

POST OCCUPANCY EVALUATION OF INDOOR ENVIRONMENTAL QUALITY WITH A FOCUS ON THERMAL COMFORT IN A GREEN OFFICE BUILDING

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by

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**POST OCCUPANCY EVALUATION OF INDOOR
ENVIRONMENTAL QUALITY WITH A FOCUS ON
THERMAL COMFORT IN A GREEN OFFICE BUILDING**

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ABSTRACT

Workplace environments are transforming in line with up-to-date concepts in office building design and technological developments in today's world, where people spend most of their time indoors. In this context, sustainability in the built environment emerges as a frequently adopted concept in design and construction approaches. Green certification systems, developed to evaluate environmental sustainability in buildings, play a decisive role in implementing this concept.

Indoor environmental quality (IEQ) is one of the factors considered in the environmental sustainability assessment by green building certification systems. Specifically, for commercial buildings, indoor environmental quality is often associated with employees' health, productivity, work efficiency, and consequently, economic gain. However, many post-occupancy evaluation (POE) studies, conducted in green-certified office buildings where energy efficiency is prioritized, report various problems related to indoor environmental quality by the users. To address this issue, this thesis aims to analyse indoor environmental quality in a green-certified office building.

The research was conducted for a green-certified, multi-story office building located in Istanbul. To investigate the indoor environmental quality, particularly the thermal comfort perception of the occupants, a post-occupancy evaluation study was carried out. The methodology of the study consists of literature review, identification of research questions, selection of the case study building, survey design, data collection (document collection, surveys, personal interviews), analysis of results and overall evaluation.

The survey prepared for the occupants focuses on thermal comfort but also includes other components that determine indoor environmental quality, such as visual comfort, acoustical comfort and indoor air quality. In this regard, it aims to gather information on occupant's awareness level regarding the sustainable building concept, their behaviours in relation to it and their experiences and satisfaction with indoor environmental quality. To achieve this goal, the survey presented to the occupants includes various types of questions.

The data obtained through the survey and the personal interviews conducted in this thesis study were evaluated comparatively. The findings indicate that the building occupants who participated in the survey voted for high satisfaction with indoor environmental quality initially. However, in personal interviews, it was frequently observed that occupants reported complaints about thermal discomfort and other indoor environmental quality problems.

The findings also show that an increase in occupant awareness levels brings about more sensitive behaviours in terms of sustainability. In this respect, the results underline the importance of awareness-raising activities on the subject.

While the findings of the study are specific to the field study addressed, the methodology followed in the study can be applied to different buildings. This way, it can contribute to improvement of occupant experience and promotion of sustainable practices.

ÖZETÇE

İnsanların zamanının büyük bölümünü kapalı ortamda geçirdiği günümüzde, iş yeri ortamı, ofis binası tasarımında izlenen güncel konseptler ve teknolojik gelişmelere paralel olarak dönüşüm geçirmektedir. Bu çerçevede, yapılı çevrede sürdürülebilirlik, tasarım ve yapım yaklaşımlarında sıklıkla benimsenen bir konsept olarak karşımıza çıkmaktadır. Binalarda çevresel sürdürülebilirliğin değerlendirilmesi amacıyla oluşturulmuş yeşil sertifika sistemleri bu konseptin uygulamaya aktarılmasında belirleyici rol oynamaktadır. Kapalı mekanlardaki iç ortam kalitesi, yeşil bina sertifika sistemleri tarafından çevresel sürdürülebilirlik değerlendirmesinde dikkate alınan etmenlerden biridir. Ticari binalar söz konusu olduğunda, iç ortam kalitesi sıklıkla çalışanların sağlığı, üretkenlik, iş verimi ve dolayısıyla ekonomik kazanç ile ilişkilendirilmektedir. Buna karşın, enerji verimliliğinin öncelikli olarak ele alındığı yeşil sertifikalı ofis binasında gerçekleştirilen birçok kullanım sonrası değerlendirme çalışmasında kullanıcılar tarafından iç ortam kalitesine ilişkin çeşitli sorunların bildirildiği görülmektedir. Bu konuyu ele almak amacıyla, bu tez çalışması, yeşil sertifikalı bir ofis binasında iç ortam kalitesini analiz etmeyi hedeflemektedir.

Araştırma, İstanbul'da bulunan yeşil sertifikalı, çok katlı bir ofis binası için gerçekleştirilmiştir. Bu binadaki iç ortam kalitesini, özellikle de kullanıcıların ısı konfor algısını araştırmak amacıyla, bir kullanım sonrası değerlendirme çalışması gerçekleştirilmiştir. Çalışmanın yöntemi, literatür araştırması, araştırma sorularının belirlenmesi, alan çalışması için bina seçimi, anket tasarımı, veri toplama (belge toplama,

anket, birebir görüşme), sonuçların analizi ve genel değerlendirme adımlarından oluşmaktadır.

Araştırmada, binanın kullanıcılarına yönelik hazırlanan anket, ısı konfora odaklanmakta, ancak bununla birlikte, görsel konfor, işitsel konfor ve iç hava kalitesi gibi iç ortam kalitesini belirleyen diğer bileşenleri de kapsamaktadır. Bu amaçla ilişkili olarak, kullanıcıların sürdürülebilir bina konseptine ilişkin farkındalık düzeyine, buna bağlı olarak davranışlarına, iç ortam kalitesine ilişkin deneyim ve memnuniyetine ilişkin bilgi elde etmek hedeflenmiştir. Söz konusu hedefe yönelik olarak, kullanıcılara sunulan anket, farklı soru tiplerini içermektedir.

Bu tez çalışmasında kullanılan anket ve yapılan birebir görüşmeler aracılığıyla elde edilen veri karşılaştırmalı olarak değerlendirilmiştir. Elde edilen bulgular, ankete katılan bina kullanıcılarının iç ortam kalitesine ilişkin yüksek memnuniyet oyu kullandıklarını göstermektedir. Ancak buna karşın, birebir görüşmelerde ısı konforsuzluğa ve diğer iç ortam kalitesi sorunlarına dair şikayetlere sıklıkla yer verdikleri görülmüştür.

Bulgular ayrıca, kullanıcıların farkındalık düzeylerindeki artışın, sürdürülebilirlik açısından daha duyarlı davranışları beraberinde getirdiğini göstermektedir. Bu yönüyle, elde edilen sonuçlar konuya ilişkin bilinçlendirme faaliyetlerinin önemine dikkat çekmektedir.

Çalışmanın bulguları, ele alınan alan çalışmasına özgü olmakla birlikte, çalışmada izlenen yöntem farklı binalar için de kullanılabilir. Bu sayede, kullanıcı deneyimini geliştirmeye, ve sürdürülebilir uygulamaları teşvik etmeye katkı sağlanabilir.

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ABBREVIATIONS

Apx: Appendix.

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers.

Att: Attachment.

BAS: Building Automation System.

B+C: Building Design and Construction.

CASBEE: Comprehensive Assessment System for Built Environment Efficiency.

DGNB: Deutsche Gesellschaft für Nachhaltiges Bauen (German Sustainable Building Council).

GBC: Green Building Certification.

GBCI: The Green Building Certification Institute.

GBRS: Green Building Rating System.

IAQ: Indoor Air Quality.

ID+C: Interior Design and Construction.

LEED: Leadership in Energy and Environmental Design.

MRT: Mean radiant temperature.

ND: Neighbourhood Development.

O+M: Building Operations and Maintenance.

POE: Post Occupancy Evaluation.

SPSS: Statistical Package for the Social Sciences.

USGBC: U.S. Green Building Council.

WGBC: World Green Building Council.

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CHAPTER I

INTRODUCTION

Towards the technological development and the significant increase in human population towards the end of the 20th century, building design has been experiencing a major shift, mostly driven by the adaptation of innovative strategies and technologies [1]. This transformation is characterised by a high emphasis on the overall environmental sustainability of the project in recent years. The world has started taking some action to reduce the ecological footprint caused by humans, which is attempted in this case by minimising the environmental impact of buildings [2]. In the assessment of the environmental sustainability of buildings, one of the internationally recognized tools is green building certification systems. Green building certification has turned into a huge trend in the construction sector, which is assessed as added value for the reputation of any building project which prioritises environmental sustainability and occupant well-being [3]. Therefore, many commercial building investors are also interested in being awarded a high-level green building certificate.

The systematically categorized evaluation procedures of various green building certification systems typically share common basic criteria such as water and energy efficiency, material use, and occupant well-being based on international standards. Indoor environmental quality (IEQ), as one of these agreed-upon evaluation criteria, is a concept used to describe a space's physical and perceptual attributes [4]. Indoor environmental quality assessment covers a variety of parameters, including visual comfort, acoustical comfort, indoor air quality, and thermal comfort [5].

The indoor environmental quality of the space can often influence the overall comfort and health of the occupant [5]. In office buildings, which are the building type with the highest number of green certifications [6], this impact is associated with the health of the employees, work efficiency, productivity and consequently, economic gain as well. Therefore, continuous improvement and verification of the green building assessment outcomes in real-world conditions is very important in green-certified office buildings.

The post-occupancy evaluation (POE) is the process of investigating the project's performance after it has been occupied for some time and has reached its operational stage. POE values the feedback of occupants regarding their expectations, personal experience, and overall comfort within the space [7]. The concept of POE has gained huge popularity within the field of sustainable architecture [8]. It can validate the objective and verify if it has met the intended project's goals [9]. The project evaluation and assessment process include a wide range of essential metrics to meet the envisioned goals and objectives and deliver the desired planned outcome. energy performance, HVAC performance, acoustics, lighting, and the focus of this thesis, indoor environmental quality, can be given as examples of these metrics [10]. In this context, post-occupancy evaluation studies serve as an important tool that can provide valuable insights into how well the building is performing in terms of real-world conditions, which can effectively highlight some areas for improvement to ensure that the needs of the occupants can be effectively met [11].

The main purpose of this thesis is to conduct a post-occupancy evaluation study in a green-certified office building to evaluate the indoor environmental quality with an emphasis on the occupant's thermal comfort. To illustrate, achieving an optimal comfort level for the occupants can be seen as a significant challenge, considering that the environmentally friendly project often seems to focus mostly on energy efficiency with little consideration towards the comfort of occupants [9].

Considering the potential problems and issues the occupants may face within their workspace environment, this study was conducted in one of the green-certified office buildings in Istanbul, Turkey. The study's main objective is to investigate the user's indoor environmental quality, with an emphasis on thermal comfort and user satisfaction within a green-certified constructed environment. This includes evaluating the operational stage of the project, its impact on user personal behaviour development, and its side effects on occupants regarding their awareness, experience, and thermal comfort.

1.1 Hypothesis & Research Questions of The Study

As a significant part of green-certified building sustainability targets, it is essential to maintain a high indoor environmental quality level for the project's primary concern is the occupants, which includes the indoor temperature, air quality, lighting, noise, and thermal comfort within the space. Nowadays, many green-certified office buildings take energy and source efficiency as the prior focus, while indoor environmental quality, particularly thermal comfort, not always receive sufficient attention and remains a critical concern in sustainable design, as it usually meets the minimum specified requirements for green certification. This can lead to thermal discomfort issues for the occupants,

uncomfortable working conditions, and decreased productivity. Based on this hypothesis, the following research questions are investigated:

1. In what ways does the occupant's awareness and understanding of green building certification influence their behaviour within the project?
2. What is the satisfaction level of users regarding indoor environmental quality, particularly thermal comfort, in a green-certified office building?
3. What kind of challenges does the occupant face related to local thermal discomfort?
4. To what extent do the occupants control their indoor climate conditions, and does it promote better thermal comfort satisfaction?
5. How can different office layouts have an influence on the occupant's overall environmental comfort?

1.2 Research Methodology

To achieve a strong and precise study outcome, it is important to consider various methodologies in this study. The thesis is structured using a mixed-methodology research approach including both qualitative and quantitative methods. The conducted research methodologies of this thesis are explained below.

Firstly, preliminary research was conducted on the three topics that form the basis of the thesis's main subject: various green building certification systems, basics and criteria of indoor environmental quality, and up-to-date post-occupancy evaluation studies. Second, the study proceeded with conducting a case study of a LEED-certified office building project. Then, the study employed surveys, meetings, and interviews to

gather detailed information and perspectives. The participants were the building management, the project technical team, and random occupants using the building floors. Finally, a data analysis of the collected occupant's responses complements the rest of the methodologies to assess the overall occupant's comfort. This stage includes the use of different digital analysis software and descriptive and inferential statistics.

1.3 Structure of The Thesis

The final outline of the study's structure includes five main chapters: Introduction, Literature Search, Research Methodology & Case Study, Results & Findings, and Conclusion).

In this first chapter of the thesis, the concept of the research was briefly explained, along with the aim, hypothesis, research questions, conducted methodologies, and the structure of the study.

The second chapter of the thesis focuses on the literature search. This section is structured to explore green building certification, presenting insights into the background of green building certification systems, with an emphasis on LEED certification and an overview of assessment methods commonly used in evaluating LEED-certified buildings. Following this, the research focuses on indoor environmental quality with a huge emphasis on thermal comfort and its environmental and personal parameters. Then, the section explores the post-occupancy evaluation concept and its significance as a tool to assess the performance of the building. This literature search establishes a strong

foundation for Chapter III, where the research methodology specific to the study is delineated.

The third chapter of the thesis explains and addresses the structure behind the research methodology of the study together with its implementation in the selected case study building, which is a green-certified office building. This includes the use of quantitative and qualitative methodologies, including a literature search, case study selection, data collection, survey development, conducting the survey, meetings and interviews, and data analysis.

In the fourth chapter of the thesis, this section represents the outcome of the study based on the data collection methods, including the conducted survey, meeting, and interviews. The findings are explained using demonstrative graphs and descriptive tables.

The fifth and last chapter of the thesis, the concluding remarks are presented based on the aim of thesis, research questions and outcomes of the study.

CHAPTER II

LITERATURE SEARCH

The literature search of the study has explored a set of vital sustainable building design aspects, including green building certification, indoor environmental quality, and post-occupancy evaluation. The suggested concepts are intricately linked, which enables the researcher to investigate whether the green building standards are able to provide an overall efficient, comfortable living or working environment or if the project has successfully met its intended objective of the occupants' comfort within their surrounding environment.

The first part of the literature study delves into different types of green building certification and their professional backgrounds, including their timelines, areas of focus, and assessment methods [12], [13], [14], [15]. The main aim of this study is to deliver a complete understanding of green building certifications with an emphasis on the Leadership in Energy and Environmental Design (LEED) certification system since it is one of the most commonly used green building certification systems [3], which is also the adapted certification program in the case study of the thesis.

Secondly, this chapter explores the concept of indoor environmental quality with a huge emphasis on thermal comfort and its environmental parameters, including temperature, operative temperature, humidity, air movement, and personal parameters, including clothing and metabolic rate. This summary is essential to develop an

understanding of the potential impact on overall occupant comfort levels in indoor spaces as given in these standards [17], [18], [19], [20]. Additionally, the literature search will address the potential local thermal discomfort that can be faced by the occupants, including vertical air temperature differences, radiant air temperature asymmetry, and draughts.

Finally, this section investigates the post-occupation evaluation (POE) concept and its commonly employed and conducted methodological approaches in recent studies [21], [22], [23]. The presented literature summary will delve into the main tools and techniques to collect the occupant's feedback regarding a space, which includes surveys, personal interviews, observations, building performance measurements, and document analysis.

2.1 Green Building Certification

Towards the technological development and the significant increase in human population towards the end of the 20th century, the world has started taking some action to reduce the ecological footprint caused by humans, which is attempted in this case by minimizing the environmental impact of buildings [2]. As a result, green building certification has become a big trend in the construction sector, as it becomes a significant addition to any project's reputation, prioritizing sustainability, energy efficiency, occupant well-being and overall satisfaction [3]. The main purpose of green building certification is to assess and evaluate the overall environmental impact of the project and check if the project has met its sustainability set of standards after it was occupied for a

period of time, which can be rewarded to different building categories and types, including the residential used buildings, commercially used buildings, or even entire neighbourhoods [11].

As demonstrated in Figure 1, the timeline reveals the most frequently used green building certification programs over the years, which has led to the green building certification concept being widely adopted in the world [12][13][14][15]. Although different organizations can offer such certification, including shared assessment criteria, they still have their own process of assessing procedures to follow.

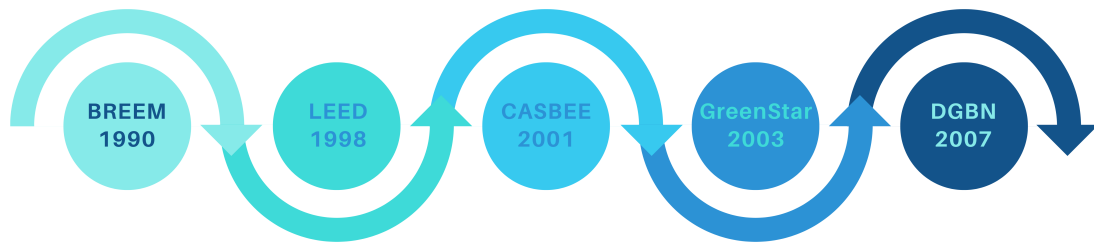


Figure 1: Timeline of Green Building Rating System [12][13][14][15].

Every organization that has sustainable building certification to offer has its own contributions and areas of focus. BREEAM is one of the first to originate in the United Kingdom (1990) which follows a comprehensive approach to sustainability by evaluating a set of factors, including energy efficiency, water usage, materials selection, and ecological impact [24]. LEED was developed in 1998 by the U.S. Green Building Council as one of the internationally recognized organizations for prioritizing energy efficiency, indoor environmental quality, and innovation while maintaining strict standards [25]. Following this, in 2001, the Japanese organization CASBEE offered a

wide assessment system designed with a focus on the East Asia market more in terms of environmental and cultural context, focusing on building environmental efficiency and sustainable development within their region of preference [26]. In 2003, the Green Building Council of Australia established Green Star, which promotes sustainable construction practices in the Australian region with an emphasis on energy efficiency, water conservation, and indoor environmental quality [27]. In 2007, the German Sustainable Building Council (DGNB) followed a comprehensive approach that includes ecological, sociocultural, functional, and economic aspects throughout the lifecycle of the project while reflecting a commitment to sustainability assessment frameworks in Germany and beyond [28].

After these green building evaluation systems were experienced in time, WELL Building Institute (IWBI) launched the WELL Building Standard in 2014 [28] introducing the idea of an improved link between the green building design and the occupant's health and wellness. The WELL standard prioritises the occupant's health and well-being in the built environment and correspondingly evaluates the projects under ten concepts, which are air, water, nourishment, light, movement, thermal comfort, sound, materials, mind, and community.

As explained above, every organisation has its own approach, focus, and priorities in promoting sustainable construction practices across the world. Since the Leadership in Energy and Environmental Design program (LEED) is one of the most requested green building certifications in the market [3], the case study of this thesis is conducted using

one of the LEED-certified building projects in Istanbul, Turkey. Therefore, more detailed information about the LEED certification system is explained below.

2.1.1 Development of LEED Certification System

Towards the late 20th century, optimizing building systems gained increased importance in developing a more sustainable and environmentally friendly project [29]. In accordance with USGBC, they established Leadership in Energy and Environmental Design (LEED) v1.0 in 1998. By conducting a number of 19 testing models, LEED for New Construction was launched in the first quarter of 2000 [30]. Following this, LEED v2.0 was released in 2001. In 2002, the USGBC hosted its inaugural Greenbuild International Conference and Expo in Austin, evolving into the world's largest major green building conference and expo. Then, in 2003, the testing project models for LEED for Existing Buildings, LEED (ID+C), and LEED (BD+C) were launched, marking a momentous milestone for LEED [29].

The Green Building Certification Institute (GBCI) was established as an independent organization by the USGBC in 2007. The main aim of this organization is to oversee the LEED certification and professional credentialing process, which leads to continuous quality and integrity control [29]. Moreover, in 2009, the USGBC launched LEED 2009, which introduced the U.S. Environmental Protection Agency's TRACI to weigh each calculated credit. Its purpose was to oblige in impact evaluation and accessing the life cycle, process design, pollution prevention, and industrial ecology. The National Institute of Standards and Technology (NIST) and its developed weightings also exist.

Concurrently, the two practices can deliver a reliable foundation to determine the value of one point per credit in LEED 2009 [31]. Subsequently, LEED v4 was released in 2015. It introduced a performance-based, innovative grid approach, increased flexibility, emphasized materials and resources, and utilized a comprehensive approach to water [32]. LEED v4.1 was introduced in 2019; this version of the system is more inclusive; it was revised and updated in terms of its reference standards, which qualifies projects to gain LEED points through monitoring the building performance [33]. Following this, the LEED v5 rating system is expected to be fully available for public use by 2025. The new LEED system framework will be divided into three main study areas that will be focused on to improve and elevate the potential threats that can be faced by the occupant's comfort, including climate action, quality of life, and ecological conservation and restoration. It is deeply focused on identifying. These areas will guide the future versions of the rating system and will also help prioritize the way project teams are rewarded for pursuing different strategies [34]. Figure 2 depicts the timeline representing the progress of LEED certification over the years.

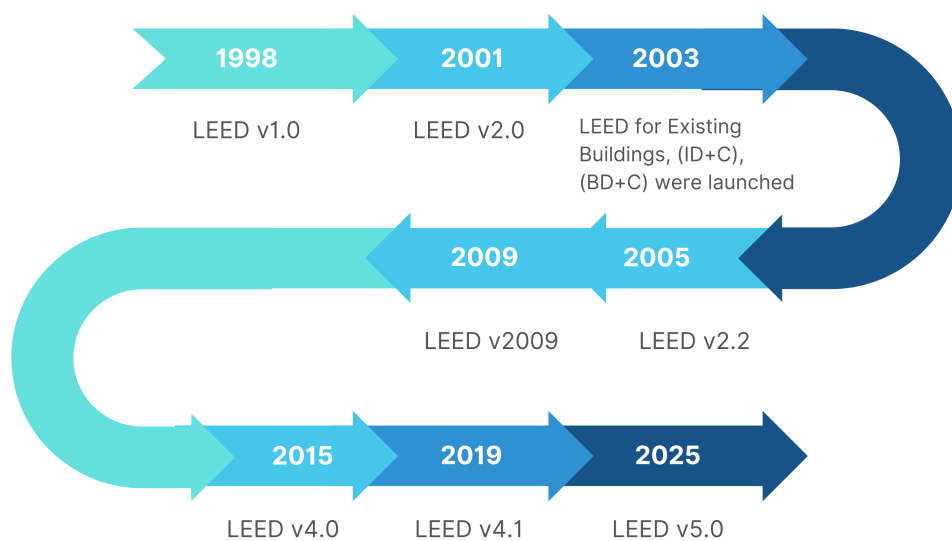


Figure 2: LEED Timeline.

LEED is a well-recognized standard with 75,000 projects in 140 countries in all climates [35], [36], [37]. Locally in Turkey, there are a total of 566 LEED-certified buildings, including 37 Certified, 75 Silver, 378 Gold, and 76 Platinum-rated projects [38].

The LEED certification approach considers all project stages, including the design, pre-construction, post-construction, construction, and operation stages. The program evaluates environmental factors and parameters of the applied project, including site sustainability, water efficiency, energy use, materials and resources, indoor environmental quality, and innovation and design [39].

2.1.2 Assessment Criteria for LEED Certification

LEED certification systems assess and evaluate the building projects based on credits in five main environmental categories:

- 1 Sustainable Sites (28 Points)
- 2 Water Efficiency (10 Points).
- 3 Energy & Atmosphere (37 Points).
- 4 Materials & Resources (13 Points).
- 5 Indoor Environmental Quality (12 Points)

Additionally, there are two extra categories that can that offers bonus credits for the project application results, including:

1. Innovation in Design (Bonus 6 Points).

2. Regional Priority (Bonus 4 Points).

The certification reward is followed by a system that defines the project's total score regarding its recorded performance. In total, there are 100 achievable base points from the five main LEED categories, with a chance to earn 10 bonus points allocated to two extra categories as mentioned above [40].

LEED certifications are granted in four different levels depending on how efficient the project is and its potential in the application, with each level representing a higher standard of sustainability and environmental responsibility. As shown in Figure 3, according to the USGBC (2011) guidelines, these certification levels and corresponding score ranges are [41]:

- Certified Level: 40 - 49 points rewarded.
- Silver Level: 50 - 59 points rewarded.
- Gold Level: 60 - 79 points rewarded.
- Platinum Level: 80 - 110 points rewarded.



Figure 3: The Four Different LEED Certification Levels [2].

LEED certification offers various programs to achieve different sustainability goals for different project types. The Building Design and Construction (BD+C) program

focuses on new construction and significant renovation projects. The Interior Design and Construction (ID+C) program aims for complete interior fit-out projects in various sectors' categories. Following this, the Building Operations and Maintenance (O+M) certification program focuses on the existing building that is within the process of improvement work or nominal renovations. The Neighbourhood Development (ND) program aims to assess and evaluate the entire community regarding its sustainability and connectivity. The LEED for Homes certification program's main focus is on single residential properties, with a high emphasis on low-rise buildings and single-family home units. The Cities and Communities program assesses entire urban areas and subsections, with a focus on the human experience and different energy consumption. LEED Zero is intended for projects aiming for net-zero energy, waste, water, or carbon resources goals [42].

Indoor environmental quality is one of the five major environmental categories in the LEED certification program. It includes several comfort-related parameters that can determine the occupant experience within the project, as will be explained in the following section.

2.2 *Indoor Environmental Quality*

Considering that the majority of today's urban population works in indoor environments, which makes maintaining a productive and healthy work environment is an essential right for the occupant [43]. Indoor environmental quality (IEQ) is a concept used to describe a space's physical and perceptual attributes [4]. Since the environmental

characteristics and parameters of the interior space can often influence the overall comfort and health of the occupant, the LEED certification program [5] considers indoor environmental quality, including visual comfort, acoustical comfort, indoor air quality, and thermal comfort, which is the major focus of this thesis study.

2.2.1 Visual Comfort

Visual comfort is defined in the EN 12665 standard as a subjective state of visual well-being that relies on the physiology of the eyes and the physical properties describing the amount and distribution of light. Indoor visual comfort can directly improve the health and productivity of the occupants within a space [44].

It was revealed that having a daylight element through such windows or skylights within the workplace can leave a positive impact on the occupants, which can undoubtedly boost the productivity and performance of the workers in the company directly or indirectly [43]. Moreover, maintaining a balance between natural daylight and artificial lighting can determine overall visual comfort. The accessibility and quality of entering light in the space is important since natural daylight has the most positive scientifically proven impact on human physical and mental health when compared to artificial lighting sources [43].

For the office buildings, which is the focus of this thesis, the visual comfort parameters are defined in EN 12464-1 standard as follows: Maintained illuminance, unified glare rating limit, uniformity and colour rendering [45].

2.2.2 Acoustical Comfort

Noise level is one of the causes of occupant discomfort [46]. Sound distribution is often determined by the layout of a space [4]. Open-plan offices generally have higher levels of noise and distractions, leading to less productivity in some cases [47]. Additionally, the ability to access private and shared spaces allows occupants to adapt according to their needs, catering to overall user satisfaction [4]. The LEED certification system evaluates the acoustic performance of the space among the criteria of indoor environmental quality. The criteria is based on HVAC background noise, sound transmission, and reverberation time [48].

2.2.3 Indoor Air Quality

The indoor air quality (IAQ) can directly affect the health of the occupants as well as their overall satisfaction within a space [49]. The IAQ can be categorized into three main factors, which are: Human factors, including personal health status, sensitivity rate and personal climate control preference; Air pollutant factors, including exposure times and pollutant levels; and physical factors, including humidity, ventilation, and ambient temperature [4]. The addition of good ventilation systems and regular maintaining the HVAC can be seen as an opportunity to improve the IAQ of the space, in which controlled humidity and ambient temperature can be used to sustain a healthy indoor environment [50].

EN 16798–1 standard describes requirements for indoor environmental parameters related to air quality in buildings together with the requirements regarding thermal conditions, lighting, and acoustics for building system design and energy performance assessments [51].

2.2.4 Thermal Comfort

The concept of satisfaction and thermal comfort is considered one of the major parameters that can influence the human experience within space [52]. The human body is built to maintain a relatively constant thermal balance, which can increase the chances of higher thermal conditions for the body [53]. However, to fully understand the heat exchange between the human body and the surroundings, it is important to study and analyse the concept of thermal comfort together with the parameters that have an influence on it. The term "comfort" can be defined as the sense of satisfaction, which is characterized by the connection between the human body and its direct present physical surroundings [54]. According to a number of scientists, the concept of comfort is a constantly developing topic with a high potential for research [55] [56], [57]. There are two major models that are commonly followed in thermal comfort evaluation and enhance the targeted group experience, which are the Fanger model and the Adaptive Comfort Model.

The Fanger model is a predictive model for assessing overall thermal comfort, which Povl Ole Fanger developed in the second half of the 1960s [58]. The concept is based on the heat balance of the whole human body within its surrounding space [59].

The model was presented as a predicted mean vote (PMV), which has turned into an internationally recognized thermal model that predicts the user's mean thermal comfort in space [58]. The main focus of the model is primarily on heating, air-conditioning, and finding the optimum temperature for the assessed space [59]. The PMV model approach takes different variables that impact the thermal sensation of the human body either naturally or as a result of personal choice, which includes mean radiant temperature, air velocity, air temperature, relative humidity, clothing (insulation), and activity level [60].

The concept of the Adaptive Comfort Model unveils the human perception and the ability to adapt to their comfort zone within their surrounding environment through different physiological, physiological, and behavioural changes [61]. The model is based on the human reaction and adaptation to variants of temperature, humidity, and different climate and seasonal changes. The aim of this model is to provide users with different combinations of thermal variables, of which the users find their preferences range from neutral to comfortable [62].

Multiple distinct standards and guidelines have been found and partially adopted some thermal comfort models as the foundation, including the Fanger model and the Adaptive Comfort Model, to ensure thermal comfort is achieved in a variety of environments. These serve as the foundation for designers and engineers to promote human well-being. The most commonly used standards are ASHRAE Standard 55 [17], the KS06 Comfort standard [18], EN 15251 [19], and the ISO 7730 standard [16]. They offer a comprehensive evaluation and assessment framework to achieve optimal thermal comfort in various settings.

“According to ASHRAE [17], thermal comfort is the condition of mind that expresses satisfaction with the thermal environment”. However, creating a space that is comfortable for everyone can be challenging due to physiological and psychological interpretations and personal preferences from one person to another. This concept can be subjective and may vary based on parameters that influence user comfort within a space, and even any slight changes to the indoor environment may be perceived as thermal discomfort by some users. The thermal comfort parameters are explained under the following subtitle. A subsequent title concentrates on local thermal discomfort circumstances since it is also one of the main focuses of this research.

2.2.4.1 Thermal Comfort Parameters

The overall thermal balance of the human body can determine the thermal comfort of the occupants, which is influenced by two major parameters, including environmental and personal parameters [53].

2.2.4.1.1 Environmental Thermal Comfort Parameters

In order to reach an optimal thermal comfort level for the occupants of the space, it is essential take various environmental related parameters into consideration, including Temperature, Humidity, and Air Movement [53].

- **Temperature**

The air temperature term indicates the temperature of the air in the given space and its surroundings, which can be monitored and read using a fixed-in-place thermometer [18]. Achieving the optimal temperature range can create a pleasantly comfortable environment for the place's occupants [17].

On the other hand, the Mean radiant temperature (MRT) term technically refers to the overall temperature of a specific surface that can emit a similar amount of radiative heat flux as the received amount from its surrounding environment [16]. Moreover, the human sensation of coolness, chilliness, or warmth within their space is highly caused by MRT rather than air temperature [63].

The average space contains countless sources of radiant heat, including windows, ceilings, walls, radiators, lights, and more [18]. If the occupant is using a room with high indoor temperature surfaces, the mean radiant temperature will be high in this environment, which can induce a sense of warmth in the user even if the air temperature is low. Contrariwise, if the sources of radiant heat are cold, it can induce a sense of coolness in the user even if the space was maintained within a comfortable range of air temperature [64].

- **Operative Temperature**

According to ASHRAE, the operative temperature is categorized as a significant tool to evaluate the overall user comfort within the space. By taking the temperature of surrounding air and nearby surfaces into consideration, the operative temperature can

deliver an indication if the users are feeling overly warm or cold with utmost accuracy and precision [65]. According to ASHRAE in 1995, The operative temperature has been calculated using a standard mathematical formula as given in Equation 1 [66].

$$T_{op} = \frac{h_r T_{MRT} + h_c T_{air}}{h_r + h_c}$$

T_{op} : operative temperature, h_r : linear radiative heat transfer coefficient,
 h_c : convective heat transfer coefficient, T_{air} : air temperature, T_{MRT} : mean radiant temperature

Equation 1: Operative temperature formula according to ASHRAE [4].

The operative temperature is considered a more accurate and precise method to measure the local thermal discomfort when compared to air temperature or mean radiant temperature. To illustrate, the air temperature does not take the heat gain or loss into consideration, whether it was caused by radiant energy exchange with walls, windows, or radiative heating systems. Similarly, the mean radiant temperature does not take the warming effects of the surrounding air into attention, which makes the operative temperature more trustworthy for more comprehensive assessment results [67].

- **Humidity**

The humidity can be defined as the balance of the water vapour in a specific area or space, and it is usually represented in ratios in relation to the temperature and pressure [18]. The direct correlation between the humidity and air temperature makes them closely intertwined. Relative humidity (RH), which is a considered concept in thermal comfort evaluation, is the ratio of water vapour amount in the air compared to the maximum water vapour amount possible at a given temperature [68]. To illustrate, as high as the relative humidity level increases, the higher the air temperature can be perceived. However, when

the relative humidity level decreases, a lower temperature can be perceived [69]. The humidity limits are commonly determined by ensuring optimal thermal comfort conditions, which prioritise comfort factors like skin dryness, skin wetness, eye irritation, and thermal sensation [16].

The overall humidity rate can impact the human's heat body balance. Thus, thermal comfort through evaporation is one of the causes of occupants' heat loss [16]. To illustrate, the air will be fully parched if the humidity level has ever reached 0%. Similarly, if the humidity level reaches 100%, the air will reach the highest saturation point, which can cause condensation if exposed to any additional moisture [18]. According to the CIBSE Guide A [70], the relative humidity between 40% and 70% RH are generally acceptable". Anything below or above this range can result in uncomfortably dry or sticky living conditions.

- **Air Movement**

Studies have found that moving air can significantly impact overall thermal comfort. Meaning that the airflow can influence the user's sensation and experience regarding the temperature of the used space [71]. Air movement represents a complicated phenomenon that exhibits a dual nature with both positive and negative aspects, its ability to provide cooling effects during warm conditions while simultaneously amplifying the risk of undesirable cool drafts. The occupants of space may perceive the air movement to be indicative of pleasant, fresh, breathable air, yet at the same time, it can be identified as a source of discomfort [72]. Additionally, the speed and velocity of the moving air optimisation are key to ensuring individuals' comfort within the space provided. To

illustrate, if the airspeed within the space is too high, it can lead to develop complaints regarding draught. Conversely, if the air speed is too low, the air quality can deteriorate over time and potentially become stale and stuffy [73].

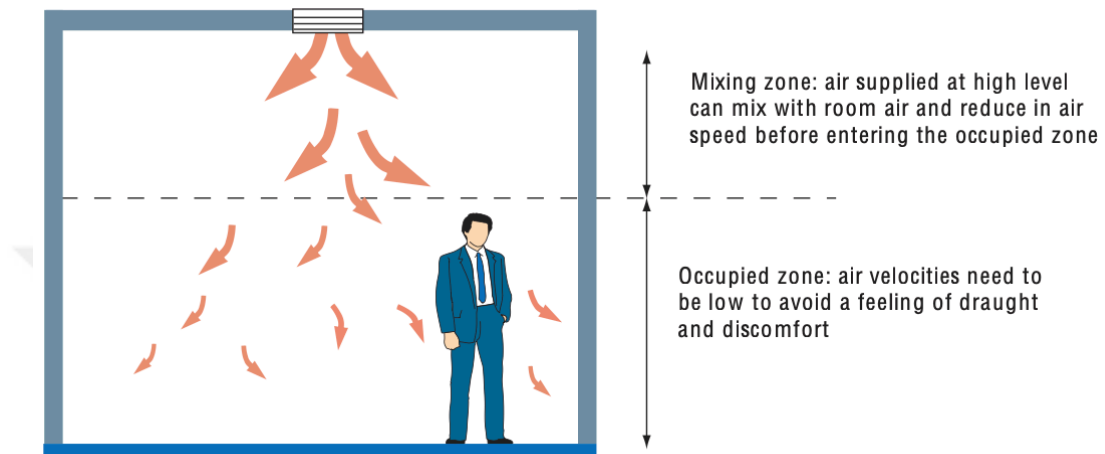


Figure 4: Air movement within an occupied space [73].

2.2.4.1.2 *Personal Thermal Comfort Parameters*

In order to reach an optimal thermal comfort level for the occupants of the space, it is essential take various personal parameters into consideration, including their clothing choice and their metabolic rate [53].

- **Clothing**

Clothing preference is one of the significant personal parameters that can highly impact the user's comfort. It has a critical influence on the occupants and how they perceive their indoor temperature, determining whether the indoor environment is comfortable or not, which may lead to instabilities in their thermal comfort conditions [16]. Clothes can be considered a vital tool that helps occupants adapt comfortably to the

surrounding temperature [73]. The occupants can express in response to the altered environmental conditions in various ways, which are voluntary reactions, including changing their clothing preference, to involuntary reactions such as shivering or sweating [73]. According to (BS ISO 9920) [74], the unit used to measure the thermal resistance caused by different types and layers of clothing is referred to as clothing insulation (clo), which calculates to what extent the clothing traps heat and temperature regulation in the human body. To illustrate, the average top, pants, and jacket provide around 1.0 Clo. However, when the thickness of the material increases, the clothing value increases as well, where the average winter clothes can vary from 1.5 to 2.0 Clo.

- **Metabolic Rate**

The metabolic rate of energy production, known as the metabolic rate, refers to the energy produced by the human body through oxygen to metabolise food and convert it to one form of energy [73]. The metabolic rate can impact the human body significantly through heat generation. To illustrate, the users of the space who manage have a higher metabolic rate tend to produce more internal heat, which requires external highly efficient cooling system mechanisms to maintain comfort conditions. Contrariwise, people with lower metabolic rates tend to produce slower internal heat, which may potentially turn into a source of discomfort within environments with insufficient cooling.

Studies revealed a correlation between physical activity and the amount of heat that is produced by the human body. When the physical activity of the human increases, the human body produces a high amount of internal heat simultaneously. According to (EN 28996) [75], the unit which is used to quantify the energy spent during different

physical activities is referred to as the metabolic equivalent (met). For instance, while sleeping, the average person has a base production rate of around 1 met; while doing office or schoolwork, the rate increases to 2.5 met, and for physical activities such as dancing or gym work, it elevates to 4 met. This highlights a critical factor in maintaining comfort, which is the need to balance heat production by ensuring an equivalent amount of heat loss from the body [73].

2.2.4.2 Local Thermal Discomfort

Local thermal discomfort can be defined as unwanted heating or cooling sensations perceived by the occupant within a specific environment. The leading causes of thermal discomfort include high air temperature differences between the human head and feet levels, when the floor gets substantially colder or warmer, or when there is a high radiant temperature asymmetry within the space and draught [16].

- **Vertical air temperature differences**

Vertical air temperature differences refer to the variations of the indoor air temperature between different heights within the space. These differences are usually studied on the human body while sitting on the working desk at averaging height difference ranging from 0.1 to 1.1 meters above the floor (the user's head to ankle level), which is a factor that can significantly influence the user's thermal comfort [76]. According to ASHRAE 55 standards, when the vertical air temperature difference between the head and feet is 3 K/m or less, it can be considered an acceptable condition for the users. Moreover, it is required to ensure that the maximum rate of dissatisfied

occupants is no more than 5% [72]. When the vertical air temperature in a room exceeds the suggested three-degree standard limit, it can result in discomfort for the occupants. When the air temperature has an uneven vertical distribution in a room, this can cause an imbalance in the overall temperature, which induces a sense of discomfort for the occupants, leading to thermal discomfort issues for the users within the space [76]. Figure 5 depicts the temperature variation in the space, highlighting vertical temperature differences within the user occupation zone and overall space [73].

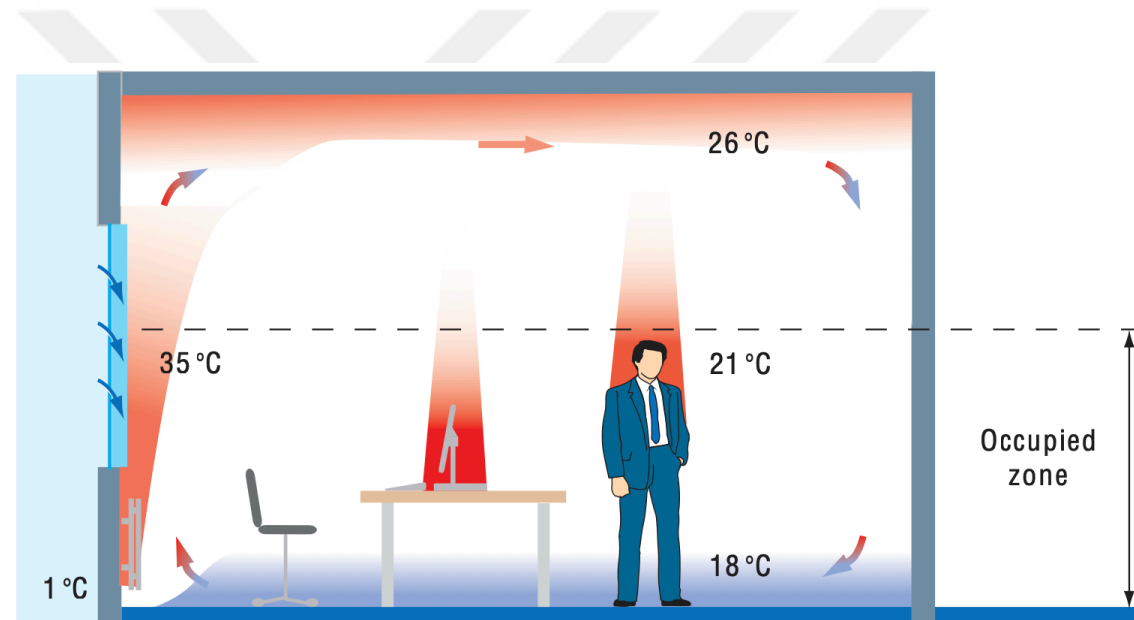


Figure 5: Vertical temperature variations within the space [73].

- **The radiant temperature asymmetry.**

The radiant temperature asymmetry is the process of exchanging the radiant temperatures between two different surfaces with significant differences in temperature [70]. Asymmetric radiation is often looked up when the average radiant temperature fails to define the radiant environment [75]. However, asymmetric radiation is one of the sources of local discomfort; it is one of the common concepts that can boost the occupant's dissatisfaction within a space. To illustrate, radiant temperature asymmetry can be

perceived as a source of discomfort in three distinct forms of action, including having an external heating source such as a radiator or overhead lighting directed closely to the human body. Similarly, being exposed to a cooling source such as a single-glazed window, and when short-wave and solar radiation penetrate through glazing, introduces the space to localised heat gain [70].

- **Draught.**

A draught is an unwelcome and perceptible airflow within an indoor environment, and it is the most common cause of local thermal discomfort [16]. It was revealed by some studies that thermal discomfort caused by draught cannot be a result of mean air speed and local air temperature but also due to airspeed variations [76]. To illustrate, draughts are typically caused by the movement of air with varying temperatures, which leads to a noticeable breeze that can make room occupants feel uncomfortable [72]. When air speeds within a space exceed 0.15 m.s^{-1} , it is advisable to adjust the temperature to counteract any cooling caused by the air movement, which can achieve more still air temperature. Moreover, it is necessary to mention that air speeds surpassing approximately 0.3 m.s^{-1} may not be acceptable and can lead to thermal discomfort except during summer in naturally ventilated buildings when higher air speeds can be desirable for their cooling benefits [70]. The appropriate airspeeds vary depending on the temperature and direction of the moving air. In case the air is warm, a higher speed might be tolerable for the users, while in the case of cool air, a low speed can cause a draughty, uncomfortable feeling [16], [73].

2.3 *Post-Occupancy Evaluation*

Post-occupancy evaluation (POE) is the process of investigating the project's performance after it has been occupied for some time and has reached its operational stage. The main purpose of POE is to investigate the project to identify the pros and cons of the project and areas for development, including the spatial layout, aesthetics, functionality, environmental parameters, and thermal comfort [77]. The project evaluation and assessment process include a wide range of essential metrics to meet the envisioned goals and objectives and deliver the desired planned outcome. These metrics include thermal comfort, energy performance, HVAC performance, acoustics, lighting and workspace comfort [10]. Indoor environmental quality (IEQ) based POE values the feedback of occupants regarding their personal experience with indoor air quality and overall comfort within the space [7].

Conducting a POE study can assist architects, designers, and construction owners in understanding whether the project meets its objectives, prevents potential issues, and how it can be improved for future projects in terms of functionality, comfort, and sustainability [77].

2.3.1 *Common Methodologies in Post Occupancy Evaluation Study*

In order to achieve an effective post-occupation evaluation (POE) focusing on IEQ, a set of mixed methodologies, including quantitative and qualitative, are used to evaluate and assess the overall comfort of occupants within their workspace. The main

stages of conducting a POE study mainly include Data Collection, Data Analysis, and Reporting to identify action items.

2.3.1.1 Data Collection

Data collection is the most time-consuming stage of the POE process, is the data collection. The process of obtaining this stage of data and information relies upon complete accuracy, which requires allocating a significant amount of time to spend on the site of the studied project. The building-related information and data collection can be achieved through a wide range of methods, including surveys, personal interviews, observations, and document analysis [78].

Surveys are one of the quantitative data collection methodologies widely used in conducting a POE study. Surveys can provide comprehensive and direct insights regarding the occupants' expectations, preferences, levels of awareness, and the overall performance of the investigated project [79]. Recent studies have revealed that surveys can pinpoint as many as 80% of all needed indicators to assess the building's performance precisely [80]. The survey typically consists of different types of questions to ensure accuracy and comprehensiveness, and the design of the survey is what makes it critical since it is the success key of a survey. Moreover, selecting the appropriate survey and question types that align with the research aim, purpose, and targeted audience [81]. To illustrate, there are four main question types of surveys that can be adapted to the desired study, each demonstrating a distinct approach and results; they include open-ended questions, closed-ended questions (multiple-choice), matrix questions (Likert scale), and

contingency questions [82]. The Likert scale is a commonly used tool in surveys that allows participants to indicate their level of agreement or preference with each argument with a wide range of options to choose from [83].

Personal interviews are one of the essential methodologies used to gather qualitative data while conducting a POE study. This method's main objective is to acquire primary data by asking participants to discuss their personal experiences and opinions [84]. The interviews are a valuable tool that can develop an understanding of the occupant's viewpoints regarding a specific topic [85]. Interviews are conducted with direct interaction with the participant, which can reveal outcomes not specified in the survey [86].

Three main types of interviews can be conducted to investigate a research study including structured, unstructured, and semi-structured. Firstly, the structured interviews follow a predetermined set of questions asked to all participants in the same order and format, which follows a consistent flow and facilitates quantitative analysis. The unstructured interviews can seem similarly conducted as an open-ended conversation, where the interviewer moderates the questions based on the participant's answers and interaction. The semi-structured interviews involve a set of predetermined questions which additionally require a follow-up to explore specific topics in more detail. This method offers both consistency and depth, making it widely used in qualitative research [87]. All types of interviews can be conducted according to the participant's preference, including face-to-face discussions, telephone calls, and video calls, and in some cases, different formats can be organised, such as focus groups or one-on-one sessions [84].

Observation is a qualitative data collection methodology that includes a number of steps to be conducted accurately and learn people's routine habits. It includes sparing time within the studied project while sticking to a strict time sampling to record the observed actions and adapting a checklist to mark off pre-established actions [88].

Observations are usually conducted in combination with more quantitative measurements. This approach is efficient when used with questionnaire surveys, as it allows for a more comprehensive understanding of the subject matter [80], which verifies the collected data from the participants in interviews when compared to the observed actions on-site [89]. Before conducting any research observation within the space, it is important to plan where, when and what to observe exactly. Moreover, it is a major step to find the objective and determine the appropriate approach that can line up with the outcome expectations of the study [90].

There are two distinct approaches that can be employed for an effective observation outcome: participant and nonparticipant observations. First, the participant observation approach involves the researcher's participation in their own project, which includes their active presence in the study and a high level of personal interaction with the participants. However, it is important to note that this approach can indirectly influence the study's outcome since the occupants are aware of the study process and that they are being watched. Second, nonparticipant observation does not involve the researchers in any act or event regarding the study, which makes the participants in this approach act more inherently, as they are unaware of being watched [90]. Conducting such a methodology assessment of the research process may identify weak points in the

project among the witnessed use of the space, which can require improvement or remediation to ensure optimal functioning for the occupants [91].

Document analysis is a qualitative data collection methodology that can be used to conduct a POE study, which requires the researchers to adopt a mixed approach to acquire data with the most accuracy, which can be done by creating the data or using pre-existing data that aligns with their research study objective [92]. This method entails a structured and systematic procedure for reviewing, assessing, and evaluating both physical and digital materials [93]. These materials include books, official publications, reports, photographs, academic journal articles, institutional reports, and any document containing text that can be used as a reference for qualitative research [94].

In addition to written documents, this methodology is commonly conducted in combination with other qualitative research methodologies, as it can be referred to as triangulation [95]. The concept of triangulation refers to the use of multiple methodologies or datasets that use the same phenomenon within a similar research study field. The concept is widely considered a valuable tool that increases the validity, accuracy, and reliability of the outcome of the study while minimizing any potential research bias risk [96]. In this case, document analysis can often be employed with additional tools, including personal interviews, participant observations, and physical artefacts. By integrating various techniques and methodologies, the researchers can develop a more academic and comprehensive understanding of the subject of the study, which ensures delivering more precise and accurate outcomes [95].

2.3.1.2 Data Analysis

Data analysis is the fourth stage of the POE study process. The process includes the collected data and building-related information in the earlier stages to a detailed analysis and examination. Then, the first draft of the report is developed based on the initial findings of the study, which can be presented to the client seeking their feedback. In the end, after receiving the client's feedback, the final report is developed for a re-review [78].

2.3.1.3 Reporting

Finally, the last stage of the process includes reporting to identify action items. This stage takes up to approximately four weeks to identify the major actions to address the highlighted issues in the study. As a result, considering the clients' opinion, the advised changes can be incorporated by either enhancing the existing building or passing them on into a future design and planning process. All in all, this stage ensures that the results of the conducted study are effectively translated into actionable recommendations [78].

2.3.2 State-of-The-Art In Post-Occupancy Evaluation

Over the past years, a huge number of studies have been conducted through POE, examining different building types and contexts regarding building performance, occupant satisfaction, and many more, with the aim of contributing design approaches. This section delves into some case studies along with the methodologies that have been

conducted from 2011 until 2023, as given in Table 1. These studies have been selected because they are considered to be able to serve as a reference for this thesis work.

Table 1: Case studies conducted between 2011 until 2023.

Paper Num	Title of the Study	Author	Year	Methodologies
1	Predicted Vs. Actual Energy Performance Of Non-Domestic Buildings: Using Post-Occupancy Evaluation Data To Reduce The Performance Gap.	- Anna Carolina. - Menezes Andrew Cripps.	2011	- TM22 methodology - In-depth monitoring of the electricity consumption. - Data Collection
2	Bridging The Gap Between Energy And Comfort: Post-Occupancy Evaluation Of Two Higher-Education Buildings In Sheffield	- Ranald Lawrence. - Charlotte Keime.	2016	- Case Study - Literature Review - Questionnaire Survey
3	Thermal Comfort Evaluation Of A Mixed-Mode Ventilated Office Building With Advanced Natural Ventilation And Underfloor Air Distribution Systems	- Xiang Deng.	2018	- Literature Review. - Case Study (monitoring) - Questionnaire Survey. - Data analysis and statistical methods.
4	Building Energy Certification Versus User Satisfaction With The Indoor Environment: Findings From A Multi-Site Post-Occupancy Evaluation (POE) In Switzerland	- Luisa Pastore.	2019	- Literature Review - Case Study (monitoring: temperature, lighting, air quality) - Questionnaire Survey - Data analysis and statistical methods
5	Post Occupancy Evaluation Of Adaptively Reused Buildings: Case Study Of An Office Building In Saudi Arabia	- Mohammad Hamida. - Mohammad Hassanain.	2020	- Literature Review. - Case Studies. - User Satisfactory Survey. - Interviews. - Walkthrough Tour. - Data Analysis.
6	Post-Occupancy Evaluation Of Indoor Air Quality And Thermal Performance In A Zero Carbon Building	- Polina Trofimova. - Ali Cheshmehzangi.	2021	- Questionnaire survey. - On-site measurements (digital Sensors).

7	Post-Occupancy Evaluation Of Office Buildings' Indoor Environmental Quality From The Perspectives Of Architects And Non-Architects	- Ashkan Rahanjam.	2021	- Literature Review - Case Study (observation) - Questionnaire Survey - Data analysis and statistical methods
8	Indoor Environmental Quality and Comfort in Offices: A Review	- Virginia Isabella Fissore. - Silvia Fasano.	2023	- IEQ Monitoring System. - Wireless Sensor Network. - Cloud platform and Software

Paper (N.1) discusses the gap between the predicted and the actual energy consumption within a non-domestic building project. The conducted methodologies of the study were TM22 methodology proposed by the Chartered Institution of Building Services Engineers (CIBSE) [70] and an in-depth monitoring system of the building's electricity, including lighting system, power and catering equipment. The outcome of the study presented a comparison analysis and its potential through monitoring exercises [97].

Paper (N.2) highlights the importance of balancing energy efficiency and the comfort of institutional building occupants. The study involved conducting a case study using data collection methodologies through a survey and literature review. The study's outcome emphasised the need to balance energy efficiency and occupant comfort by adapting different active and passive design strategies [98].

Paper (N.3) was carried out to assess thermal comfort in a mixed-mode ventilated office building that utilizes sophisticated natural ventilation and underfloor air distribution systems. The study incorporated a post-occupancy assessment (POE) that employed a variety of methods, including literature review, monitoring of the

implemented case study, survey, and statistical data analysis. The findings of the study indicated that there were variances in thermal comfort across different seasons and that diverse thermal comfort models were appropriate for various seasons [99].

Paper (N.4) evaluates a green-certified case study building with an emphasis on user satisfaction and the indoor environment. The study involved a wide range of methodologies, including a literature review, survey, statistical data analysis, and monitoring sensors. The results revealed that the building has not met the expected occupant satisfaction level, the temperature and air quality were classified as critical sources of comfort, and the personal decisions of the occupants have influenced the overall comfort in the building [83].

Paper (N.5) examined the adaptively reused buildings with a case study from Saudi Arabia. The study was conducted utilising a mix of methodologies, including a user satisfaction survey, interviews, focus group discussions, a walkthrough tour, a literature review, case studies, and data analysis. The study revealed positive feedback from users regarding the performance of the adaptive reuse building received, indicating the success of adaptive reuse projects in meeting performance requirements [100].

Paper (N.6) investigates the post-occupancy evaluation of the indoor air quality and thermal performance within a zero-carbon building in China; the study was conducted using a combination of methodologies to evaluate the project, including a questionnaire survey that is based on the building use studies (BUS). Additionally, the implementation of on-site measurements with the help of digital sensors. The study revealed that despite

exceeding standard temperature limits, occupants rated the building's thermal environment positively. Acoustics were satisfactory, and illuminance levels were mostly high. However, a percentage of respondents reported symptoms of sick building syndrome, indicating potential concerns about indoor air quality or other environmental factors [101].

Paper (N.7) explores the post-occupancy evaluation of indoor environmental quality within office buildings from the perspective of two specific groups of people, architects and non-architects. The study methodologies involve a literature review, survey, observations, and statistical data analysis. The results revealed that the non-architect group prioritised sustainable building design and set a higher level of satisfaction than the architects group [102].

Paper (N.8) reviews the indoor environmental quality of an office building with an emphasis on the occupant's health, comfort, well-being, and work productivity. The study of the paper was conducted through different methodologies, including IEQ monitoring systems, wireless sensor networks, and cloud platforms and software. The study outcome verified that the IEQ domain can impact the occupant's productivity, comfort, and well-being, and personal factors, including age, gender, office type, and location, can greatly influence each occupant's experience [103].

CHAPTER III

RESEARCH METHODOLOGY & CASE STUDY

This thesis is structured using a mixed-methodology research approach, with the aim of achieving a precise study outcome. Therefore, the study includes a mix of qualitative and quantitative methods. The data sets are analysed separately and then merged for a comprehensive analysis and understanding [104].

The research is conducted through four main stages outlined within a systematic research process to properly evaluate a green building's performance in terms of its occupant's thermal comfort. After the research questions of the research are defined, first, the process starts off with a literature search to direct the framework design of the thesis, which involves the definition of the criteria to select the case study of the building, the design process of the survey, and preparing the interview questions. The next stage involves the data collection methods of the thesis, which are conducted using the survey and interview as the main data collection tools. The subsequent data collection process includes gathering initial information and conducting surveys and interviews. Finally, all of the collected data, including survey results and the evaluation of the local thermal discomfort through the interviews, which can all be comparatively analysed through IBM SPSS software, which serves as the outcome of the research process and the overall evaluation of the results of the thesis study. Figure 6 summarizes the whole research methodology applied in this thesis research.

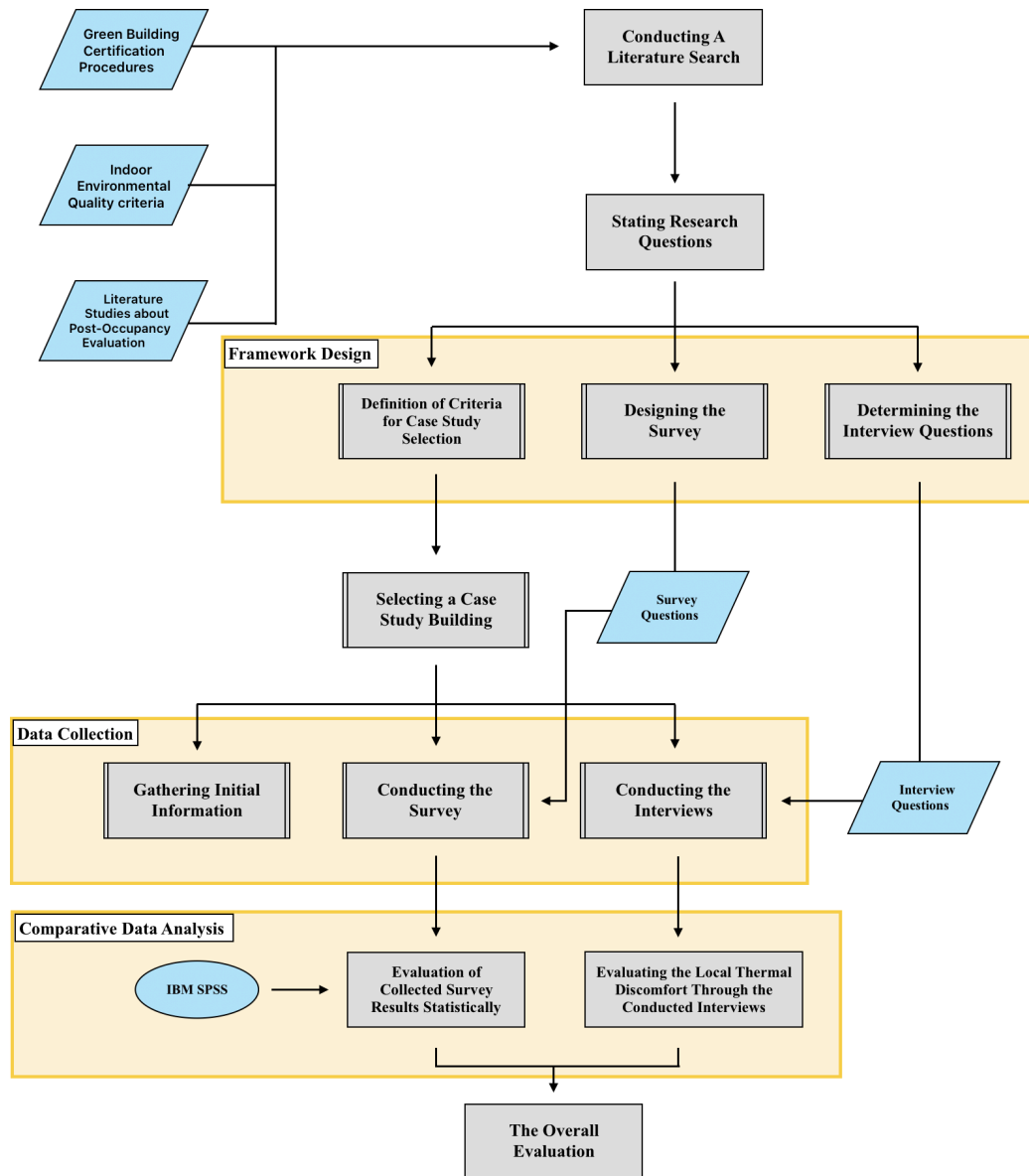


Figure 6: The conducted methodologies in the thesis.

3.1 Literature Search

This study conducted a literature search as a major part of the qualitative methodologies. This approach, which was explained in Chapter 2 in detail, includes identifying and analysing the existing publications and resources regarding the topics of

the thesis, including green building certification, indoor environmental quality, and post-occupancy evaluation. The main purpose of adapting and adopting this method is to investigate and gather the most d information, which is linked with the overall occupant's comfort and well-being within a specific published study. The conducted literature search can contribute to evaluating the overall usage of the case study building when it is applied to the thesis study.

3.2 Case Study Building Selection

The study has incorporated a case study that is used to acquire specific data and details related to the study within a real-world case scenario and participants, including the participants of the selected building. Moreover, this method has been widely adopted in many recent studies as one of the research approaches, including those referenced in [105], [106], [107]. The selected building that will be used as a case study for the thesis should meet the defined criteria stated in the initial hypothesis of the study, which includes to be an office building with a green building certificate that features a fully glassed façade design, which occupies a high number of occupants.

Depending on the defined criteria of case study building selection, Nidakule Levent office building was selected to conduct the thesis case study by applying the designed research methodology. The building image is given in Figure 7 below.



Figure 7: NidaKule Levent building project [108].

The project comprises a single commercial tower located in Istanbul, Turkey [109]. The project was designed to implement major design strategies, technologies, and innovations with respect to energy efficiency.

3.3 Data Collection

This thesis study's data collection methodology is planned to be conducted in three main stages to contribute to the study's outcome. These include gathering initial information, conducting meetings, and distributing surveys to engage participants within their respective workplace environments [110].

3.3.1 Gathering Information About the Case Study

This stage of the data collection method includes gathering general information about the selected thesis case study. The researched data includes building project drawings, information about the building's LEED certification, adapted technologies into the building, and the overall consumption of the building. Collecting this data provides a rounded view of the overall building's design, functionality, and sustainability, which can develop an understanding of how to evaluate the indoor environmental quality and thermal comfort in the subsequent stages of the research.

3.3.1.1 General Information About the Case Study Building

The project reached completion in the fourth quarter of 2016, taking up a total of 53,000m² construction area span with a total height of 140 meters [109]. The project accommodates its workplaces and serves its occupants through twenty-seven floors. It offers seven different office layout design categories: meeting halls, a food hall, cafes, a sports centre, and an underground parking lot (refer to Figure 8) [108]. The exterior façade of the building is a glazed curtain wall façade. The building features pointed, sharp, and angular edges that deviate from its original design.

The sharp-edged exterior design decision has masterfully manipulated the floor plan layout, segmenting it into three main configurations. The first section spans from the first to the fourteenth floor, while the second section is the fifteenth to the twenty-fourth floor, and the final section includes the twenty-fifth to the twenty-seventh floor (refer to Figure 9 for a visual representation). However, as the floors move up in levels, there are

noticeable differences in each layout's total floor area as it gradually gets smaller. Moreover, the central core of the building features two uninterrupted staircases that run from the eighth basement floor up to the 27th floor, as illustrated in Figure 10.

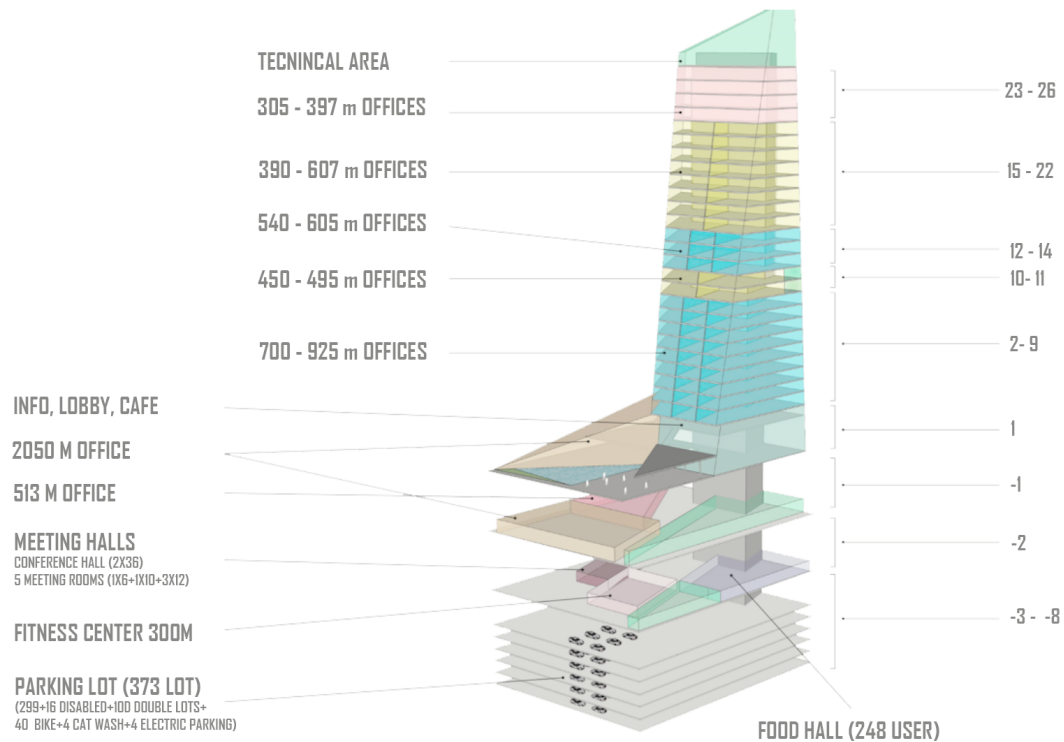


Figure 8: The case study Section Cut Diagram [108].

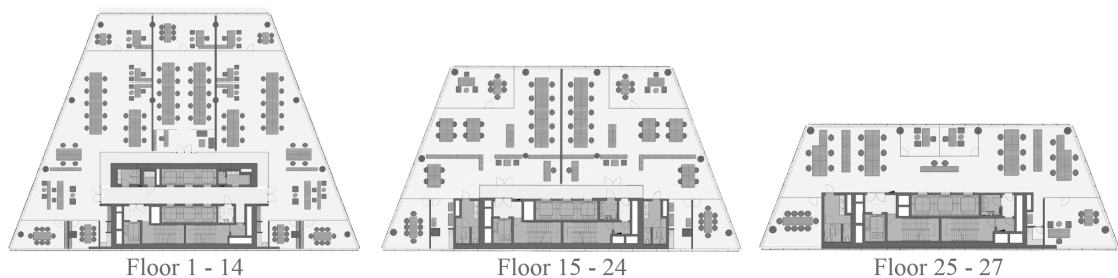


Figure 9: The floor plan variations of the case study building [108].

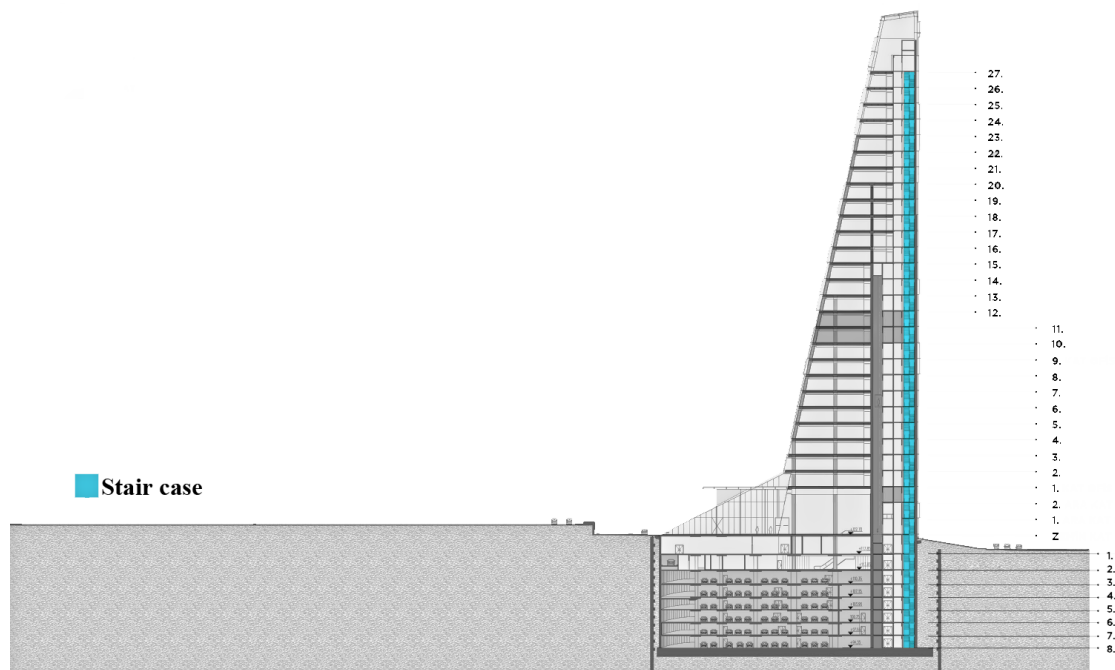


Figure 10: The case study section cut [108].

3.3.1.2 *Information Regarding Leed Certification of The Building*

As NidaKule Levent Building has been developed to claim the project sustainability. In October 2017, the building received its golden LEED certification award. This project can be seen as a whole reflection of a comprehensive approach to sustainable design development. The project was evaluated based on different criteria such as Sustainable Sites, Water Efficiency, Energy and Atmosphere, Material and Resources, Indoor Environmental Quality, Innovation, and Regional Priority Credits.

As a result of the official LEED certification score page published by the USGBC (refer to Figure 11) [111]. The results have demonstrated evident efforts in promoting sustainability, as the project has noted great points in several categories. To illustrate, the building was committed to achieving the best energy efficiency results by performing

notable success in fundamental energy performance, commissioning, and energy utilisation. Moreover, the building has promoted more environmentally friendly transportation options, incorporating low-emitting materials, optimising water use and reducing wastage [112]. Taking the quality of the indoor environment into consideration and innovation in design, The project resulted in a total score of 65 out of 110 [108]. The building stands as a certified exemplar of sustainable construction, showcasing a multifaceted approach and a commendable commitment to environmental responsibility within its design and operation stage.

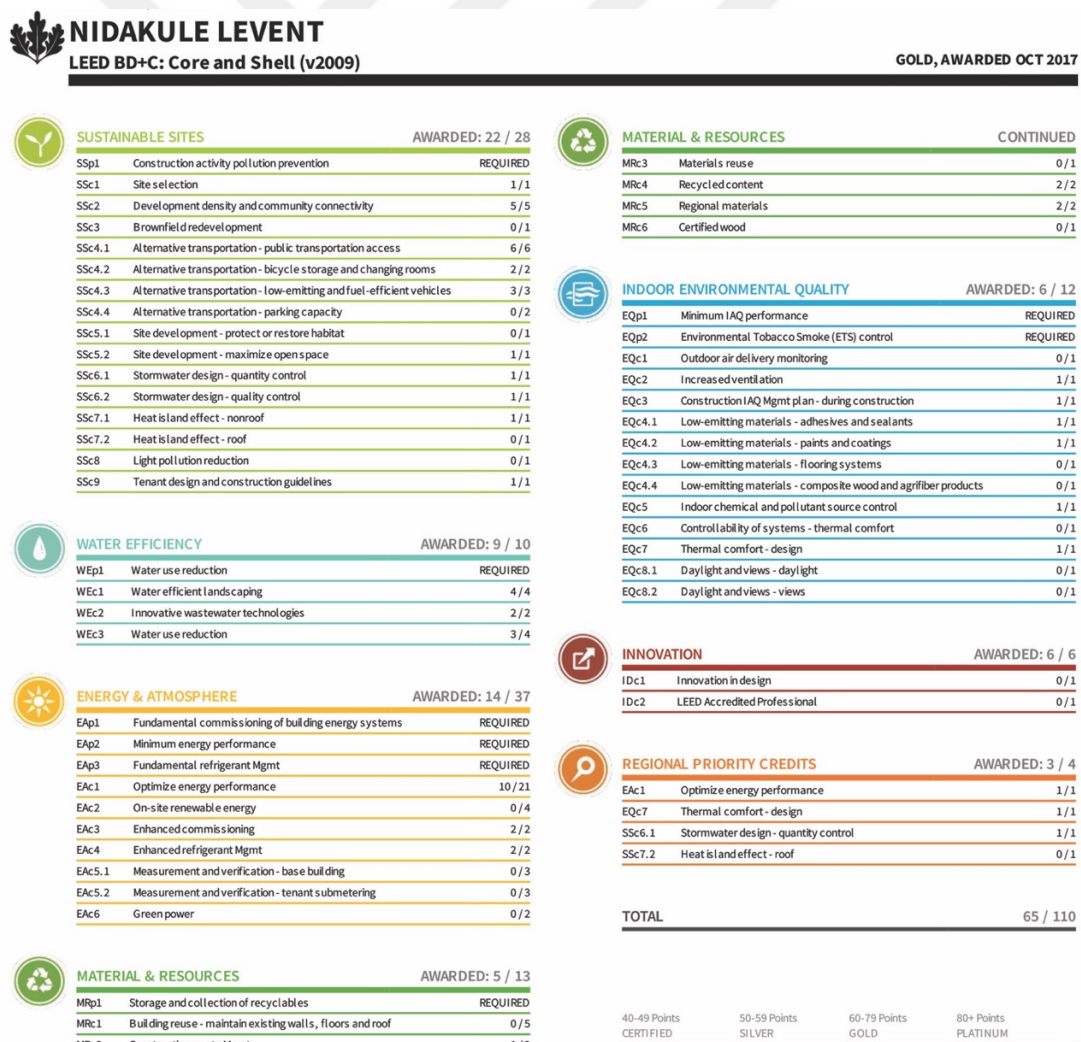


Figure 11: The score page of the NidaKule LEED certification [112].

The building has adapted different technologies and features to achieve sustainable practices and energy efficiency. The design also considers waste reduction and pollution prevention to follow eco-conscious construction practices in the modern urban landscape. The design's features and systems comply with certified international standards, ensuring sustainability is at the forefront of the building's functionality and operation.

Rainwater collection infrastructure is one of the vital features implemented in the building [112]. The project has implemented a rain harvesting system located on the 27th floor of the building's technical section. This system collects rainwater and utilises different stages of filtration for use in various building parts [113]. The goal is to achieve at least 40% water efficiency compared to EPA standards [108]. The system collects the rainwater from the rooftop of the building and directs it into the water tanks on the basement floor. After the filtration process, the water is transferred into a clean tank to be used across the building. The water goes through another filtration process to put the grey water again into use in sanitary fixtures for maximum water conservation. This method of recycling rainwater reduces water consumption, prevents soil erosion, and reduces strain on stormwater drainage systems, which can result in substantial water savings [113]. Figure 12 demonstrates the process of rainwater harvesting within the project.

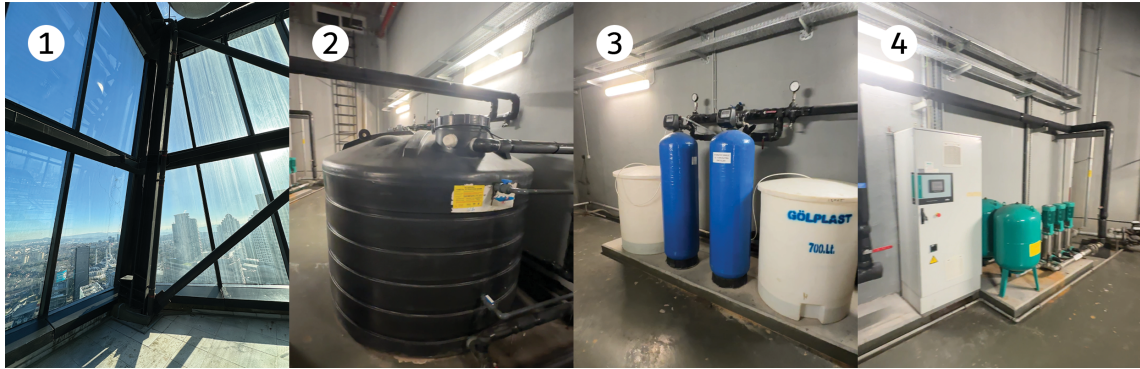


Figure 12: The process of rainwater harvesting.

Another vital green feature in the building is energy efficiency [112]. Various systems were implemented in the building to assist in achieving its sustainability. For example, the building has implemented a building automation and monitoring system to track the energy usage on every floor through computerised energy models, which can ensure the sustainability track of the building while providing a comfortable environment for the occupants. This includes energy, water, heating, and cooling system consumption. The system plays a significant role in building structures by actively monitoring, controlling, and fine-tuning the energy consumed. The building automation system is linked to a digital program that automatically generates daily, weekly, monthly, and annual reports for the technical team, providing a comprehensive evaluation and understanding of the building's energy efficiency [113]. Figure 13 displays the software used in the building.

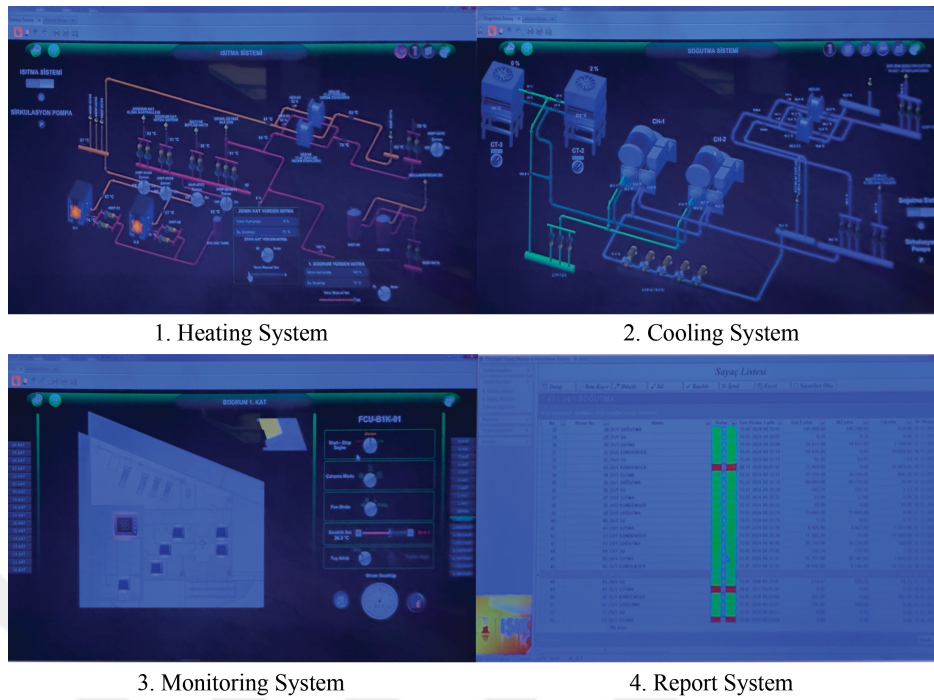


Figure 13: Different systems implemented into the building.

3.3.1.3 *The Overall Consumption of The Building*

As part of the thesis's initial data collection process, the following report and charts were prepared in collaboration with Nidakule Levent's technical chief and manager. As explained in the previous section [113], the overall building usage and consumption are monitored through the reporting system. Then, the data is generated on a monthly basis, including the consumption of electricity, natural gas, and water within the building between 2018 and 2023.

- **the Annual Electricity Consumption**

While monitoring the building for the past six years, it has revealed across all years a pattern of an increase in overall consumption of electricity from the month of January until July. This can be explained by the summer season, as the temperature

significantly increases and the higher demand for cooling systems increases accordingly. Contrariwise, the overall consumption of electricity from the months of August to December decreases, which indicates that the seasonal pattern is highly affected by seasonal change. However, it can be observed that the month of April 2020 onwards has marked an unusual decrease in readings, which can be caused as a result of the COVID-19 pandemic. All in all, the highest recorded reading in the charts was reported in May 2022, while the lowest was in April 2020, as given in Figure 14 and Table 2.

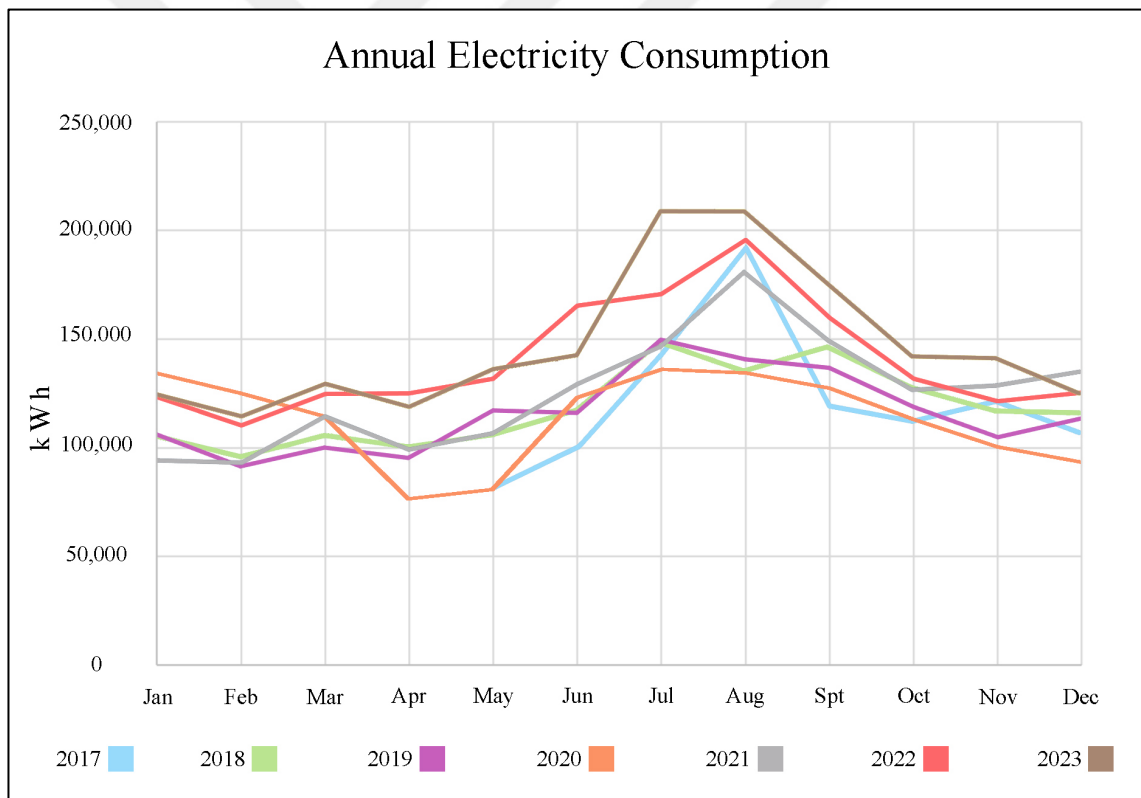


Figure 14: The annual electricity consumption in Nidakule Levent.

Table 2: The annual electricity consumption in Nidakule Levent.

2018		2019	
Month	Electricity Consumed	Month	Electricity Consumed
January	104725,44	January	114716,64
February	96042,48	February	102851,4
March	104871,72	March	109872,84
April	100124,52	April	105934,32
May	105128,4	May	123474,12
June	115668,84	June	122441,88
July	144014,04	July	149525,76
August	131908,68	August	142200,7
September	142109,64	September	139186,8
October	125061,12	October	124873,4
November	115293,48	November	113629
December	114556,56	December	120551,28
2020		2021	
Month	Electricity Consumed	Month	Electricity Consumed
January	133581,24	January	96293,64
February	125102,52	February	95551,2
March	115241,04	March	112533,48
April	80004	April	100375,68
May	84014,4	May	106320,72
June	123228	June	124533,96
July	135242,76	July	138477,48
August	133768,92	August	165983,64
September	127318,8	September	140773,8
October	113924,52	October	122488,8
November	102153,12	November	124059,24
December	95672,64	December	129195,6
2022		2023	
Month	Electricity Consumed	Month	Electricity Consumed
January	123396,84	January	124271,76
February	110369,64	February	114669,72
March	124691,28	March	129375
April	125143,92	April	118900
May	131875,56	May	135761,64
June	165434,4	June	141941,28
July	170639,76	July	206624,64
August	195761,28	August	206580
September	159732,24	September	173910,36
October	131743,08	October	141524,52
November	121464,84	November	140699,28
December	125439,24	December	125000

- **The Annual Natural Gas Consumption**

The reports of the overall consumption of natural gas in NidaKule have revealed a potential pattern in the last monitored years. The charts demonstrated averagely low readings during the summer season (May to August) and higher average readings in the winter (December and January). This can imply a higher demand for heating systems during colder months of the year, which can again indicate that the seasonal pattern is highly affected by seasonal change. Moreover, according to the chart, it can be noticed that the consumption of natural gas is in high demand, which is constantly increasing every year. For example, December 2021 witnessed an increase closer to double the consumption of 2018. All in all, the highest recorded reading in the charts was reported in January 2022, while the lowest was in May in most of the yearly reports, as given in Figure 15 and Table 3.

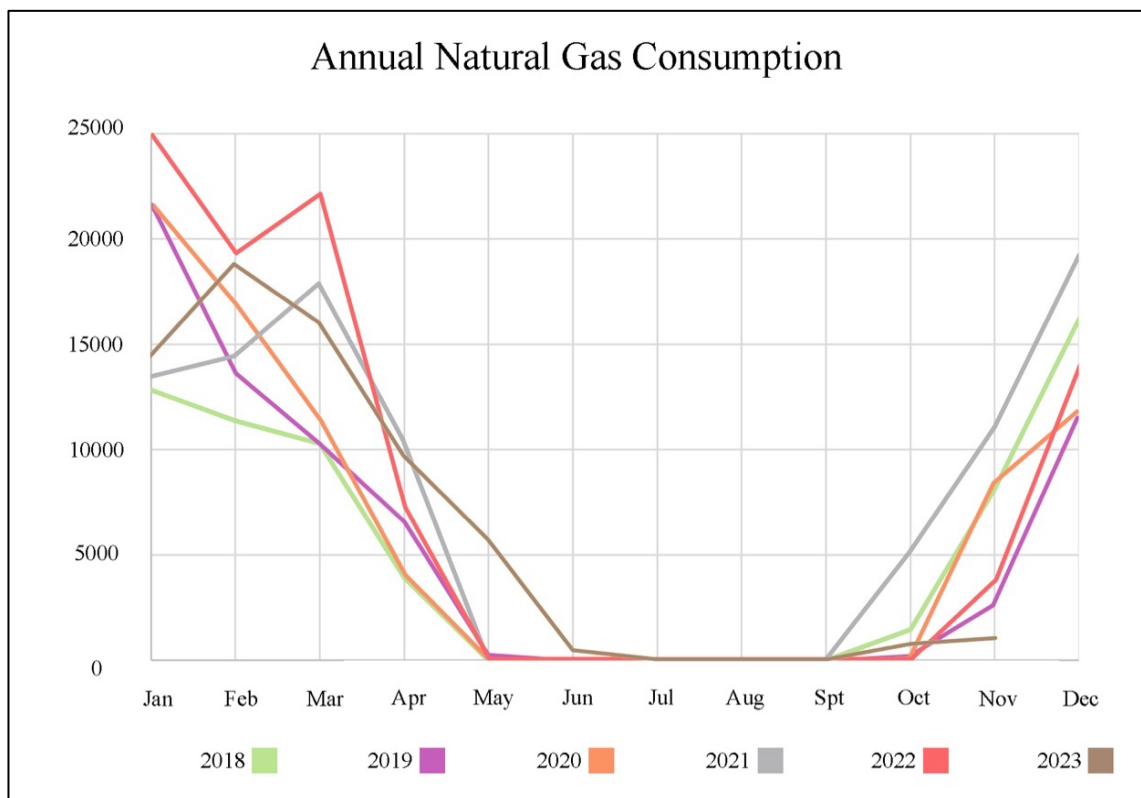


Figure 15: The annual natural gas consumption in Nidakule Levent.

Table 3: The annual natural gas consumption in Nidakule Levent.

2018		2019	
Month	Natural Gas Consumption	Month	Natural Gas Consumption
January	12816	January	21490
February	11367	February	13538
March	10294	March	10204
April	3905	April	6529
May	0	May	266
June	0	June	0
July	0	July	0
August	0	August	0
September	0	September	0
October	1469	October	216
November	8138	November	2609
December	16191	December	11462
2020		2021	
Month	Natural Gas Consumption	Month	Natural Gas Consumption
January	21475	January	13390
February	16750	February	14368
March	11305	March	17803
April	4028	April	10401
May	0	May	0
June	0	June	0
July	0	July	0
August	0	August	0
September	0	September	0
October	91	October	5116
November	8355	November	11029
December	11743	December	19146
2022		2023	
Month	Natural Gas Consumption	Month	Natural Gas Consumption
January	24676	January	14269
February	19097	February	18657
March	21904	March	15886
April	7157	April	9619
May	0	May	5651
June	0	June	415
July	0	July	0
August	0	August	0
September	0	September	0
October	0	October	717
November	3734	November	986
December	13902	December	

- **The Annual Water Consumption**

The reports of the overall water consumption in NidaKule have revealed a seasonal trend pattern in the summer seasons starting from May to August. Moreover, according to the reports, water consumption is constantly increasing every year. This can imply either intensified usage or a higher growing population in the building. All in all, the highest recorded reading in the charts was reported in July 2023, while the lowest was in February 2021, as given in Figure 16 and Table 4.

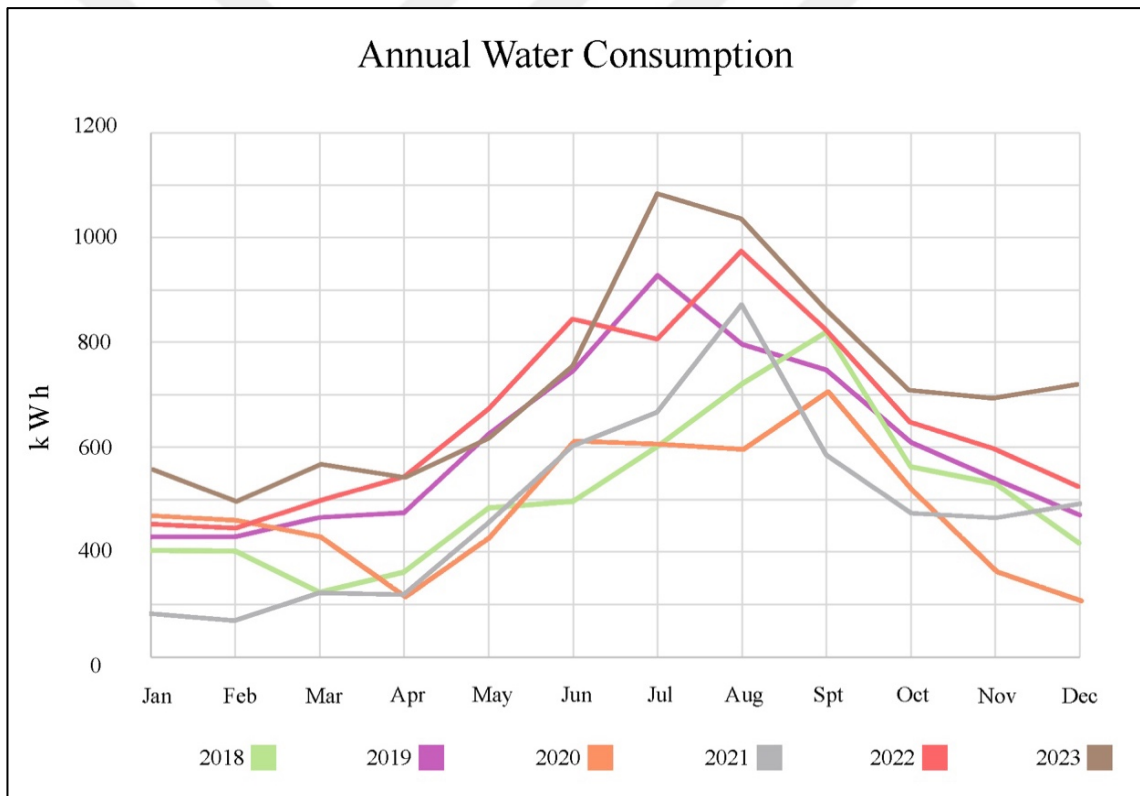


Figure 16: The annual water consumption in Nidakule Levent.

Table 4: The annual water consumption in Nidakule Levent.

2018		2019	
Month	Water Consumption	Month	Water Consumption
January	403	January	458
February	399	February	458
March	243	March	531
April	320	April	550
May	566	May	851
June	590	June	1093
July	802	July	1456
August	1040	August	1193
September	1238	September	1094
October	725	October	818
November	661	November	679
December	430	December	541
2020		2021	
Month	Water Consumption	Month	Water Consumption
January	540	January	172
February	523	February	145
March	459	March	250
April	234	April	243
May	457	May	513
June	821	June	806
July	809	July	933
August	790	August	1341
September	1006	September	772
October	636	October	552
November	329	November	533
December	219	December	588
2022		2023	
Month	Water Consumption	Month	Water Consumption
January	504	January	718
February	489	February	595
March	594	March	736
April	687	April	686
May	942	May	835
June	1284	June	1110
July	1208	July	1763
August	1542	August	1669
September	1246	September	1326
October	892	October	1017
November	793	November	986
December	649	December	1040

3.1.3.4 Survey Development

The development of the survey was structured by a thorough analysis of relevant literature reviews on the topic [83], [99], [114], which contributed to the investigation of the study. The overall process of the survey was developed using a mixed-question methodology to investigate the occupant's feedback regarding their personal experiences related to IEQ. The survey incorporated four different question types to confirm the participants' input through different question formats, including closed ended (multiple choice), open-ended, pointing, and Likert scale questions. The whole set of questions and answer options for multiple-choice questions are given in this chapter of the thesis. The survey design layout was divided into five main sections, each representing a different purpose and expected information outcome out of the respondents:

The first section of the survey is designed to gather general information about the participants. The participants are asked about basic personal information, which includes their current age, gender, highest educational level, and the floor on which their office is located, as given in Figure 17.

Your Current Age	
Your Gender	
Your Highest Educational Level	
Your Office Floor	

Figure 17: The personal set of survey questions.

The second section of the survey was designed to investigate the participant's usage of the space and their occupancy patterns and schedules. The questions delved more deeply into the participants' experiences in the building to understand the occupant's time spent in the setting, including the following multiple-choice questions:

- How long have you been working in this building?
- Have you experienced the building during different climatic seasons (winter & summer)?
- How often do you switch to working remotely (from home or other locations) in a typical workweek?
- When you visit the building, what is the duration of your stay (In hours) each day?
- What type of office layout do you work at?
- How often do you utilise communal areas (breakout rooms, lounges, shared workspaces) in the office for collaborative work or meetings?

The third section of the survey is designed to understand occupant behaviour regarding control of indoor environmental conditions, such as adjustment of the temperature and lighting. For this purpose, the following multiple-choice questions were posed to the survey participants.

- Do you have control over the lighting system in your workspace?
- How often do you manually adjust the lighting in your workspace?
- Do you have control over the temperature thermostat in your workspace?
- How often do you manually adjust the temperature thermostat in your workspace?
- What would you do if you experienced uncomfortable room temperature in a space within the building?

As a major part of the survey, it is essential to consider the occupant's level of awareness regarding the LEED certification and the sustainable strategies implemented into the building, as well as their behavioural development within the building in terms of personal or sustainable acts. Therefore, the fourth section of the survey is developed, including the following questions:

- Are you aware of any energy-saving guidelines provided by the company or building management?
- How often do you follow these energy-saving guidelines, if there are any?
- If yes, do you actively turn off electronic devices (computers, monitors, printers) when not in use?
- What would you do if you encountered an empty space with lights/heating or cooling system left on?
- Did you know if the building has received a LEED certification award?
- After learning about the LEED certification, have you noticed any changes in your personal behaviour regarding building usage?
- Are you aware of any sustainable energy efficiency practices implemented in this workspace?

The fifth section of the survey can be referred to as the main section of the survey since it aims to understand the satisfaction level of occupants regarding indoor environmental quality. The questions in this section refer to thermal comfort, visual comfort, noise control, and indoor air quality-related experiences and perceptions of the occupants. This section includes various question types, including open-ended questions,

multiple choice questions and Likert scale questions. The following open-ended question aims to get overall feedback:

- Regarding your overall experience, have you encountered any challenges or sources of thermal discomfort within your time spent in the space?

In order to link the occupant's responses with the space, the following question is added to the survey by providing a floor plan which is zoned and numbered accordingly for their answer.

- Are there any specific areas within the workplace environment where you experience heightened productivity or increased comfort while working?
If affirmative, could you mark those spots on the floor plan? (Participants will answer according to which floor they are using)

The following set of questions in the fifth section are designed in multiple-choice format:

- How likely are you willing to stay and work in the building comfortably using the space?
- Do you have access to natural daylight in your workspace?
- Have you encountered any issues with glare inside the building, especially during the summer season?

This section of the survey also includes a list of statements regarding the user IEQ based satisfaction using the Likert scale. The scale ranges from 1 to 5, with 1 signifying "Strongly Disagree," 2 representing "Disagree," 3 indicating "Neutral," 4 representing "Agree," and 5 indicating "Strongly Agree." as given in Table 5.

Table 5: Importance of variables v1

Value	Rating Importance of Variables
1	Strongly Disagree
2	Disagree
3	Neutral
4	Agree
5	Strongly Agree

In order to determine the overall satisfaction among the participants within the space, the following statements are provided for Likert scale evaluation:

- I am satisfied with the overall comfort regarding the temperature in the workspace.
- I am satisfied with the overall comfort regarding the thermal comfort in the workplace.
- The indoor temperature is well-regulated when the outside temperature is too cold.
- I am satisfied with the overall comfort of the lighting system in the workplace.
- I am satisfied with the overall comfort regarding the noise in the workplace.
- The fresh air inside is regulated well with the ventilation system.
- The amount of natural daylight entering through the windows is sufficient.

Since the IEQ conditions and consequently occupant satisfaction may vary seasonally, in this section of the survey, the participants who experienced the building in both seasons only were asked to indicate their overall level of satisfaction again using a Likert scale. The following factors are given for assessment:

- indoor temperature
- artificial lighting
- natural daylight
- air quality, noise
- overall comfort

The assessment scale ranges from 1 to 5, with 1 signifying "Extremely Dissatisfied," 2 representing "Dissatisfied," 3 indicating "Neutral," 4 representing "Satisfied," and 5 indicating "Extremely Satisfied." as given in Table 4.

Table 6: Importance of variables v2

Value	Rating Importance of Variables
1	Extremely Dissatisfied
2	Dissatisfied
3	Neutral
4	Satisfied.
5	Extremely Satisfied.

3.1.3.5 Conducting the Survey

The implementation of a POE study is widely common as a major tool to assess any building in terms of its performance or occupant's comfort [115]. In the context of the thesis post-occupancy evaluation process, a survey was designed to be used as one of the data collection methods. Conducting a survey is a critical tool for communicating with the occupants of the building, which enables the researcher to acquire valuable direct insights regarding their personal experiences within the setting. Therefore, POE studies

imply the importance of taking user feedback into consideration, which can deliver the source of any deficiencies and improve the user experience within the building [116].

As an important stage, before conducting the survey, it is important to mention that the study was approved both by the ethical department of the educational institute and the project management in which the case study will take place.

The overall period of the thesis study was carried out as a one month-long field experiment. The research period and survey distribution within the building were initiated on February 1st, 2024. During this period, survey responses were received progressively until the final response was delivered on February 20th. The survey was prepared to be handed over randomly to the occupants across different floors of the building to gather more other different perspectives. With the participation of 52 employees in the building, the occupants of the building were invited to participate in the survey in two different ways according to their personal preference: either by receiving an email with access to an online survey link, which was sent through the building management, or after visiting the site and handing out a physical QR code to scan to access the digital format of the survey online. In the end, all of the survey results are all gathered and linked to be stored in the cloud software, which can then be generate the results in excel form to be used in IBM SPSS software to statistically analyse the outcome of the collected data.

3.1.3.6 Conducting the Meetings & Interviews

On the quantitative methodology front of the project evaluation process, the implementation of meetings and interviews is one of the significant components of the research methodology of the thesis study. The meetings and interviews are utilised to gain a deep understanding of the user's perspective and use it to improve the project's outcomes. By directly engaging with participants of the interviews, we can systematically query them to gauge their perceptions and experiences, which assists in gathering valuable insights from their perspective by asking them specific questions related to experience within the project and overall satisfaction.

In the case study, several on-site interviews were conducted with different groups of building users, including the building management and security guards. The highest number of participants were the occupants who worked in different companies and sectors on different floors of the building. The interviews were conducted in this study because their outcome can reveal more specific feedback from the occupants. To illustrate, when the person engages in a conversation, they are more likely to share more data and information talking in person rather than filling out the survey, which can reveal a list of pros and cons that can be pointed out from their point of view after they had the chance to experience the project. With 28 participants in the conducted interviews in the building, the occupants were invited to engage in a short conversation with a duration of ten to fifteen minutes. The participants were chosen from different floors and interior spaces of the building to cover different user experiences and their overall input to the study. In the end, all of the collected data results were gathered and listed on an Excel

sheet, which can be used for further comparative analysis of the outcome of the overall collected data.

The interview section of the study has incorporated a wide range of questions for the participants, which can provide a better level of understanding regarding the occupant's thermal comfort. The questions delved more deeply into the participants' experiences in the building to understand the occupant and time quality spent in the setting, including the following questions categories:

- Thermal experience.
- Sunlight and temperature control.
- Lighting control.
- Indoor air quality
- Indoor air ventilation
- Office environment
- Personal & natural parameters.

3.1.3.7 Evaluation of The Results

This part of the study elaborates on the process behind the methodology employed to collect the data for the survey, which assists in comparing and evaluating the data collected from different methods quantitatively. As a result, 52 valid survey responses were gathered from the participants. The gathered data is then analysed comparatively and statistically using the IBM SPSS Statistics software, and visually represented graphics and charts based on the data collected were created using the MS Office Excel

and Adobe Photoshop programs. IBM SPSS is a computational software program designed to conduct statistical analysis in social science research. The program can be used by researchers to efficiently manage, analyse, and interpret data collected while offering a wide range of statistical tests, data visualisation tools, and reporting features, which makes it easier to identify trends, patterns, and insights from the gathered data [117]. A more detailed explanations of the results are given in the following chapter.



CHAPTER IV

RESULTS & FINDINGS

This chapter presents the results of the thesis study, including the directly acquired and comparatively analysed results collected from the conducted survey, meetings, and interviews.

4.1 Survey Results

The survey involves responses from volunteers from all building floors in an attempt to ensure a broad and inclusive input range. It is worth noting that two-thirds of the participants had prior experience in the building across both seasons, summer and winter, while a smaller number had only participated in the winter season. The results show that, on average, the participants spend a minimum of six hours per working day in their office.

With the participation of 52 employees in the survey, the overall population of the participants has revealed a balanced distribution of identified gender with a slight predominance of male ratios over females with an average age of 31 to 40 years old range, which can indicate a relatively young population. Regarding spatial distribution within the building, the most populated floors are the ground floor up to the 14th. In terms of the educational level of the occupants, the results have revealed an overall high level of education, where the majority of the occupants have earned their bachelor's degree, while smaller groups have earned a high school diploma, a master's degree, which indicates a

diverse range of high educational backgrounds within the building. A brief summary of crucial participant characteristics, such as their identified gender, age, and which floor they participated from, is given in Figure 18.

		Numbers	Ratios
Gender	Male	27	52.90%
	Female	24	47.10%
	Total	52	100%
Age	Under 30 years old	15	28.84%
	31 - 40 years old	18	34.61%
	41 - 50 years old	15	28.84%
	over 50 years old	04	07.69%
	Total	52	100%
Occupied Floor	Basement Floors	05	09.61%
	G to 14	36	69.23%
	15 to 24	11	21.11%
	Total	52	100%
Highest Educational Level	High School Diploma	11	21.20%
	Bachelor degree Master's degree	29	55.80%
	Other	08	15.40%
		04	07.60%
	Total	52	100%

Figure 18: Characteristics of the survey participants.

4.1.1 Survey Responses

The first part of the survey results demonstrates some of the selected results that are received directly from the survey responses from the occupants (refer to Appendix B for the entire survey and results). The results obtained for overall user satisfaction are presented in Figure 19 below. It revealed that the participants felt neutral and satisfied with the regulation of temperature and fresh air. It is worth noting that there is a high satisfaction rate with natural daylight, with many respondents expressing extreme

satisfaction, which was an expected outcome considering that the building has a fully glassed facade design. However, the overall occupant satisfaction levels regarding indoor noise varied more widely, with a notable ratio of occupants feeling extremely satisfied, satisfied, and neutral.

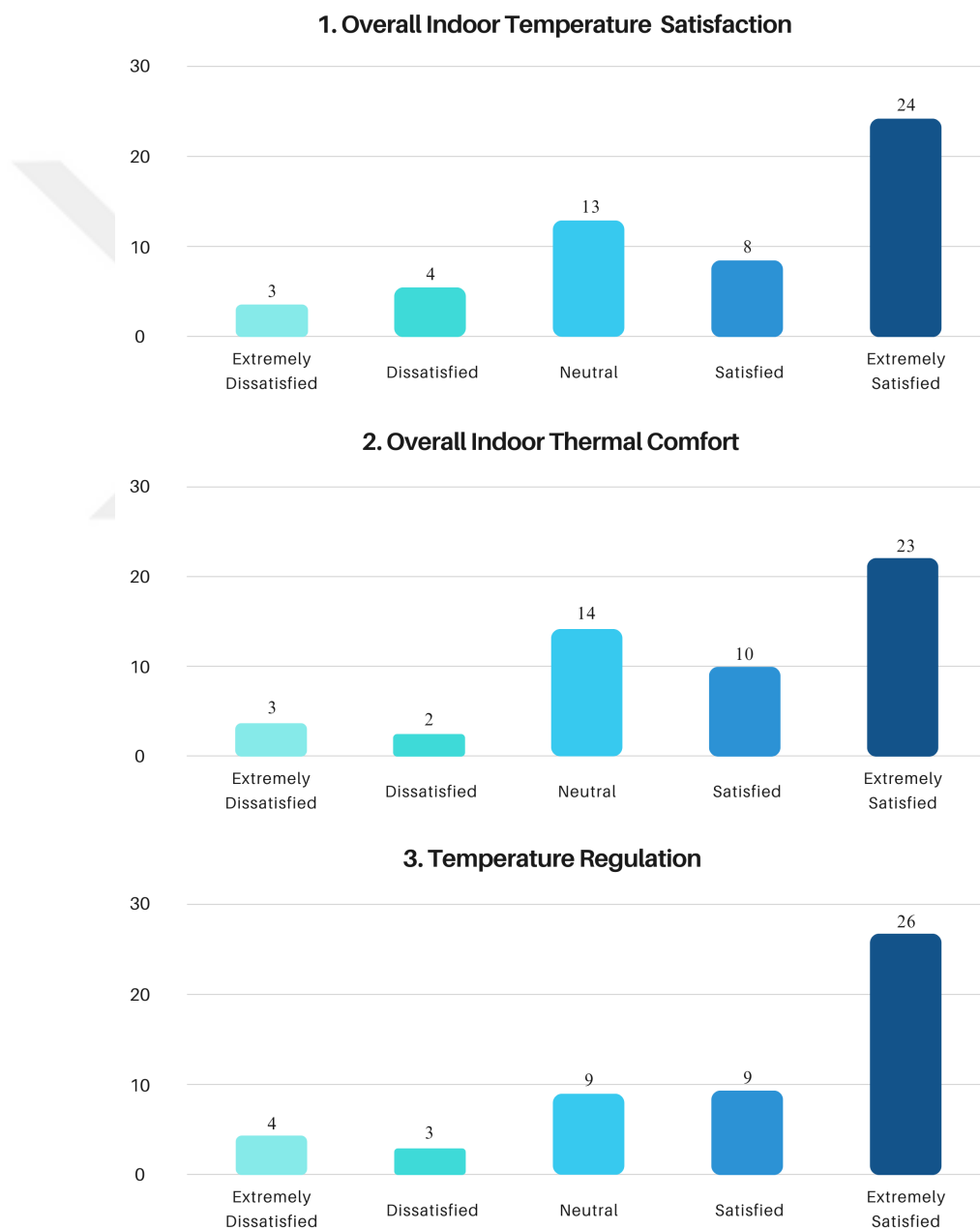


Figure 19: The overall user satisfaction.

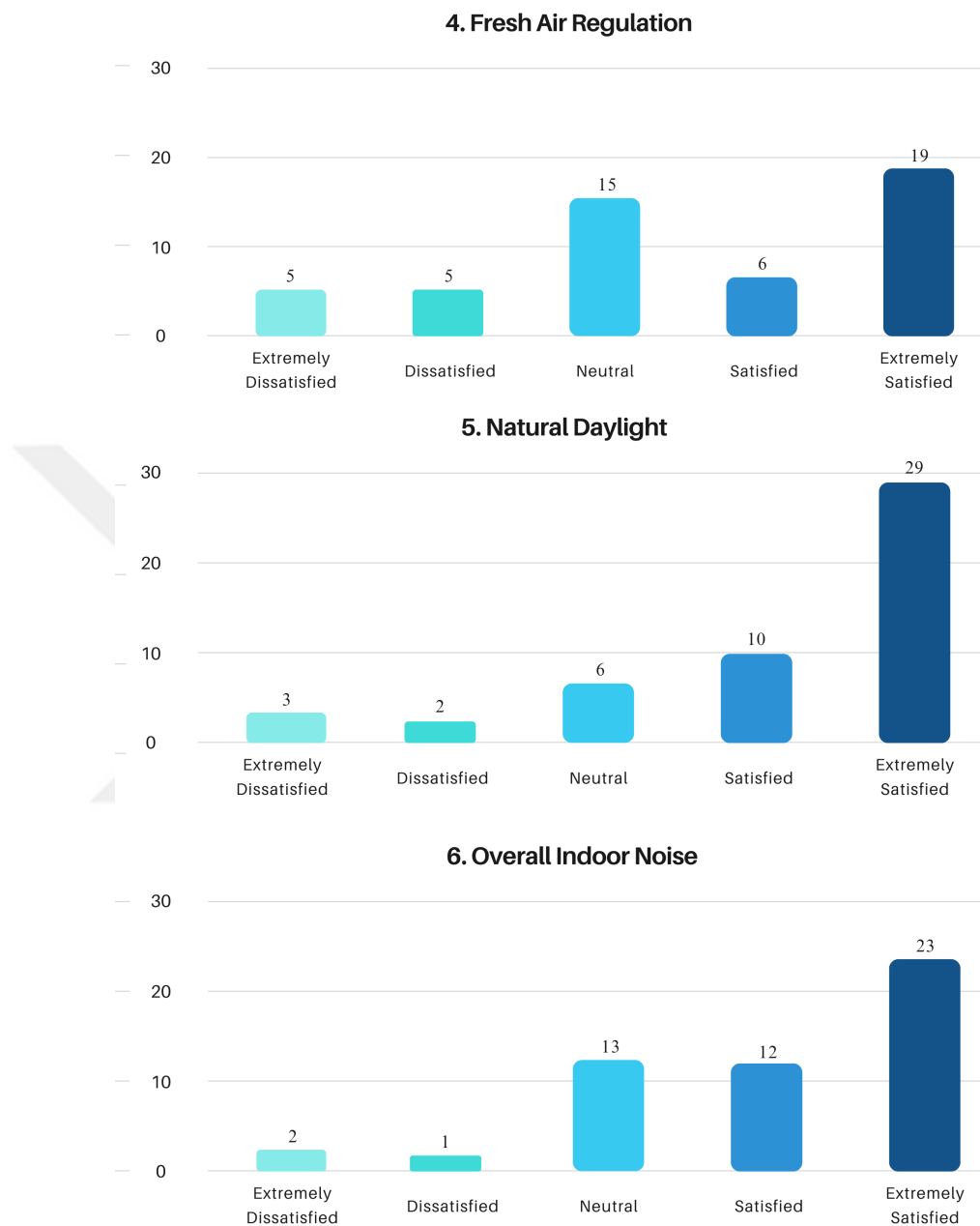


Figure 19 (continued): The overall user satisfaction.

The thesis study also investigated how the occupants perceive and prioritise sustainable practices and indoor environmental comfort quality within their workplace, as shown in Figure 20. As shown in the figure, the survey has reported a significant

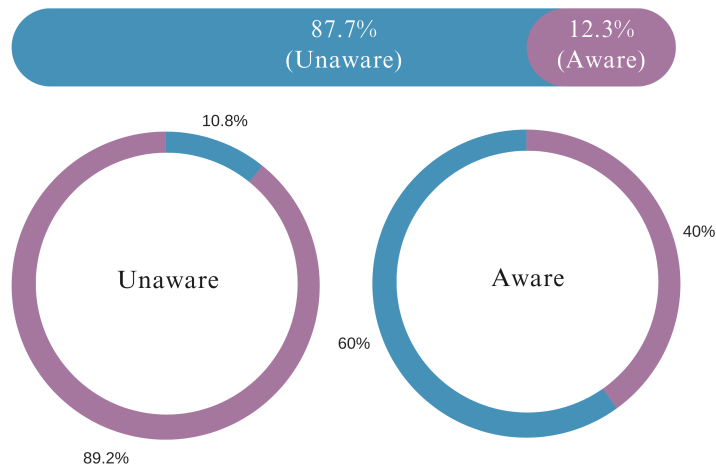
awareness among the building occupants. The results revealed that only 12.3% of the occupants were aware of the building's LEED certification, while 87.7% of respondents were unaware. On a bright note, the majority of 60% of the occupants have expressed some noticed behavioural changes after learning about the LEED certification regarding their building usage. Moreover, the survey has unveiled a relatively high level of awareness, 57.1%, regarding implementing sustainable energy efficiency practices within the building.

The occupants of the building play a critical role in user behaviour adaptation within the space. This theory is tested by asking them questions regarding their behaviour and how they would act in specific situations that represent inefficiency in terms of environmental sustainability. The occupants were asked if they would usually turn off unused electronic devices, including computers, monitors, and printers. The results demonstrated high active participation in energy conservation among the participants, with 84.6% of the occupants stating that they would always turn them off. Additionally, one of the survey questions asked about their reaction in encountering an unused space with lighting, heating, or cooling systems left on. The results have shown that the occupants are willing to contribute to maintaining a sustainable environment, as revealed 53.3% of the occupants would rather report it to the technical team of the building, while 40% would turn it off, and 6.7% would leave it as is.

OCCUPANTS LEED AWARENESS

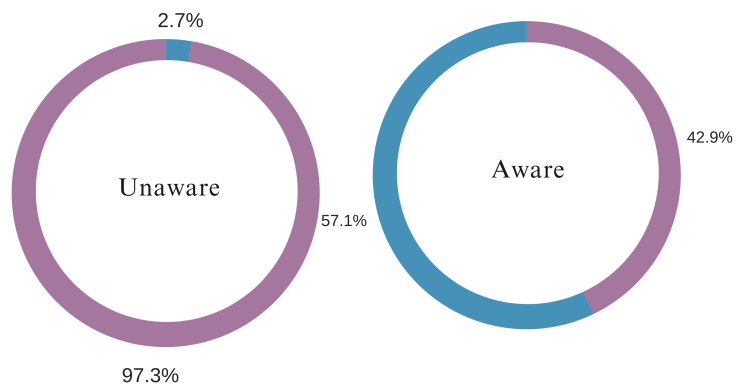
After learning about the LEED certification, have you noticed any changes in your personal behaviour regarding building usage?

- Yes
- No



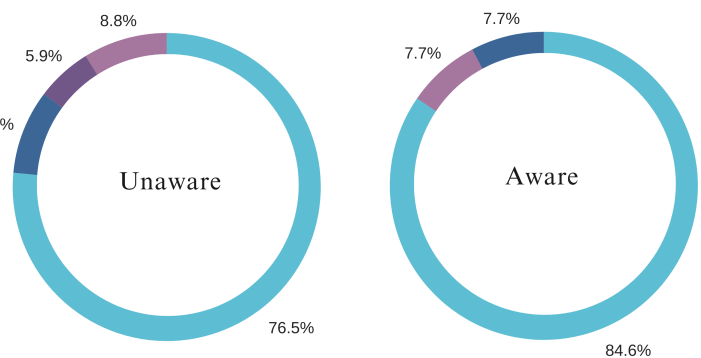
Are you aware of any sustainable energy efficiency practices implemented in this workspace?

- Yes
- No



Do you actively turn off electronic devices (computers, monitors, printers) when not in use?

- Always
- Sometimes
- Rarely
- Never



What would you do if you encountered an empty space with lights/heating or cooling system left on?

- Report it to the technical team
- Turn it off
- Leave it as it is

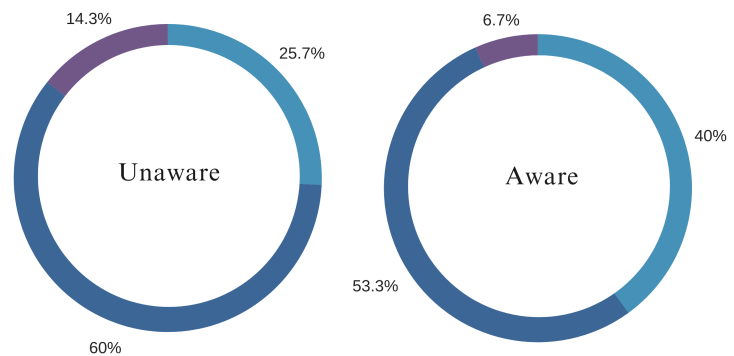


Figure 20: Occupant's behaviour and level of awareness.

The survey of the study investigated a variety of environmental parameters, which revealed a clear pattern when it was reviewed by taking the seasonal variations and user perceptions of comfort within indoor environments into consideration. However, the survey has shown a higher overall satisfaction in the winter regarding indoor temperature, air quality, natural daylight, and artificial lighting. The overall comfort results have revealed mixed responses, with a higher ratio of the occupants expressing extreme satisfaction during winter while maintaining balanced satisfaction levels across different seasons, as given in Figure 21. Based on the initial survey results, most respondents perceive the indoor environment positively. The majority of participants expressed either satisfaction or neutrality towards the indoor temperature and thermal comfort.

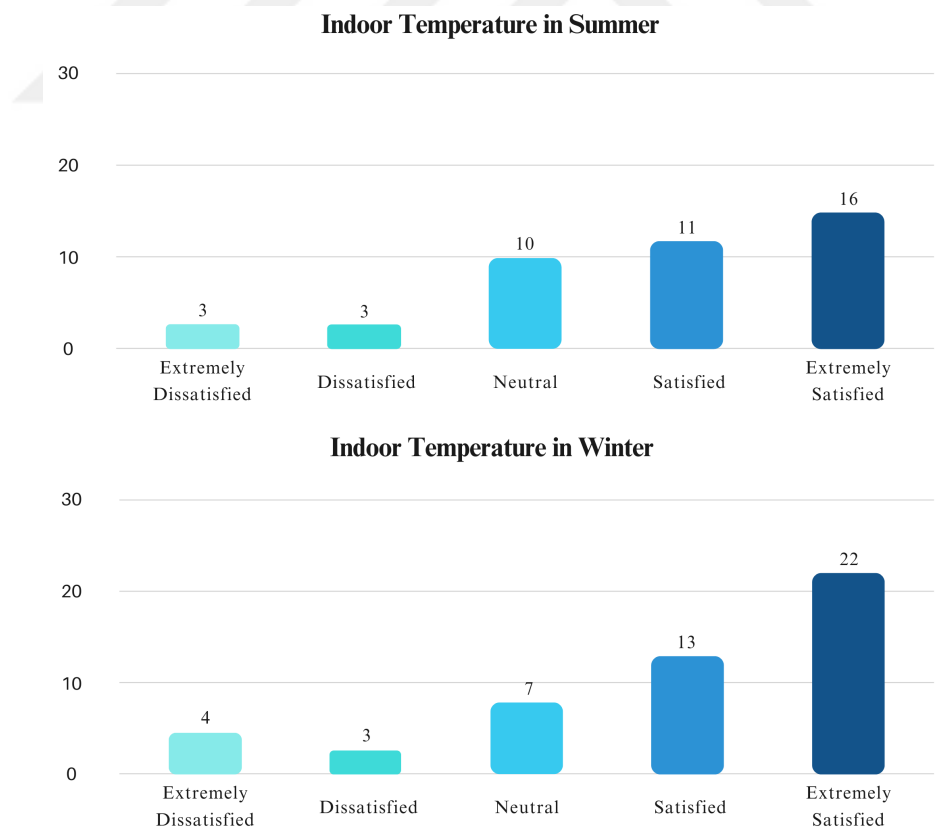


Figure 21: The overall user satisfaction in summer and winter.

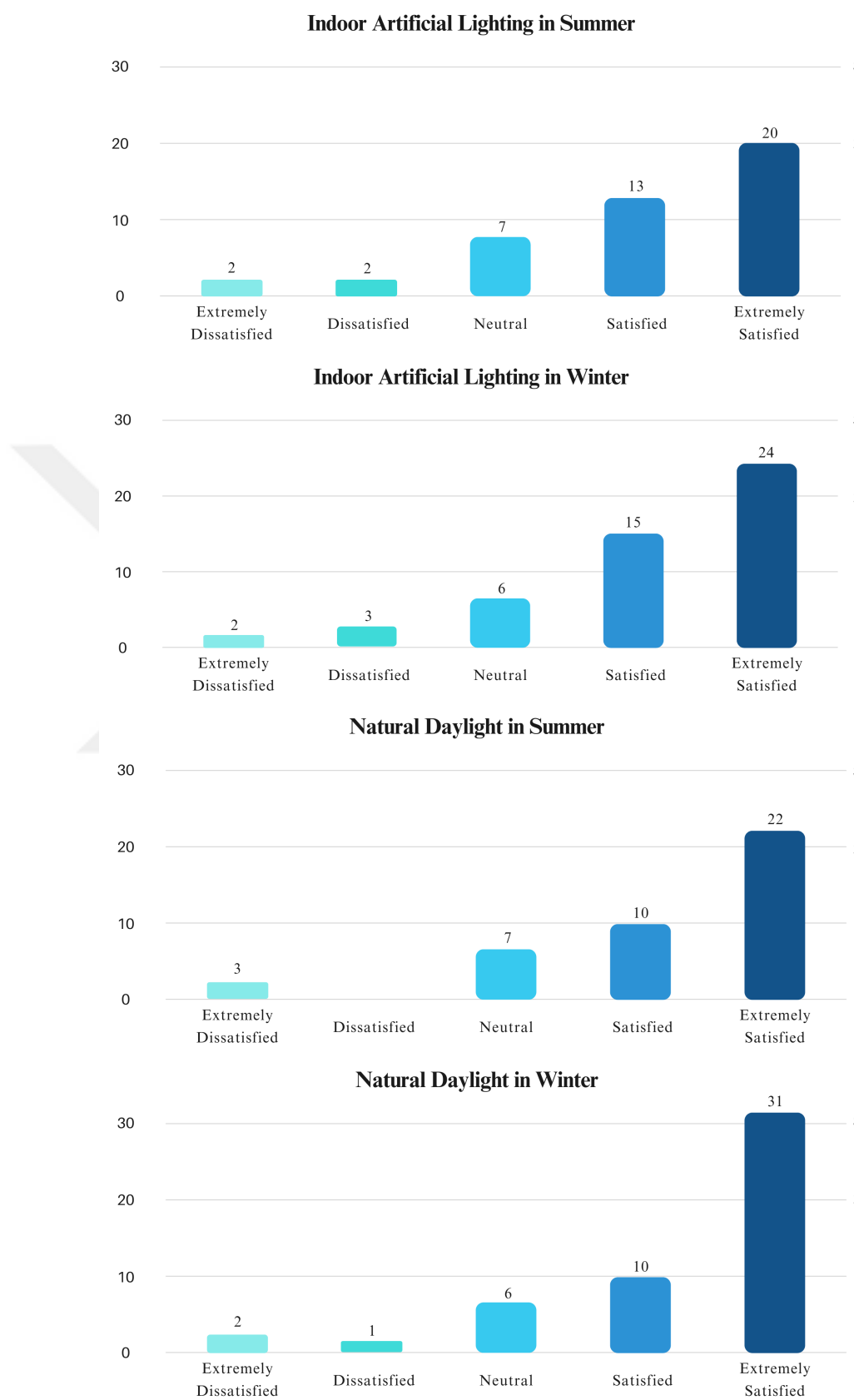


Figure 21 (continued): The overall user satisfaction in summer and winter.

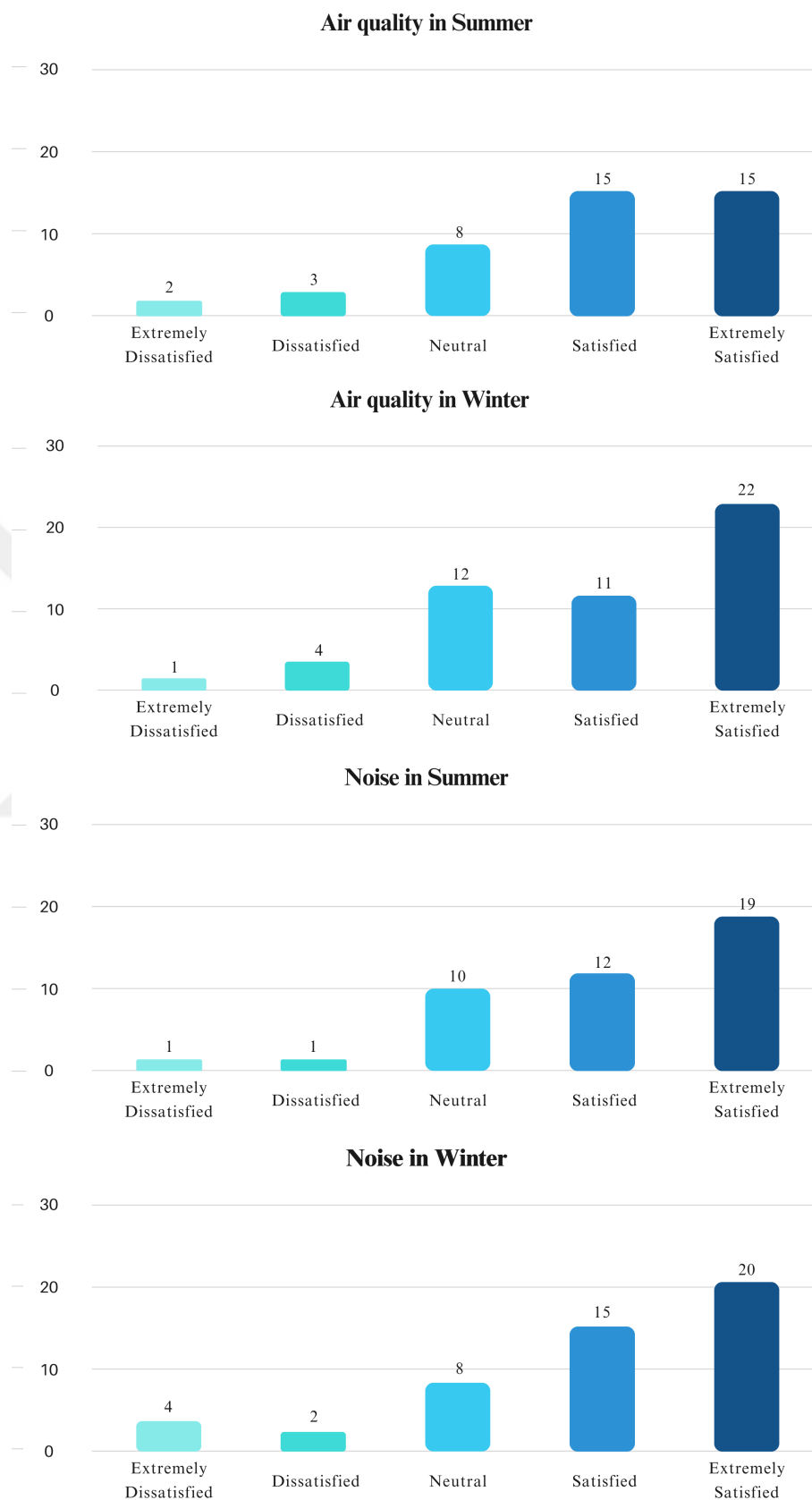


Figure 21 (continued): The overall user satisfaction in summer and winter.

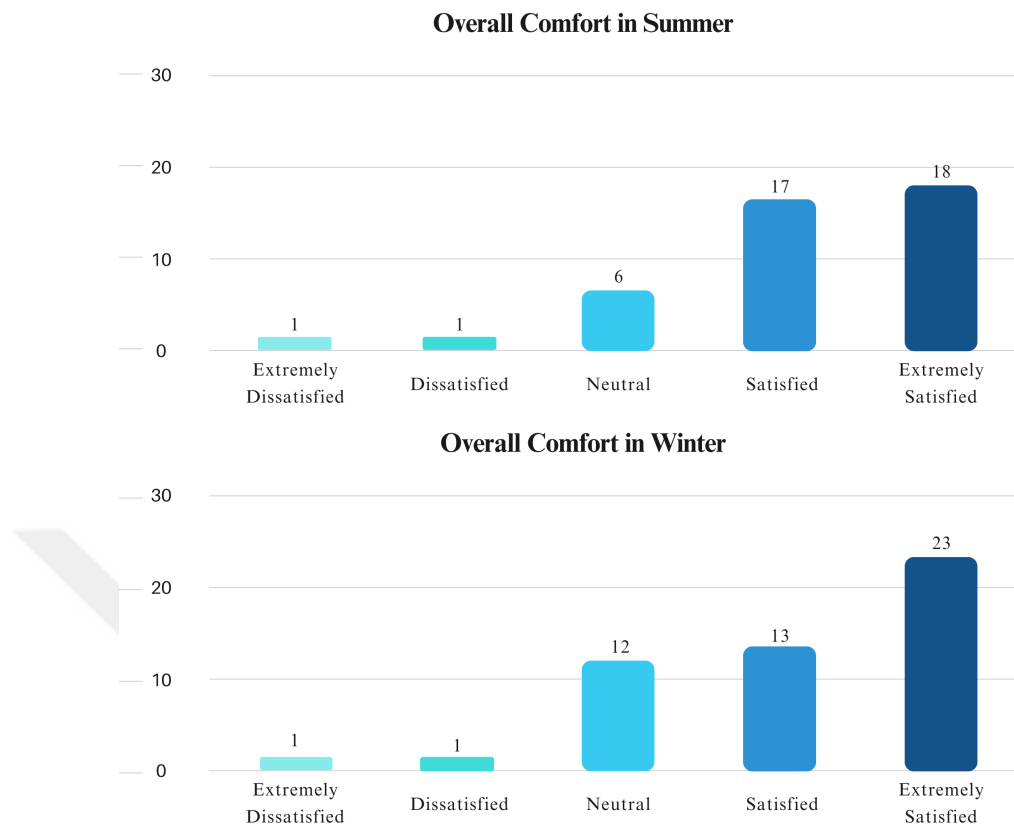


Figure 21 (continued): The overall user satisfaction in summer and winter.

4.1.1 Comparative Analysis of The Selected Survey Results.

In the second part of the study's outcome, the survey results were analysed using IBM SPSS software. In this section of the study, to find correlations between the responses from occupants and answer the research questions, the data was statistically tested by analysing different means of two variables (independent samples) or within the same subject (paired samples).

Firstly, the survey results were analysed to compare the overall user satisfaction with an emphasis on thermal comfort in both summer and winter as the occupants have identified themselves as male and female, as given in Figure 22. To illustrate, during

summer, male occupants display a relatively balanced distribution of satisfaction, with a significant ratio of males being extremely satisfied. Comparatively, the female participants revealed a higher level of satisfaction, indicated by a substantial number of females expressing their satisfaction, while the minority implied extreme dissatisfaction. On the other hand, the dynamic has shifted during winter. The male participants revealed a greater increase in extreme satisfaction conditions, while female occupants demonstrated an equal ratio of neutral, satisfied, and extremely satisfied expressions. All in all, the outcome of these results can indicate the differences in their personal thermal perception and preference between males and females.

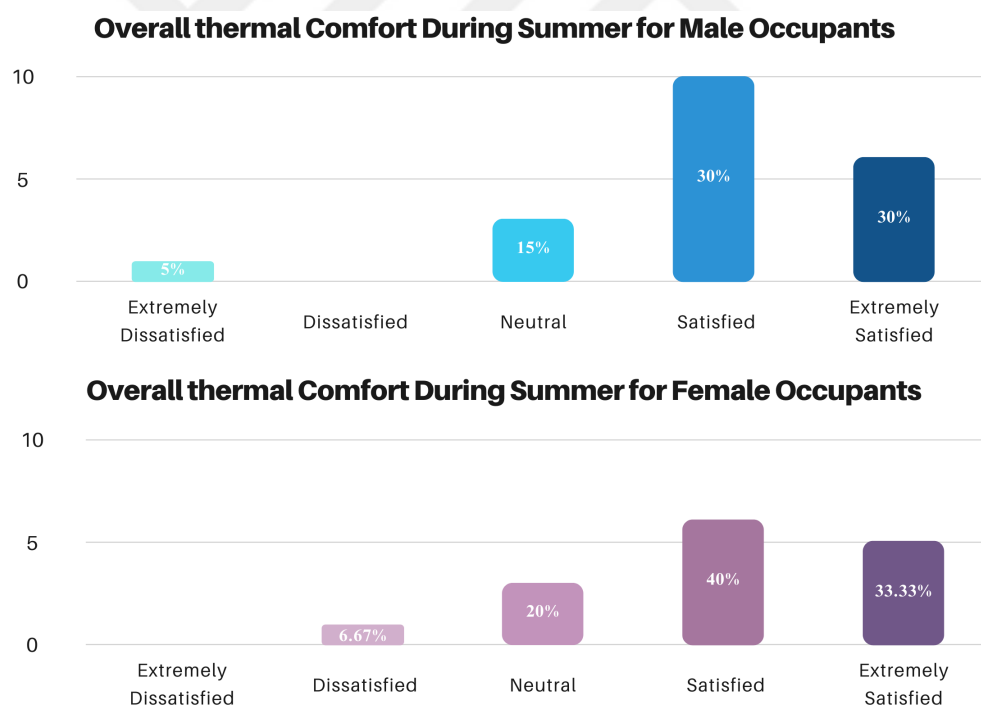


Figure 22: The overall satisfaction within the space between males and females.

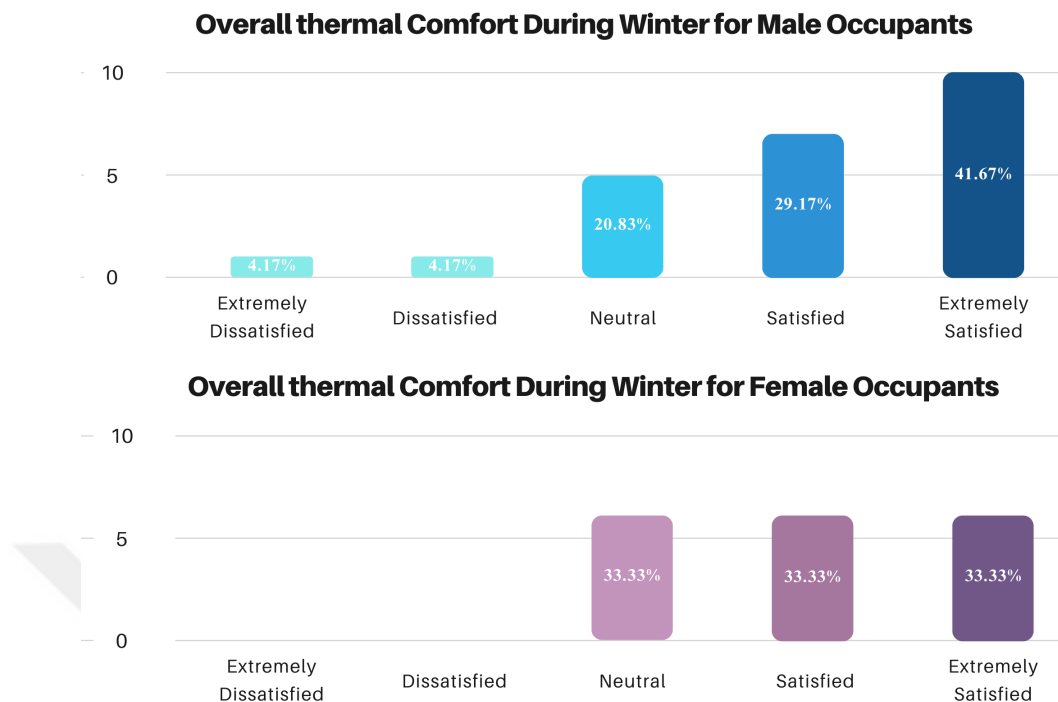


Figure 22 (continued): The overall satisfaction within the space between male and female occupants.

According to the survey results, it has revealed the number of 84.3% of the occupants have access to control over the thermostat within their working space, whereas 15.7% do not. This brought the attention of a remarkable result that was observed based on one of the Likert scale questions listed in the survey: “The indoor temperature is well regulated when the outside temperature is too cold”. This question was filtered according only to the participants who could adjust the thermostat to their comfort preference and compared to the occupants who did not have access to adjust the thermostat, as given in Figure 23. This section of the study aims to investigate the potential correlation between user preference and behaviour to achieve overall satisfaction within their environment. The survey had reported that when the occupants had access to adjust the thermostat, they had a relatively high level of satisfaction with the indoor temperature regulation. On the

other hand, the occupants who do not have access to adjust the thermostat have reported a different pattern of responses. Despite being a smaller group of people, they have perceived their comfort differently. To illustrate, a significant number of participants have expressed their satisfaction with the indoor temperature regulation. However, most importantly, there were also significant dissatisfaction voices with one person reporting dissatisfaction and three expressing extreme dissatisfaction.

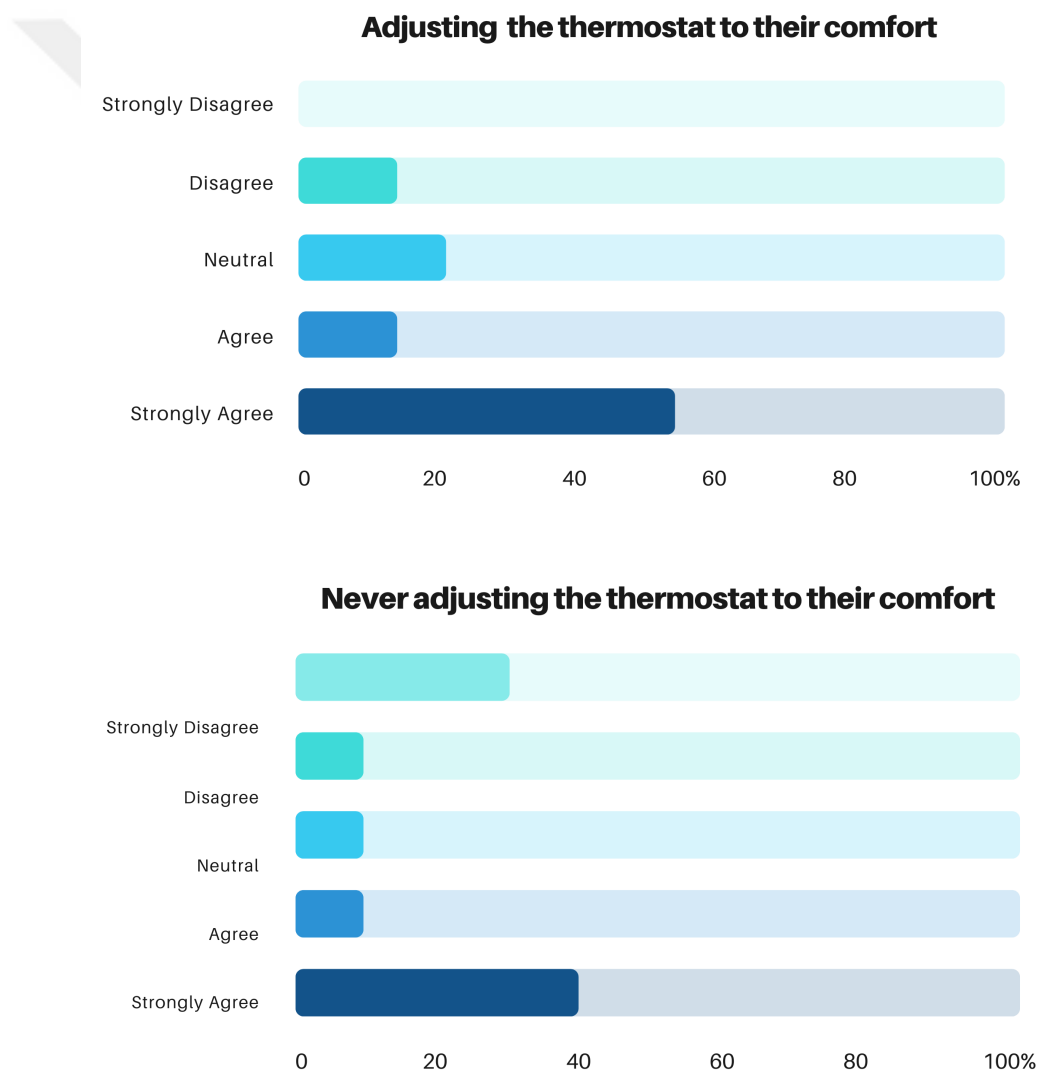


Figure 23: The user satisfaction according to their behaviour.

After analysing and filtering the survey results according to office plan layout, the building revealed four distinguished office types used within the project: a combi office (9.62%), a cellular office (9.62%), a flexible office (34.62%), and an open-plan office (46.11%) as given in Figure 24 (refer to Appendix B). In this study, it is decided to focus on the cellular and Open office types for further comparison since these two types represent major distinctions. Owing to uncertainties surrounding participants' understanding and perception of the space, this could arise due to the participant's limited knowledge. This section of the study investigates the potential correlation between the user's occupied office layout and the overall satisfaction within their environment in summer and winter.

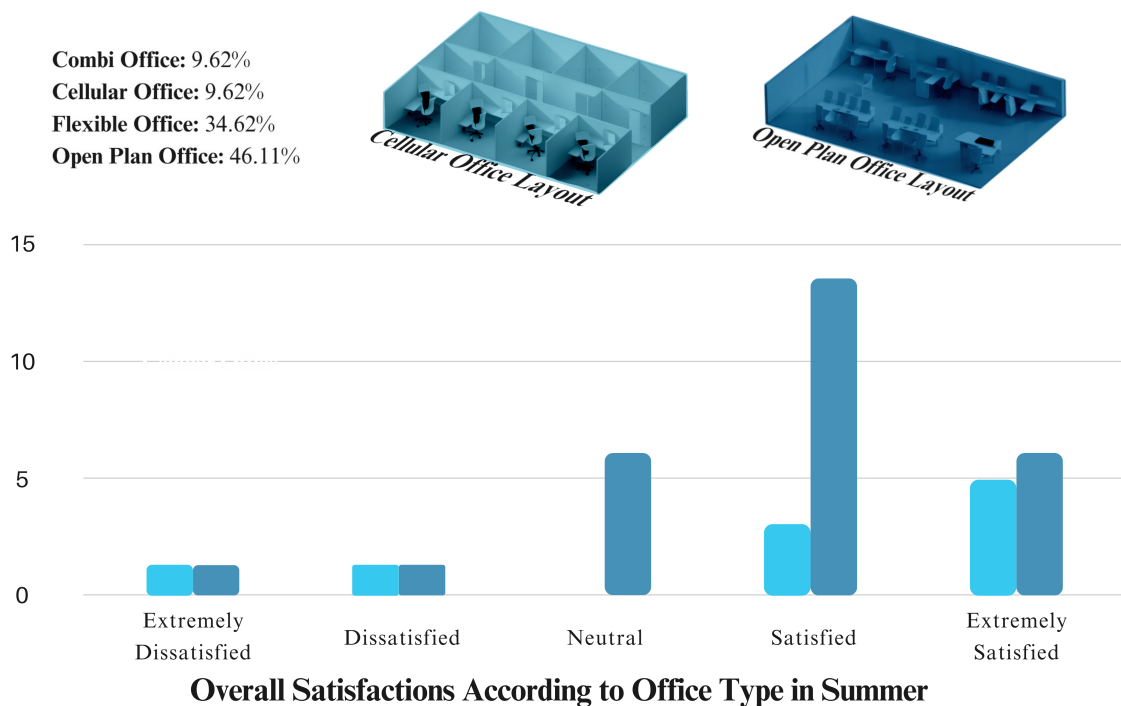


Figure 24: The overall user satisfaction according to their office type.

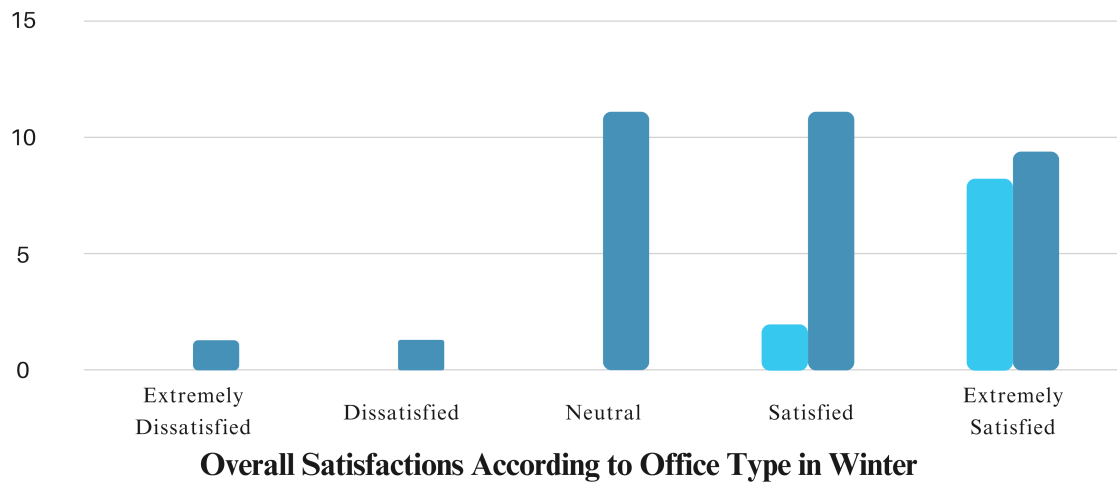


Figure 24 (Continued): The overall user satisfaction according to their office type.

The survey has reported a generally high satisfaction pattern in both summer and winter. In the summer, the occupants who are working from the cellular office layout express their satisfaction and extreme satisfaction, while a smaller number of occupants express their dissatisfaction. Comparatively, the occupants of the open-plan office layout have indicated a higher ratio of neutral, satisfaction, and extreme satisfaction conditions. In the winter season, the majority of the occupants who are working from the cellular office layout have expressed their extreme satisfaction, while the open-plan office occupants had neutral, satisfaction, and extreme satisfaction conditions, with a voice of a minority of the occupants expressing their dissatisfaction. Overall, the results revealed that the occupants prefer the open-plan office layout during the warmer summer. On the other hand, the occupants have indicated their preference for a cellular office layout during winter. However, this could be caused due to different factors, including air circulation and effective temperature regulation in both spaces.

The survey investigated each occupant's working preferences within their working floor environment. Figure 25 displays the plan used in the distributed survey and provides a summary of the participants and their selected areas and choices. The survey results have revealed that the occupants who are using floors floor from 1 to 14 have indicated 30.55% of their preference to use area number 1 and area 5 with a 27.77% ratio. It is important to note that areas number one and five, with a total of 58.32% of the occupant's preference, are both located closer to the northern façade of the building. The user preference of the occupants can be justified by the direct sunlight, which can lead to radiant temperature asymmetry, as mentioned in the literature review [70]. The layout position of areas number one and five sets them back as the furthest point from any potential direct sunlight along the east-west façade of the building, which can provide a more consistent and comfortable non-direct lighting space throughout the day. However, when it comes to area number eight, the survey revealed that it was the occupant's third preferred area with a 11.11% ratio, which makes it less preferred when compared to other locations. Furthermore, it is still worth mentioning that areas number four and six are the least used spaces, which are both used primarily as lobbies and entrance points for each company in the building and are typically not available for any other purposes.

On the other hand, the survey results for floors 14-24 revealed equal feedback from the occupants in the areas on the north-eastern facade side of the building floor (areas 9,10,11). Moreover, according to the area preference acquired from the occupants who experienced glare within the building, as given in Figure 26. The survey revealed that area five was the top choice for the occupant. Being in the centre of the building floor can prevent glare experiences and promote more comfortable working conditions.

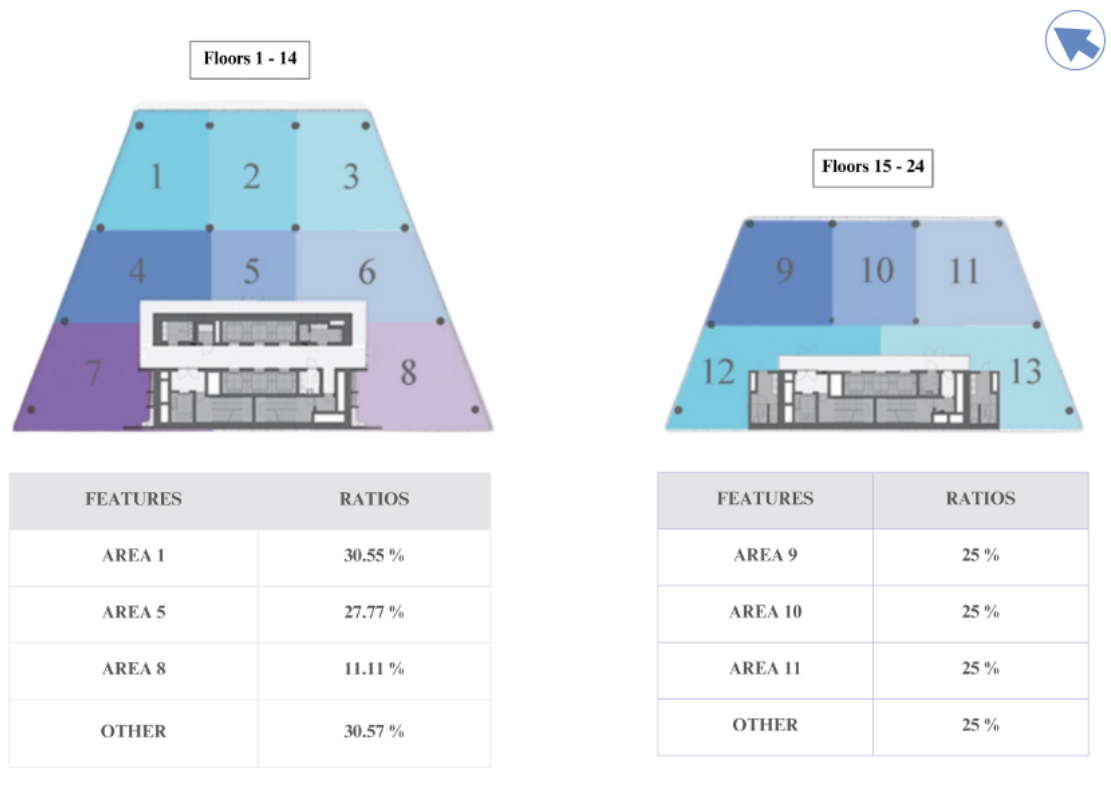


Figure 25: The overall user satisfaction according to their workplace preference.

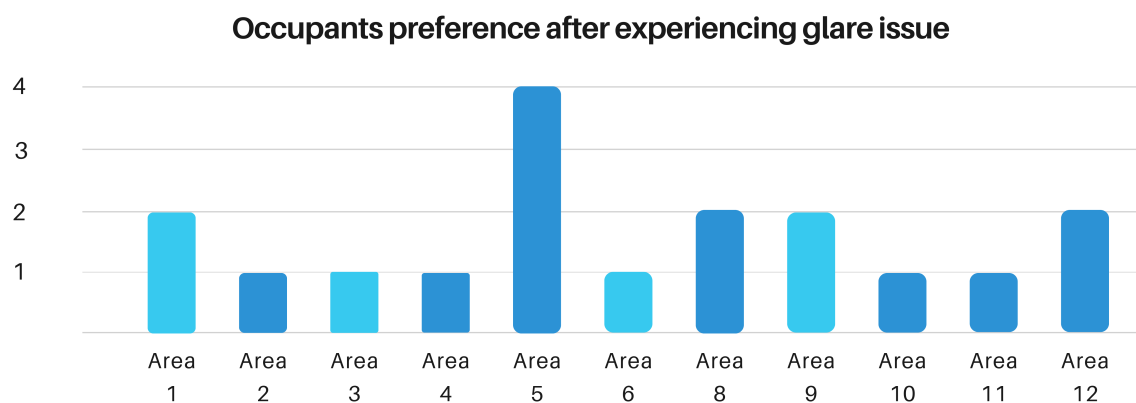


Figure 26: Area preference according to occupants who experienced glare.

4.2 Personal Interview Results

During the research process of this study, several personal interviews were conducted on-site with a total of 28 occupants of the building. The outcome of the interviews revealed more specific feedback from the occupants when they were talking

in person rather than filling out the survey, which revealed a list of complaints that can be pointed out from their point of view after they had the chance to experience the project. The data presented in the table is a combination of comments obtained during the interview process and written comments gathered from dedicated sections within the survey. Notably, the participants who communicated their thoughts through the survey and the interview process, leading to overlapping issues, have been excluded from the overall complaint count in the table as given in Table 7.

Table 7: The user complaints and issues faced in the building.

Category	Complaints	Count
Sunlight and Temperature Control	Curtains fail to block excessive sunlight effectively.	4
	Excessive sunlight compounded by reflection from skyscrapers.	1
	Uncomfortable heat waves near glass facade.	2
	Spaces too cold in winter and too hot in summer.	9
Lighting Control	Some lights automated, cannot be individually controlled.	1
Indoor Air Quality and Ventilation	Insufficient natural ventilation and indoor air quality.	11
	Need for open-air areas for fresh air circulation.	1
Unpleasant Odors	Unpleasant odors in certain areas.	3
Noise Disturbances	Noise issues within the building.	2

After analysing the complaints addressed by the occupants, several significant points of view towards some issues have been identified within the building. Firstly, the occupants expressed that sunlight and overall indoor air temperature were sources of

discomfort during the overall usage of the building. To illustrate, four complaints have mentioned the inefficiency of curtains in blocking excessive sunlight, and some have even expressed their concerns about the reflected sunlight from the nearby skyscrapers, which was experienced more on the upper floors of the building. This has caused people to complain about the heat waves experienced by people working near the glass façade. As was explained in the literature review, the more sunlight is excessively directed into the building, the higher the chance of experiencing radiation imbalances. As a result, this can expose the occupants to potential local thermal discomfort that can still be experienced even if the other side of the human body is unaffected. For example, despite maintaining an appropriate average temperature within the building, sitting directly beside the glass facade of the building window during summer or winter or next to a cooling, heating or cooling system can cause imbalances to a lesser air temperature degree. To avoid such discomforts, the key is to avoid large imbalances in radiant temperatures [73]. One more point is that, proving this theory, nine building occupants have reported their discomfort with the indoor temperature. During winter, they find the space too cold to work in comfortably, while the heat is intolerable in summer. The occupants have suggested that the building management needs to improve the climate control system to regulate the temperature concerning the outer environment and the parameters that can influence the overall temperature and thermal control.

Based on the feedback received, the Indoor Air Quality and Ventilation category has been identified as the most significant and concerning issue. One of the most highly received issues was the poor air quality and lack of natural ventilation within their indoor environment. As mentioned in the literature review, it is one of the major comfort-related

parameters that should be the priority of every project, which is the key to the occupant's overall experience, comfort, and productivity [71]. According to some of the occupants, they have expressed the constant need to exit the building to take in some fresh air.

Some other complaints have come to light, some of the occupants have reported that not all people have the authority to control the lighting system within their working area. Moreover, unpleasant odours and noise disturbances have also been reported. Thus, these issues can induce a feeling of inconvenience, which may develop into a source of discomfort and significantly affect the overall indoor environmental quality of the space and the productivity of the occupants.

CHAPTER V

CONCLUSION

In recent years, green-certified projects have turned into a huge trend in the design and construction sector, which has increased the value and reputation of any project. However, achieving an optimal level of indoor environmental quality for the occupants can be seen as a significant challenge, considering that such environmentally friendly projects often seem to prioritise energy efficiency with little consideration towards the comfort of occupants.

This thesis research investigated the overall indoor environmental quality of the occupants with a high emphasis on thermal comfort within a green-certified constructed environment through a post-occupancy evaluation (POE). The case study of this thesis was conducted in one of the LEED-certified office buildings in Istanbul, Turkey, since commercial buildings provide an important opportunity to perform a POE and the comfort of the occupants is a major tool to boost their working productivity.

By prioritising the human factor in the study, the operational stage of the project became a primary focal point, with its impact on occupant behaviour and potential side effects on occupants' overall experience and awareness regarding indoor environmental quality.

The study can be interpreted around occupant perception of IEQ in their workplace environments. The participants have communicated their feedback on different environmental factors, including indoor temperature, air quality, natural daylight, artificial lighting, and more. The initial study of the thesis hypothesised that some green-certified projects, including such LEED-certified buildings, target energy consumption as their main priori, which can lead to decreased productivity and local thermal discomfort conditions perceived by the occupants of the building. Based on this hypothesis, a few research questions are investigated, and they have revealed significant findings and direct insights. The obtained results reveal that, although the building occupants highly voted for the high satisfaction levels related to the thermal environment, lighting, indoor air quality and noise, they still often report local thermal discomfort issues related to temperature, air movement, and humidity, which are caused by vertical air temperature differences, high radiant temperature asymmetry, and draughts. The reason behind it could be caused by a number of factors, including the occupant's most used location within the building floor, the distance from the glass façade of the building, and the personal parameters of the occupant. Therefore, it is highly suggested to consider conducting interviews as an additional method and tool to confirm the acquired results from the distributed survey.

The results highlighted the need to raise more awareness among the occupants regarding sustainable energy efficiency practices. An increased level of awareness and understanding of green building certification among the occupants can induce a sense of responsibility. They tend to express more conscious behaviours and develop a curious mindset to learn more about such innovations and technologies that are adapted to the

building. This outcome emphasises the importance of increasing the awareness level of the occupants to reach sustainability targets in buildings.

The building occupants have revealed that having access to the thermostat and complete control over their indoor climate conditions can significantly promote better thermal comfort satisfaction.

Different office layouts have demonstrated a notable influence on occupants' overall environmental comfort in different seasons associated with different climatic conditions. In summer, the open office plan layout was the occupants' preference, while in winter, the cellular office layout was the occupants' preference.

According to the outcomes of this study, the location of the occupant's working space can also significantly influence the user experience within the building. Users have revealed their preference for areas in the centre of the floor plan or facing the north façade of the building.

Indeed, this research has its own research limitations that can affect the scope and the outcome of the study. It is worth noting that the outcome of this study may not be valid for all green-certified buildings due to differences in design concept, location, and user demographics that can all significantly affect comfort and satisfaction. Nevertheless, the methodology of this research can be adopted in order to analyse different buildings with the same perspective.

During this research, a major disadvantage was the limited collaboration and data shared by the company responsible for producing intended energy consumption goals calculations for LEED certification. Despite efforts to establish connections and partnerships, no response was received regarding their participation in the study related to the building. The declined collaboration presented a significant limitation as it restricted our access to valuable comparative data and insights that could have enriched the study's structure and results.

In terms of future studies, it is highly suggested to establish strong connections with all of the related organisations before conducting the study, which can help facilitate any potential collaboration during the study. In the case of this thesis, data collection was the most challenging aspect of the process, and it significantly impacted the duration of the process.

In terms of the outcome of the study, for future studies, it is recommended to conduct the survey within the span of one year, where the survey can be replied to by the same participants in the winter and summer seasons since the occupant's answers can relate more to the season they are living under its conditions, conducting the survey in both seasons can ensure a high level of results accuracy.

APPENDIX A - OFFICIAL LEED SCORE PAGE

SUSTAINABLE SITES (28 POINTS)

- SSp.1 Construction Activity Pollution Prevention - (Required Point).
- SSc.1 Site Selection - (1 Point).
- SSc.2 Development Density and Community Connectivity - (5 Points).
- SSc.3 Brownfield Redevelopment - (1 Point).
- SSc.4.1 Alternative Transportation: Public Transportation Access - (6 Points).
- SSc.4.2 Alternative Transportation: Bicycle Storage and Changing Rooms - (2 Points).
- SSc.4.3 Alternative Transportation: Low-Emitting and Fuel-Efficient Vehicles - (3 Points).
- SSc.4.4 Alternative Transportation: Parking Capacity - (2 Points).
- SSc.5.1 Site Development: Protect or Restore Habitat - (1 Point).
- SSc.5.2 Site Development: Maximize Open Space - (1 Point).
- SSc.6.1 Stormwater Design: Quantity Control - (1 Point).
- SSc.6.2 Stormwater Design: Quality Control - (1 Point).
- SSc.7.1 Heat Island Effect: Nonroof - (1 Point).
- SSc.7.2 Heat Island Effect: Roof - (1 Point).
- SSc.8 Light Pollution Reduction - (1 Point).
- SSc.9 Tenant Design and Construction Guidelines - (1 Point).

WATER EFFICIENCY (10 POINTS)

- WEp.1 Water Use Reduction - (Required Point).
- WEc.1 Water Efficient Landscaping - (4 Points).
- WEc.2 Innovative Wastewater Technologies - (2 Points).
- WEc.3 Water Use Reduction - (4 Points).

ENERGY & ATMOSPHERE (37 POINTS)

- EAp.1 Fundamental Commissioning of Building Energy Systems - (Required Point).
- EAp.2 Minimum Energy Performance - (Required Point).
- EAp.3 Fundamental Refrigerant Management - (Required Point).
- EAc.1 Optimize Energy Performance - (21 Points).
- EAc.2 On-site Renewable Energy - (4 Points).
- EAc.3 Enhanced Commissioning - (2 Points).
- EAc.4 Enhanced Refrigerant Management - (2 Points).
- EAc.5.1 Measurement and Verification: Base Building - (3 Points).
- EAc.5.2 Measurement and Verification: Tenant Submetering - (3 Points).
- EAc.6 Green Power - (2 Points).

MATERIAL & RESOURCES (13 POINTS)

- MRp.1 Storage and Collection of Recyclables - (Required Point).
- MRc.1 Building Reuse: Maintain Existing Walls, Floors and Roof - (5 Points).
- MRc.2 Construction Waste Management - (2 Points).
- MRc.3 Materials Reuse - (1 Point).
- MRc.4 Recycled Content - (2 Points).
- MRc.5 Regional Materials - (2 Points).
- MRc.6 Certified Wood - (1 Point).

INDOOR ENVIRONMENTAL QUALITY (12 POINTS)

- IEp.1 Minimum Indoor Air Quality Performance - (Required Point).
- IEp.2 Environmental Tobacco Smoke (ETS) Control - (Required Point).
- IEc. 1 Outdoor Air Delivery Monitoring - (1 Point).
- IEc.2 Increased Ventilation - (1 Point).
- IEc.3 Construction Indoor Air Quality Management Plan: During Construction - (1 Point).
- IEc.4.1 Low-Emitting Materials: Adhesives and Sealants - (1 Point).
- IEc.4.2 Low-Emitting Materials: Paints and Coatings - (1 Point).
- IEc.4.3 Low-Emitting Materials: Flooring Systems - (1 Point).
- IEc.4.4 Low-Emitting Materials: Composite Wood and Agrifiber Products - (1 Point).
- IEc.5 Indoor Chemical and Pollutant Source Control - (1 Point).
- IEc.6 Controllability of Systems: Thermal Comfort - (1 Point).
- IEc.7 Thermal Comfort: Design - (1 Point).
- IEc.8.1 Daylight and Views: Daylight - (1 Point).
- IEc. 8.2 Daylight and Views: Views - (1 Point).

INNOVATION (6 POINTS)

- IDc.1 Innovation in Design - (5 Points).
- IDc.2 LEED Accredited Professional - (1 Point).

REGIONAL PRIORITY CREDITS (4 POINTS)

- EAc1 Optimize energy performance - (1 Point).
- EQc7 Thermal comfort - design - (1 Point).
- SSc6.1 Stormwater design - quantity control - (1 Point).
- SSc7.2 Heat Island effect - roof - (1 Point).

APPENDIX B - SURVEY QUESTIONS & RESULTS

Personal Questions

- Your Current Age:

Age	Under 30 years old	15	28.84
	31–40 years old	18	34.61
	41–50 years old	15	28.84
	Over 50 years old	4	7.69
	Total	52	100%

- Your Identified Gender:

Gender	Male	27	52.90
	Female	24	47.10
	Total	52	100%

- Your Highest Educational Level:

Highest Educational Level	High school diploma	11	21.2
	Bachelor degree	29	55.8
	Master's degree	8	15.4
	Other	4	7.6
	Total	52	100%

- Your Office Floor:

Occupied Floor	Basement Floors	5	9.61
	G to 14	36	69.23
	15 to 24	11	21.11
	Total	52	100%

Research Questions

- How long have you been working in this building?

- A. Less than one year (53.8%)
- B. 1-2 Years (26.9%)
- C. 3-4 years (9.6%)
- D. More than 5 years (27.7%)

- Have you experienced the building during different climatic seasons (winter & summer)?

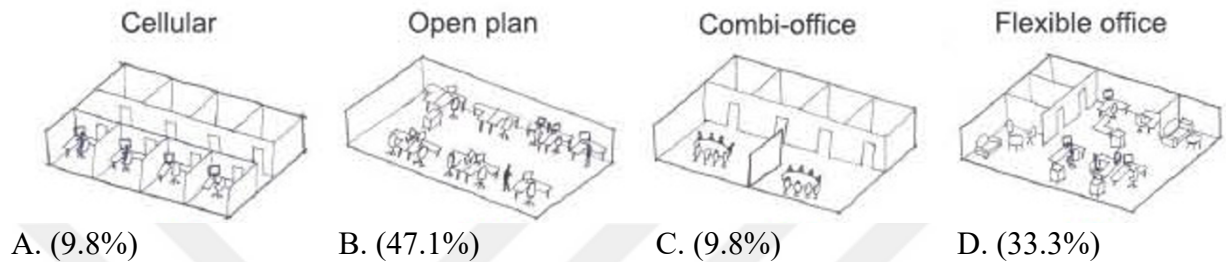
- A. Yes (67.3%)
- B. No (32.7%)

- How often do you switch to working remotely (from home or other locations) in a typical workweek?

- A. 1-2 days a week (21.2%)
- B. 3-4 days a week (7.7%)
- C. Almost every day (7.7%)
- D. Rarely (9.6%)
- E. Never (53.8%)

- When you visit the building, what is the duration of your stay (In hours) each day?
 - A. 1-2 Hours (1.9%)
 - B. 3-4 Hours (5.8%)
 - C. 5-6 Hours (11.5%)
 - D. 7+ Hours (80.8%)

- What type of office layout do you work at?



- How often do you utilize communal areas (breakout rooms, lounges, shared workspaces) in the office for collaborative work or meetings?

- A. Daily (55.8%)
- B. Weekly (21.2%)
- C. Monthly (0%)
- D. Rarely (23.1%)
- E. Never (0%)

- Do you have control over the lighting system in your workspace?

- A. Yes (90.4%)
- B. No (9.6%)

- How often do you manually adjust the lighting in your workspace?

- A. Multiple times a day (19.2%)
- B. Daily (34.6%)
- C. Weekly (1.9%)
- D. Rarely (21.2%)
- E. Never (23.1%)

- Do you have control over the temperature thermostat in your workspace?

- A. Yes (84.3%)
- B. No (15.7%)

- How often do you manually adjust the temperature thermostat in your workspace?

- A. Multiple times a day (26.9%)
- B. Daily (28.8%)
- C. Weekly (5.8%)
- D. Rarely (17.3%)
- E. Never (21.2%)

- What would you do if you experienced uncomfortable room temperature in a space within the building?

- A. Nothing (3.8%)
- B. Adjust the thermostat myself (63.5%)
- C. Report it to the technical team (32.7%)

- Do you have access to natural daylight in your workspace?

- A. Yes (88.5%)
- B. No (11.2%)

- Have you encountered any issues with glare inside the building, especially during the summer season?

- A. Always (13.7%)
- B. Sometimes (21.6%)
- C. Rarely (25.5%)
- D. Never (39.2%)

- Are there any specific areas within the workplace environment where you experience heightened productivity or increased comfort while working? If affirmative, could you mark those spots on the floor plan? (Participants will answer according to which floor they are using)



- Considering your experiences with the current hybrid work model, what changes, improvements, or services would you like to see in the office environment?

- Necessary changes are best made by the management in mind.
- Air conditioning is not enough. It is extremely hot in summer and extremely cold in winter. In summer, sunlight hits and disturbs you directly.
- Better heating and cooling.
- There is no hot water in the sinks.
- You could have a lot of windows that could be opened.
- Cold in the first days of the week due to lack of heating on the weekend There is a problem with light and cold shooting on the glass edge.
- I would like the natural air flow.
- Let it be less sound.
- I'm satisfied with everything for now.
- Flexible Working hours.
- It looks very cold because personal items are not put Being a window in an open position.
- Openable glass.
- Window to the rear.
- Heating and resting areas.
- Heating/cooling.
- Comfortable rest chairs, beverage bar

- Regarding your overall experience, have you encountered any particular challenges or sources of thermal discomfort within your time spent in the space?

- I spend time in a very comfortable and safe area.
- Air conditioning.
- Yes, especially on sunny days, windows don't close properly.
- Smoking areas are insufficient.
- It can be even better with cleaning.
- The sink goes smell.
- I have never encountered any problems.
- There was a sound that was very disturbing; the technical team corrected it.
- Heating/cooling.

- Are you aware of any energy-saving guidelines provided by the company or building management?

- A. Yes (28.8%)
- B. No (71.2%)

- How often do you follow these energy-saving guidelines, if there are any?

- E. Always (53.3%)
- F. Sometimes (13.3%)
- G. Rarely (4.4%)
- H. Never (28.9%)

- If yes, do you actively turn off electronic devices (computers, monitors, printers) when not in use?

- A. Always (71.4%)
- B. Sometimes (19%)
- C. Rarely (4.1%)
- D. Never (6.1%)

- What would you do if you encountered an empty space with lights/heating or cooling system left on?

- A. Leave it as it is (11.5%)
- B. Turn it off (57.7%)
- C. Report it to the technical team (30.8%)

- Did you know if the building has received a LEED certification award?

- A. Yes (31.4%)
- B. No (68.6%)

24 - If yes, after learning about the LEED certification, have you noticed any changes in your personal behaviour regarding building usage?

- A. Yes (71.4%)
- B. No (28.6%)

- Are you aware of any sustainable energy efficiency practices implemented in this workspace?

- A. Yes (80.4%)
- B. No (19.6%)

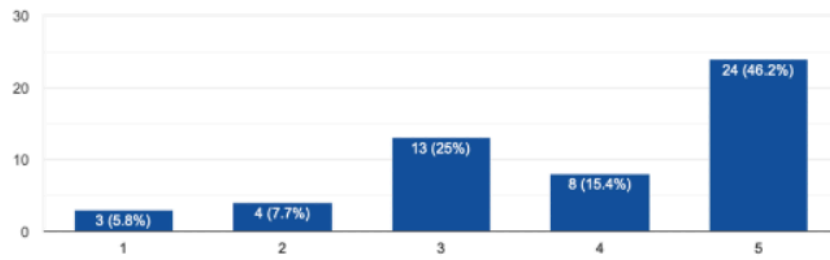
- If yes, please explain:

- In terms of the environment, waste rainwater accumulates in a warehouse, various treatments are carried out, and the building is served again, therefore creating a more economical usage area.
- Sensor lighting system.
- Conversion of Wastewater.
- Building management success.
- We can make our own light-energy adjustments on our floors.

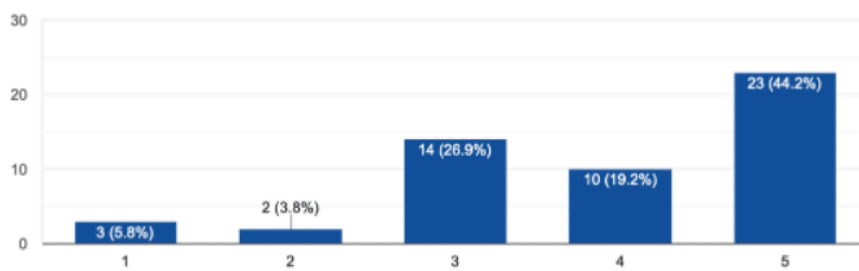
- How likely are you willing to stay and work in the building comfortably using the space?

- A. Very likely (30.8%)
- B. Likely (46.2%)
- C. Neutral (23.1%)
- D. Unlikely (0%)
- E. Very unlikely (0%)

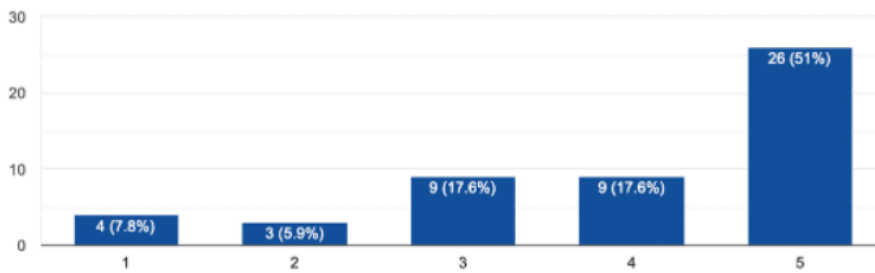
- I am satisfied with the overall comfort regarding the temperature in the workspace.



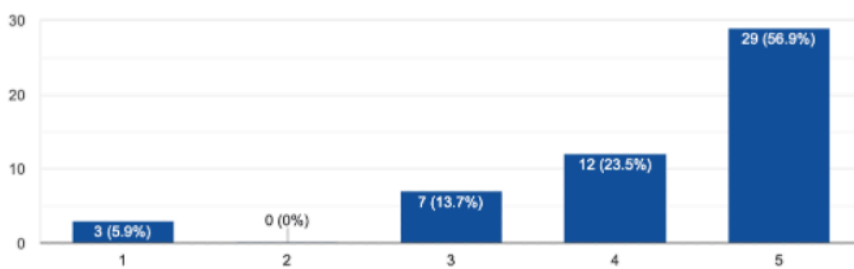
- I am satisfied with the overall comfort regarding the thermal comfort in the workplace.



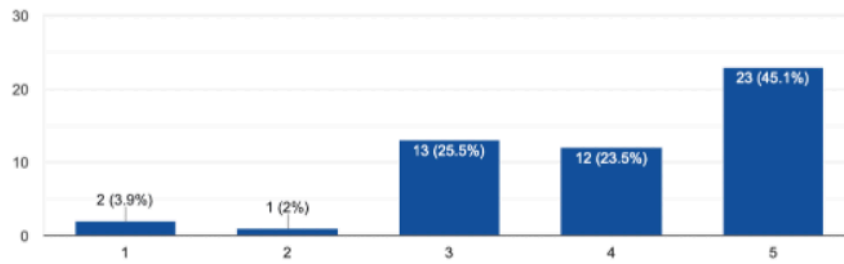
- The indoor temperature is well regulated when the outside temperature is too cold.



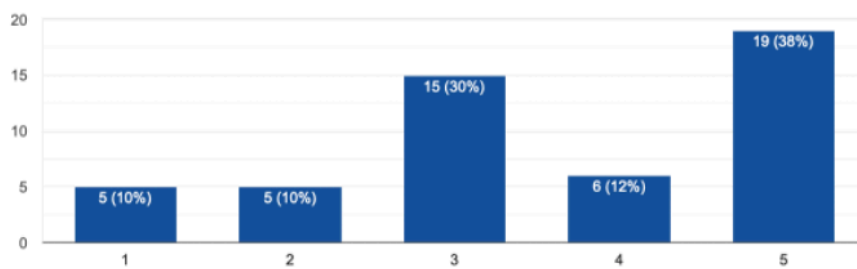
- I am satisfied with the overall comfort regarding the lighting system in the workplace.



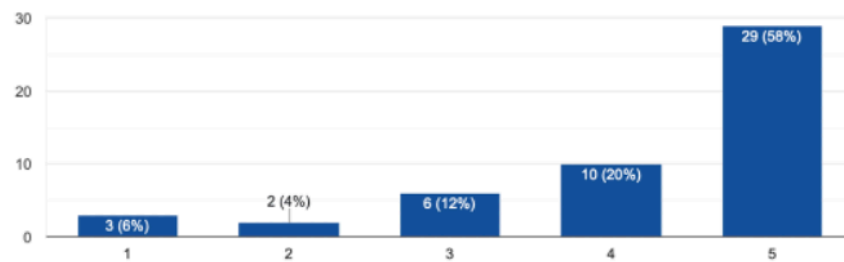
- I am satisfied with the overall comfort regarding the noise in the workplace.



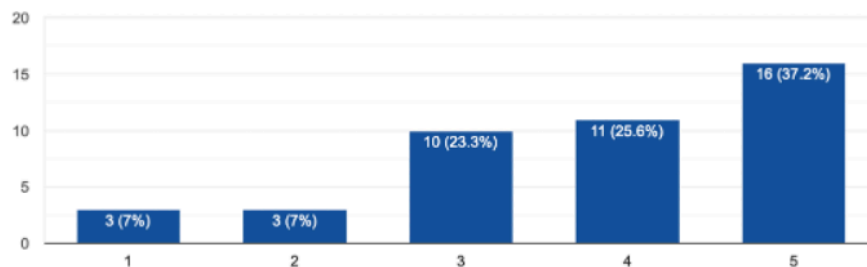
- The fresh air inside is regulated well with the ventilation system.



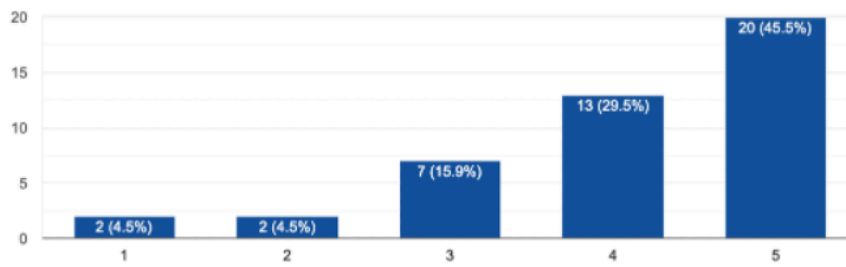
- The amount of natural daylight entering through the windows is sufficient.



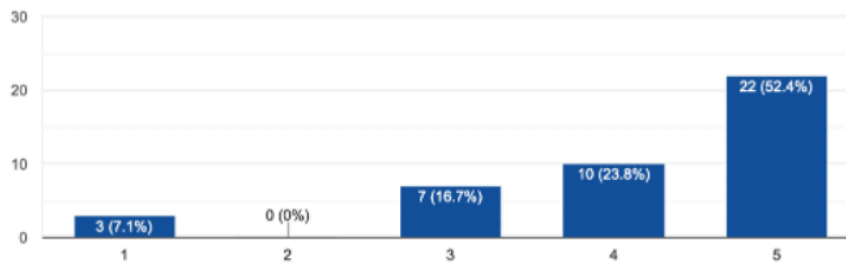
- Can you indicate how satisfied you have been with your working environment during summer (Indoor Temperature)?



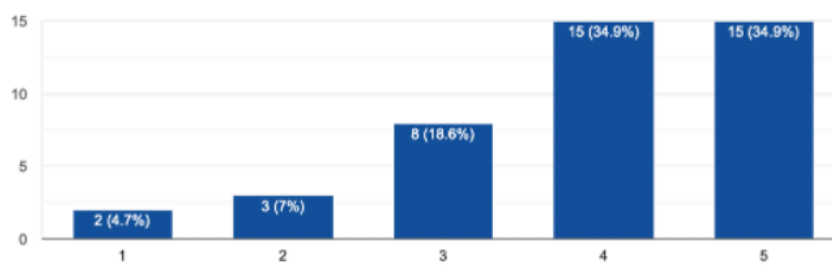
- Can you indicate how satisfied you have been with your working environment during summer (Indoor Artificial Lighting)?



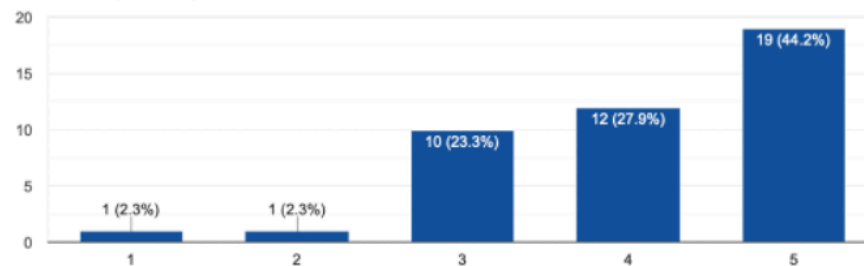
- Can you indicate how satisfied you have been with your working environment during summer (Natural Daylight)?



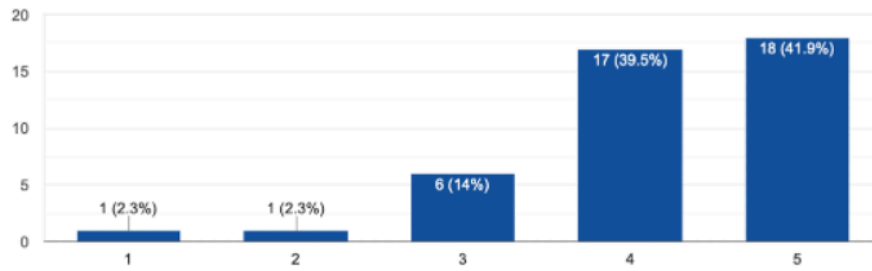
- Can you indicate how satisfied you have been with your working environment during summer (Air quality)?



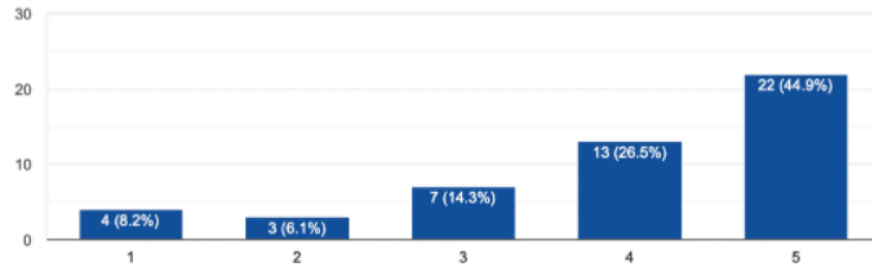
- Can you indicate how satisfied you have been with your working environment during summer (Noise)?



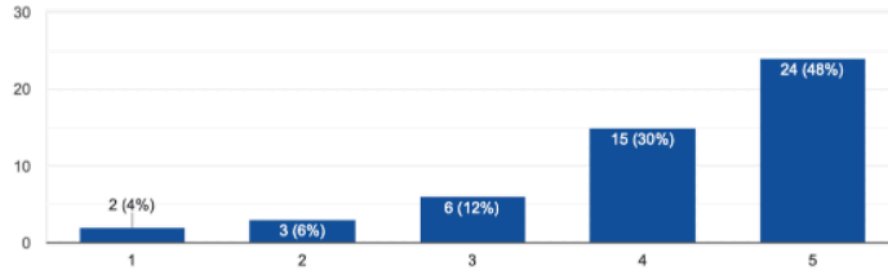
- Can you indicate how satisfied you have been with your working environment during summer (Overall comfort)?



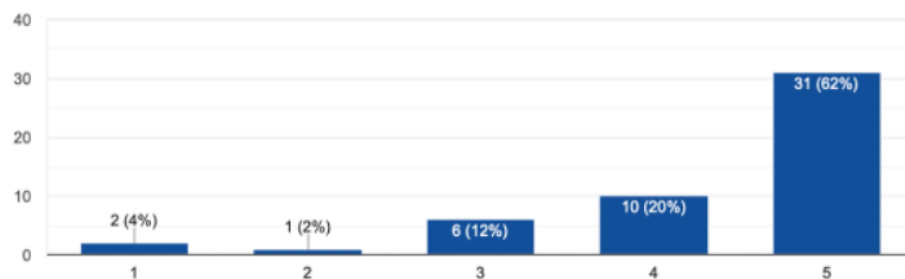
- Can you indicate how satisfied you have been with your working environment during winter (Indoor Temperature)?



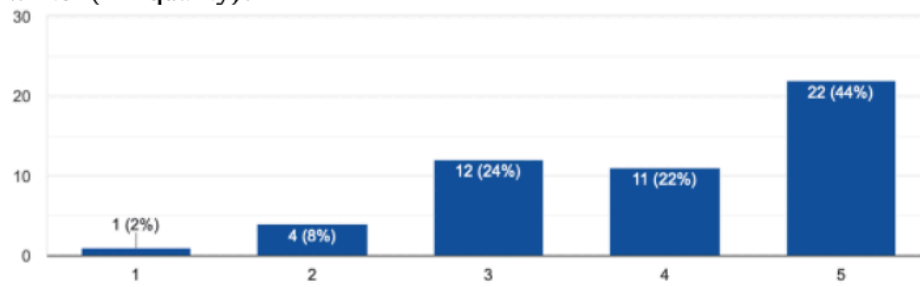
- Can you indicate how satisfied you have been with your working environment during winter (Indoor Artificial Lighting)?



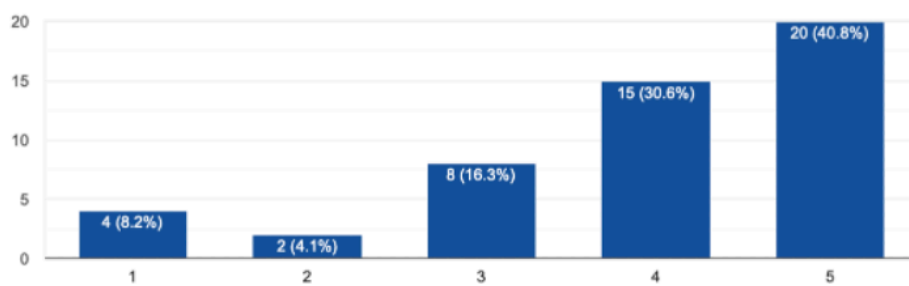
- Can you indicate how satisfied you have been with your working environment during winter (Natural Daylight)?



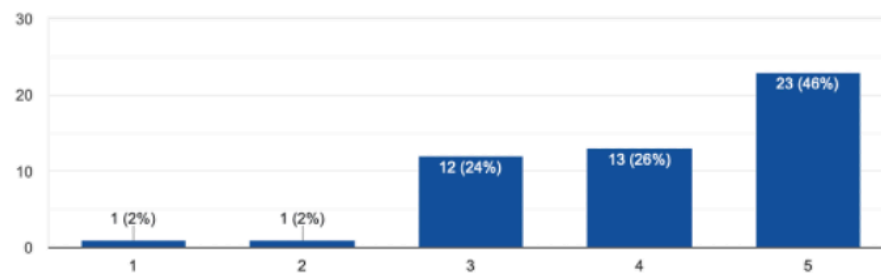
- Can you indicate how satisfied you have been with your working environment during winter (Air quality)?



- Can you indicate how satisfied you have been with your working environment during winter (Noise)?



- Can you indicate how satisfied you have been with your working environment during winter (Overall comfort)?



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