response to the climatic context. By achieving climate balance - through optimized air movement, shading strategies, and material selection - buildings can be designed to enhance occupant satisfaction across diverse climatic regions in Türkiye.

This research contributes to understanding the local climatic conditions in Gaziantep and their influence on resident behavior and adaptation strategies. The field study provided an effective methodological approach to investigate and understand issues or challenges in real-world settings. The findings offer practical insights into the impact of spatial configurations on indoor microclimates and resident satisfaction levels. By providing a scientific diagnosis of indoor environmental conditions in TOKİ residential projects, this study contributes to evidence-based decision-making for social housing design. In particular, it highlights the advantages of natural ventilation as a cost-effective and sustainable passive cooling strategy for thermal comfort.

Considering the climatic characteristics of Gaziantep, including hot and dry summers, cold winters, and high diurnal temperature variations, housing design should aim to minimize excessive heat gain and reduce thermal losses. Implementing shading devices and solar energy solutions can significantly reduce cooling demands, while evaporative cooling techniques, such as incorporating water features in outdoor spaces, align with the region's traditional vernacular principles. A major challenge in existing housing stock is thermal inefficiency due to poorly insulated envelope designs and thermal bridges. Improved insulation strategies should be prioritized to enhance building performance. The widespread use of concrete and petroleum-based products raises environmental and health-related concerns, emphasizing the need for eco-friendly materials.

Furthermore, building typology and urban form significantly impact thermal comfort. Instead of adopting a "one-size-fits-all" approach, housing developments should be tailored to local environmental conditions to optimize indoor climate regulation. This raises critical questions regarding alternative low-rise or mid-rise housing, which may offer better thermal performance than conventional high-rise developments.

The study acknowledges limitations in its data collection methodology. As stated in ASHRAE Standard 55, thermal comfort is a condition of mind that reflects satisfaction with the thermal environment. Due to its subjective nature, thermal comfort can vary for each individual, influenced by factors such as age, gender, metabolic rate, clothing preferences, and adaptation. Data collection for this study was conducted during the daytime, resulting in a non-homogeneous gender distribution among participants. Specifically, 87.4% of respondents were women due to the selected survey timing. This imbalance may limit the generalizability of findings concerning gender-related variations in clothing insulation, thermal adaptation, and comfort perception.

For future investigations into natural ventilation and thermal comfort in social housing in Türkiye, research could be expanded by incorporating indoor and outdoor environmental monitoring to enhance data accuracy. Expanding this methodology to different climate regions in Türkiye would provide broader insights into climate-responsive social housing. Additionally, integrating computational modeling with field measurements can further validate findings and refine passive cooling strategies.

In addition, given the county’s diverse climate conditions, various passive strategies can be effectively implemented to enhance thermal comfort in social housing. For instance, optimizing building orientation by aligning facades perpendicular to prevailing winds can significantly improve natural ventilation. In addition, incorporating courtyard configurations in dense urban areas can create shaded and ventilated microclimates. The use of high-thermal mass materials is beneficial in hot and dry regions like Gaziantep, as these materials regulate indoor temperatures by mitigating diurnal temperature variations. Moreover, passive solar control through deep overhangs, adjustable louvers, and green facades can effectively reduce solar heat gain, which is especially critical in humid regions. Enhancing airflow through double-skin facades, ventilated atriums, and windcatchers can further improve natural ventilation. Additionally, cool roofs and reflective surfaces like whitewashed buildings minimize heat absorption. By integrating these passive design strategies into social housing projects, a more climate-responsive and cost-effective approach can be achieved, ultimately improving occupant comfort while reducing energy consumption.

Overall, this study reinforces the importance of passive cooling strategies in improving indoor thermal comfort while reducing energy demand. In cities like Gaziantep, where urban heat mitigation is a priority, integrating bioclimatic principles into social housing and urban planning can enhance liveability, sustainability, and occupant well-being.

Author Contribution and Conflict of Interest Declaration Information

The authors declared that there is no conflict of interest.

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