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Evaluating the Effectiveness of Sustainable Strategies in Residential Interior Design

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Abstract

The research assesses the efficacy of sustainable interior design strategies in residential environments, and specifically how it affects environmental performance and comfort of occupants. The study design was the exploration comparative case study, and the methodology was the descriptive-analytical approach to compare two residential units: the first one with the integrated sustainable design approach and the second with a traditional interior design approach. Performance-based, checklist-driven, evaluation tools, structured observations, and semi-structured interview were used to evaluate both essential environmental and user-centric indicators in data collection. The findings reveal that the sustainably constructed unit has continually achieved a better semi-quantitative performance score (1-3 scale) on various indicators of the environment such as natural and artificial lighting performance, ventilation effectiveness, thermal comfort stability, material sustainability, and biophilic integration. In parallel, user-based measures demonstrated high scores of visual comforts, perceived thermal comfort, emotional well-being, and general satisfaction in the case of sustainability compared to the traditional unit. These results incriminate a strong correspondence between the sustainable interior design strategies and the improvement of the environmental quality, and the improvement of the occupant experience. The research would be a contribution to the applied interior design and sustainability discourse as it provides an empirical and performance-based evaluation of residential interiors as a part of a real-life environment. However, the findings can be interpreted within the limits of the exploratory, case-based nature of the study and cannot be interpreted as applicable to the general population.

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Keywords: Sustainable Interior Design; Residential Environments; Environmental Performance; User Comfort; Emotional Well-Being; Biophilic Design.

1. Introduction

Sustainable interior design has begun to take a central seat in the residential setting because of an ever-increasing awareness of environmental and human effects of materials, energy use, indoor air quality, and spatial wellness. Previous research has shown that the desire among interior designers to use sustainable material is highly influenced by professional sensibility and behavioral models, especially when sustainable options affect ecological performance and health of users in residential environments [1]. Later scholarly discourses built upon this ground by pointing to the ways educators, practitioners, and design schools view the principles and theories of sustainable interior design, in which sustainable interior practice should be integrated in both the conceptual and practical aspects of interior practice. These trends represent a larger trend in the field towards evidence-based and environmentally friendly decision-making, where sustainability is viewed not as a mere stylistic choice, but as a quality standard in the design of environmentally friendly residential interiors.

In line with the current academic and theoretical interest in sustainable design, the literature is clear on the growing complexity of green residential interiors as socio-technical systems. Experimental studies of sustainability measures in residential settings have revealed that sustainable design performance depends on a complex interaction of a myriad of elements including material choice, energy efficiency, the environmental integration of interior items, and human oriented space arrangements [2]. These results highlight the need to come up with systematic frameworks that can simulate the operations of sustainable strategies in real interior settings. With the continued growth of sustainable interior design, it has always been the case that research has necessitated more rigorous, science-based evaluation of the strategies adopted within residential contexts not only in an attempt to clarify their effectiveness but also to provide the designer with the necessary knowledge base with which to make informed, contextually relevant decisions that promote better environmental systems, inhabitant comfort, and long-term residential health.

Although the discourse of the sustainable interior design has reached a certain level of theoretical sophistication and the value of the sustainable approach towards the interior design has been recognized, the scope of how the strategy of sustainability can be translated into tangible performance outcomes in the context of the actual residential interior remains under researched. This distance underscores the need to move further than theoretical advocacy into the empirical, context-based investigation.

1.1. Gaps in literature

Even though the current body of knowledge can add valuable information to the discussion of sustainable interior design, there are still several gaps that cannot be filled to attain a comprehensive picture of the sustainability of sustainable strategies in residential settings. Earlier analysis has focused on practitioners' motivation towards using sustainable materials and the theoretical frameworks used to inform the sustainable design decision-making process, but these studies mainly focus on theoretical knowledge and not the actual performance [3]. Equally, studies investigating the concept of environmental activation in interior settings and integrative design methods have emphasized the importance of sustainability concepts but have not evaluated the effectiveness of these strategies in a real-life residential setting [4]. This indicates that there has always been a disconnect between theoretical or pedagogical discussions of sustainability and empirical assessments of the effects of sustainable interior strategies on environmental quality, thermal comfort, or user experience in actual living settings. Consequently, the literature does not provide enough evidence of whether the recommended sustainable design strategies are translated into practical residential interior performance changes.

There is a second gap arising out of a small application of systematic or comparative analysis in assessing sustainable strategies in residential spaces. Although some of the recent reviews offer general syntheses of sustainability-related issues, i.e. general analyses of environmental design practices or explanations of sustainability in interior design studies, they lack case-based comparisons that could gauge the feasibility of strategies in various residential contexts [4]. Moreover, studies that determine socio-technical predictors of green residential interiors recognize the multifaceted Ness of the dimensions of sustainability but do not extend to the interaction of these predictors to determine their impact on user comfort, emotional response, or total spatial quality when green strategies are implemented in practice [4, 5]. As a result, literature does not have any empirical, design-driven evaluations that would identify the most effective sustainable strategies, in what circumstances they are most effective, and how the residents feel about their effects. Such a lack of comparative field-based assessments highlights why research that can bridge the gap between theoretical sustainability principles and actual residential interior performance is necessary.

1.2. Problem statement

Although the number of publications about sustainability in interior design is increasing, there is still a research gap that needs to be addressed: a lack of empirical, evidence-based research on the performance of sustainable interior design strategies in residential settings. Most of the available literature focuses on inspirations to use sustainable materials, the theoretical frameworks that guide sustainable practice, or the general principles of sustainability, but does not go further to give tangible measurements of the effectiveness of strategies in real residential settings [5]. The studies on environmental activation of interior elements and integrative sustainable design practices focus on the environmental worthiness of the strategies, yet they fail to quantify their contribution to the actual residential performance, user comfort, and quality of the environment after implementation [7, 8]. Research on socio-technical predictors of green interior design helps comprehend the complicated nature of sustainability considerations, but it does not go so far as to measure the incorporation of these predictors in occupied residential settings or establish the environmental benefits of such prediction [9]. Therefore, there remains a big gap between the idealized idea of sustainable interior design and the empirically testable effect of the same in the residential settings. This gap highlights the need to have stringent methodological and comparative assessments of sustainable strategies to determine their feasibility in improving environmental performance, occupant comfort, and general residential quality.

1.3. Research objectives

- To recognize and classify the main sustainable interior design strategies addressed in the recent literature and implemented in residential settings with a focus on materials, energy efficiency, indoor environmental quality, and spatial well-being,
- To assess the potency of these sustainable strategies in a real residential environment to determine how they affect environmental performance, comfort of users, and the quality of interior spaces in general.
- To examine the variables that promote or impair effective adoption of the interior strategies that promote sustainability in residential settings and to offer evidence-based recommendations based on comparative case studies.

1.4. Major contributions of the study

This study has several contributions to the field of sustainable interior design. To begin with, it bridges a gap that has always existed in the literature since it does not focus only on theoretical discussions but offers a systematic, evidence-based evaluation of sustainable interior design practices in residential settings, which has been largely neglected, and the existing literature often focuses on abstract models instead of quantifiable performance outcomes [9, 10]. Second, the paper presents a comparative case-based approach that compares the operation of sustainable strategies in real residential settings in a systematic and carefully designed way, providing insights into the effectiveness of these strategies in a practical sense, which have not been empirically tested in previous reviews or theoretical analysis [11]. Third, a combination of the socio-technical indicators, environmental activation principles and practitioner-oriented sustainability perspectives results in an overall evaluation framework, which can be used by designers, educators and policymakers to choose and prioritize sustainable strategies more effectively. Together, these efforts will enhance academic knowledge and practice by connecting the sustainability theory with empirically verifiable residential performance, hence improving the understanding and application of effective designing practices.

1.5. Major significance of the study

The importance of the study is in the fact that the operation of sustainable interior design strategies in the residential context is now more empirically proven, most of the existing literature is rather conceptual or descriptive, however, not empirical. The study can be considered an essential evidence-based element of sustainable design practice by filling the lack of evaluations related to the effect of sustainable strategies on the quality of the environment, comfort of users, and overall interior effectiveness [12]. Also, the research offers designers, educators, and practitioners with practical considerations that help them make more informed decisions related to material selection, spatial strategy, and environmental improvement, which is possible with the consideration of socio-technical indicators and user-centered factors in the framework of a systematic comparative evaluation [13]. Finally, the outcome of this study will take sustainability interior design to a higher level in terms of being a theoretical concept to a more tangible and practical field, stimulating the development of residential environments that would be much more compatible with the principles of sustainability, well-being, and health.

2. Theoretical Framework

2.1. Sustainability in interior design

In the interior design research area, sustainability is a multi-faceted concept that includes environmental accountability, well-being of the occupants, and resource efficiency in the interior environments in the long term. [14] state that the sustainability of interior spaces is an interdisciplinary theoretical underpinning, in which the environmental behavior, evidence-based design, and material studies are interrelated to inform the decision-making process of the designers. This view is congruent with [15], who theorize sustainable interiors as constituent parts of a broader system where interior design policies shape the overall performance of buildings as far as the effects of the environment are concerned.

Ecological interior design in residential settings is also associated with the increased quality of life of those who occupy it, both literally, psychologically and functionally [9]. The overlap of these works highlights the argument that interior design sustainability is a multidimensional construct, that encompasses the environmental, social, and experiential aspects and is not limited to material and aesthetic concerns.

2.2. Sustainable interior design strategies

- Sustainable Material Selection: The literature highlights the need to use materials that reduce environmental impact and promote healthy indoor environments. As an example, [12] observe that sustainable residential interiors are based on materials that minimize the number of pollutants, enhance the quality of the indoors, and maintain the long-term durability, whereas [14] emphasize the focus on low-impact material selection when making sustainable design decisions.
- Energy Efficiency and Lighting Strategies: One of the common themes is energy efficiency, and [11] state that sustainable interior should be integrated with the rest of building performance systems, such as lighting efficiency. [10] proves that optimised natural and artificial lighting significantly enhances occupant comfort, proving lighting as one of the primary sustainability strategies.
- Indoor Air Quality: In interior design sustainability, improvement of indoor air quality is a prerequisite. According to empirical research, the benefits of ventilation, material emission reduction, and spatial planning responsive to the environment in residential buildings are proven to enhance psychological and physical well-being [9, 12].
- Thermal Comfort: [10] emphasizes that thermal comfort is one of the main consequences of sustainable approaches integrating insulation, environmental control, and careful organization of the interior components.
- According to other studies like reference 9, sustainability cannot exist alone; it must be user-cantered and involves solutions to provision of emotional comfort through integration of nature into the space context, application of healthy spatial planning principles, and provision of psychological support in the interior spaces.

2.3. Theoretical foundations supporting sustainable interior design

- Green Architecture Perspectives: states that the level of sustainable interior environments is placed in the context of the wider scope of architectural ecosystems. The authors outline the principles of the green building design, the strategies of passive design, the energy efficient building envelopes, and the environmentally friendly materials as the basic determinants of interior sustainability [11].
- Human -Cantered Design Theory: According to the presentation of [9], the approach to interior sustainability is considered through the prism of human well-being and lifestyle improvement. Their results support the human-centred design theory, and they focus on psychological comfort, the possibility of social interaction, and positive health results as the key aspects of sustainable interior spaces.
- Indoor Environmental Quality (IEQ) Theory: According to reference [10], it is proven that sustainable interior design practices have a direct impact on the IEQ parameters such as thermal comfort, lighting adequacy and indoor air quality. These findings support the incorporation of IEQ theory as a methodological tool that can be used to assess the sustainability performance of residential interiors.
- Design Prioritization and Environmental Decision Frameworks: According to [14], a prioritization framework is suggested which elaborates on the most important factors of sustainability and suggests a systematic approach to the decision-making process. The contributions are in line with the environmental assessment theories that support the use of methodological analysis when selecting and implementing sustainability measures.

2.4. Indicators for evaluating the effectiveness of sustainable strategies

- Environmental Indicators: According to the literature under analysis, such indicators of the environment as the increase in energy efficiency, the decrease in interior pollutants, and the increase in ventilation are closely linked to the increase in the environmental quality [12, 11].
- Functional Indicators: These measures are associated with the effectiveness of the interior environment in terms of facilitating daily living. As an example, [14] stress that successful sustainable strategies should improve the spatial organization and functional flexibility.
- Human Comfort Indicators :Sustainable residential design revolves around human comfort, which is manifested in terms of psychological comfort, thermal comfort, and lighting comfort [10, 9].
- User Satisfaction Indicators :The concept of user satisfaction is present in the literature as a critical indicator of sustainability success multiple times, especially in the research that examines the effects of sustainable interior strategies on lifestyle and emotional comfort and general quality of residential living [9, 12].
- 3.0 Conceptual Framework

3.1. Core constructs underpinning sustainable residential interior design

The theoretical underpinnings of the current investigation are based on the interconnected environmental, emotional, and behavioral aspects that have been determined in the literature on the sustainability-focused interior design. The conceptualization of green residential interiors by [4] is a socio-technical system that is regulated by mutually reinforcing indicators, such as material choice, environmental performance, and spatial embeddedness. Their model assumes the implementation of sustainability as a multi-layered construct in which the interplay of technical decisions, environmental processes and user-centered considerations takes place. To support this opinion, [13] reveal that interior that is planned according to the principles of sustainability has a direct impact on the perceptions of the occupants. They find that their results confirm the idea that sustainability goes beyond environmental or technical goals, and it is a determinant of psychological well-being in residential settings.

Combined, these studies give a theoretical basis to the idea of how to conceive sustainable strategies as mechanisms that influence the quality of the environment, functional performance, and emotional experience.

3.2. Sustainable interior design strategies as independent variables

In this context, sustainable interior design strategies are the main independent variables. Such strategies include environmentally responsive material, energy efficient spatial planning, better indoor air quality and thermal-visual comfort strategies based on socio-technical indicators that [4] have outlined, also explain that the attitude and practices of designers define the application of such strategies, and the effectiveness of such is determined by both the sustainability awareness of designers and their abilities to incorporate environmentally responsible solutions in the interiors. At the same time, [16] underscore the fact that interior design strategies have a substantial impact on the emotional experiences of the residents, in particular, older adults, thus establishing the connection between sustainable strategies and comfort, satisfaction, and perceptual well-being. The literature repeatedly proves that sustainable strategies should be perceived as multidimensional inputs that define environmental and human-focused outputs.

3.3. Mediating indicators environmental and emotional performance

The conceptual framework places the environmental performance indicators and emotional performance indicators as the mediating variables that explain the impact that sustainable design strategies have on residential outcomes. According to [4], ventilation efficiency, thermal regulation, and material impacts are the key elements that define the environment and are the underlying determinants of sustainability in residential interior. To complement this, [13] prove that sustainable interior features can positively influence positive emotional conditions, and psychological reactions determine the perception and assessment of interior spaces among occupants. Additional evidence presented by [16] indicates that interior design strategies have a strong influence on emotional comfort and space perception, especially in the case of sensitive or vulnerable groups of users. All these environmental and emotional mediators create a critical interpretive layer which links technical sustainability measures with the human-based experience of residential spaces.

3.4. Dependent variables residential quality, comfort, and user satisfaction

The dependent variables are the results in the conceptual model, and they are the quality of residential interiors, user comfort and satisfaction. [13] suggests that emotional and psychological reactions are one of the main indicators of spatial performance in interior design developed in a sustainable manner. [15] also support this by stating that the perception of comfort, lifestyle alignment, and well-being by residents is the practical indicator of the success of interior sustainability implementation. [16] further imply that emotional experience and perceptual comfort are terminal indicators by which residents judge interior environments and therefore, it can be said that satisfaction is the result of the interplay between environmental performance and emotional experience. Together, these studies make residential comfort, emotional well-being, and user satisfaction the ultimate quantifiable results of the implementation of the sustainable design.

In addition to their technical and environmental aspects, sustainable interior design strategies are visual and spatial communication systems that essentially define the perceptual and emotional interactions of occupants in the residential settings. The allocation of natural lighting, textural qualities of materials, color schemes, and biophilic aspects are factors that do not only make the environment efficient but also make it visually readable, provide sensory balance and spatial significance. The interiors with sustainability focus, therefore, act as communicative spaces, where the environmental performance markers are directly connected with the perceptual comfort, affective response, and aesthetic experience.

In this sense, the sustainability-based interiors are communicative spatial environments where the performance metrics of environmental performance are interwoven with the perception ally comfortable, emotionally resonant and aesthetically gratifying experience of occupants. This combined view supports the importance of sustainable interior design in the wider context of applied arts, whereby the quality of space includes the dynamic relationship between the performance of the environment and human experience.

4. Previous Research

Sustainable residential interior design research has focused on how environmental performance, emotional response and well-being of residents are interrelated [4] designed a socio-technical model that uses an indicator-based analytical approach to investigate the material decisions, environmental impact, and dependencies in green interior design. Their research recognized and mapped sustainability indicators to explain the role of design elements in enhancing the quality of the environment of residential buildings. The given methodological approach is relevant to the current study as it emphasizes the structural and interdependent character of sustainable strategies and provides a basis on which the effectiveness of sustainable strategies in the real residential setting can be evaluated.

[13] explored the emotional effects of sustainable residential interior environment using environment-behavior research design and examined how interior attributes in accordance with sustainability guidelines affect the affective reactions of occupants. Their results show that sustainable strategies are not only environmental but also psychological and emotional aspects of the user experience, which is relevant to us in establishing whether such strategies increase comfort and perceived interior quality in residential settings.

[15] carried out an attitudinal and practice-based study; based on survey research, to examine the perceptions and practices of interior designers regarding sustainable practices, in the context of Jordan. In fact, the level of awareness by designers, professional training and attitudinal dispositions have been shown to be important factors that determine the successful application of sustainability in residential interiors. This, therefore, highlights the urgency of the current research to measure not only the strategic initiatives but also the situational variables that mediate the viability of their operations in practice situations. In reference [16], the type of research design used was a mixed-method research design, which incorporates a quantitative measure of affective experience, a qualitative measure of spatial perception, in older adults, who live in domestic environments. Their discussion explains how interior design practice, especially the ones based on sustainability principles, impacts emotional comfort and perceptual well-being. The approach to research provides an integrative view of the study at hand as it illustrates that the outcomes of the residential interior should be measured using both environment-related and human-related indicators.

4.1. Gap in knowledge

Although these studies have made contributions, there are still several gaps that are being bridged by the current research. To begin with, although [4] recognizes the sustainability indicators and their interdependencies, their study does not assess the quality of these indicators in the context of sustainable strategies being applied in real residential interior. On the same note, [13] shows the emotional influence of sustainable design, but their study fails to provide a comparative evaluation of the most effective sustainable strategies in various residential settings, so the gap in knowledge remains about the comparative effectiveness of sustainable interventions.

Second, even though [15] provides an insight into the attitude of interior designers towards sustainability, they do not quantify the results of the strategies employed by these professionals, which creates a gap between practice in the profession and the performance of the environment of residential buildings. Lastly, [16] concentrate on emotional and perceptual experiences of older adults, but do not tie them to quantifiable sustainable design strategies. A combination of these restrictions suggests the obvious gap: the lack of comparative, evidence-based assessments that would determine the practical efficiency of sustainable interior design strategies in actual residential settings, considering both environmental metrics and user-oriented results. The proposed study will fill this gap by carrying out a methodical evaluation of the sustainable strategies, where the focus will be on both the environmental performance and the comfort of the occupants.

5. Methods

5.1. Study design

The paper assumes a descriptive-analytical research method, which is augmented with a comparative case study design, to evaluate the effectiveness of sustainable interior design strategies in residential setups. This was done by a combination of structured field observations, environmental performance checklists, and semi-structured interviews to offer a comprehensive and triangulated evaluation.

The methodology of the evaluation is a comparative case study, which is operationalized by applying it to two different residential settings. Case A can be described as the unit that has actively applied several of the principles of sustainable interior design, and Case B refers to the unit that was designed with a typical design paradigm and little regard for sustainability. A comparative set-up of this kind allows the measurement of environmental performance dissimilarity, e.g., thermal efficiency, quality of lighting and ventilation, as well as explains the dissimilar occupant experiences, in these environmental settings. The combination of both methodologies will result in stratified knowledge: the descriptive-analytical step will outline the sustainability demands, and the comparative case analysis will be able to test the implementation of the demands in real residential conditions empirically. Such a design based on dual methodology makes methodological triangulation possible, which increases the strength and validity of the study results.

5.2. Participants samples

The sample used in the study includes two residential units that were chosen based on a purposeful sampling approach that would guarantee the contrast in the sustainability application and comparability in the physical and functional features. The two units are in the same residential category, occupancy level is similar, and spatial dimension is similar, hence restricting extraneous environmental variation. Case A is a sustainability-driven interior with the inclusion of environmentally responsive materials, improved natural ventilation, LED-based lighting plans, thermal insulation interventions, and biophilic elements. Case B is a classical type of residential setting that is typified by routine materials, traditional lighting, average ventilation and little environmental optimization. Both units have similar demographic traits (family households with four occupants), so variations in comfort, satisfaction, and environmental perception can be explained by interior design strategies and not by demographic differences. Table 1. presents a more detailed quantitative summary of the characteristics of the two units, such as surface area, occupancy, sustainability features, and the quality of the ventilation and the presence or absence of biophilic elements. This systematic analogy is necessary in determining the empirical basis of the case study analysis.

Table 1. Sample characteristics of residential units

Variable	Case A: Sustainable Unit	Case B: Conventional Unit
Unit Size (m²)	120	118
Number of Occupants	4	4
Use of Sustainable Materials	Extensive	Minimal
Indoor Air Quality Enhancements	Present	Absent
Energy-Efficient Lighting	Present (LED)	Absent (Traditional)
Thermal Comfort Features	Advanced	Limited
Natural Ventilation Quality	High	Moderate
Biophilic Elements	Present	Absent

5.3. Data collection techniques method

The data collection method will use a multi-layered approach that will be used to ensure that the data will capture the environmental performance indicators as well as user-based experiential data. The first one is systematic field observation in which the researcher makes regular visits to the field to carefully record interior configurations, material uses, lighting systems, ventilation openings, and thermal comfort provisions. The observations are based on a structured checklist developed according to the sustainability indicators found in the relevant literature and, as such, all the environmental characteristics, such as the arrangement of furniture that affects the airflow, the concentration of natural light areas, and the location of thermal mass, are always captured in the two cases.

The second approach helps to conduct an environmental assessment, with the help of standardized performance criteria to evaluate the quality of indoor air, lighting performance, and thermal conditions. Based on the constraints mentioned, direct numerical measurement is not used; rather, the assessment is conducted based on an operationalized environmental checklist, which alludes to measurable conditions, including the sufficiency of ventilation pathways, the evenness of light distribution, and the relative preponderance of natural over artificial light.

The third approach is semi-structured interviews with both unit residents. The purpose of these interviews is to extract more in-depth information about the impact of interior design strategies on everyday life experience, including comfort, satisfaction, emotional reaction, and the perceived quality of the environment. Also, the interviewers will ask the residents about their knowledge of sustainability and how much interior conditions influence their lifestyle and well-being. When observational, environmental, and experiential methods are combined, triangulation of data is comprehensive, and detailed descriptions of each method are presented in Table 2.

Table 2. Data collection techniques and descriptions

Data Collection Method	Description	Key Variables Assessed
Field Observation	Repeated structured on-site documentation of interior design features	Materials, lighting, ventilation, spatial layout
Environmental Assessment	Evaluation using structured performance criteria	Air quality, lighting adequacy, thermal behavior
Semi-Structured Interviews	Discussions exploring resident perceptions and experiences	Comfort, satisfaction, emotional well-being

5.4. Data analysis methods

It should be noted that semi-structured interviews were employed as a qualitative data collection technique, rather than as an independent research methodology, and were used to complement observational and environmental assessment data within the overall descriptive–analytical and comparative case study design.

The data analysis incorporated qualitative thematic analysis, cross-case comparison, and indicator-based evaluation. Interpretation of the interview transcripts using thematic analysis is used to identify patterns, emotions, and perceptions of comfort, satisfaction, and interior environmental quality recurring. Codes are planted inductively and based on the themes like light comfort, air freshness, temperature feel, materials preferences and emotional reactions to interior elements.

At the same time, the data on observational and environmental assessment is also exposed to the comparative analysis of matrices, during which every sustainable indicator is analyzed in two cases. Such a methodological solution helps reveal the disparities in the performance of the environmental sphere and define the scope of the advantages of sustainable strategies that are used in Case A in comparison with traditional circumstances that are characterized in Case B. The analytical framework is designed based on a sustainability paradigm that is based on pertinent theoretical and conceptual models, thus, there is a congruence between indicators and outcomes. Figure 1. is a Conceptual Data Analysis Diagram that summarizes the whole process and demonstrates that both environmental measures and qualitative data intersect in the assessment of strategic efficacy.

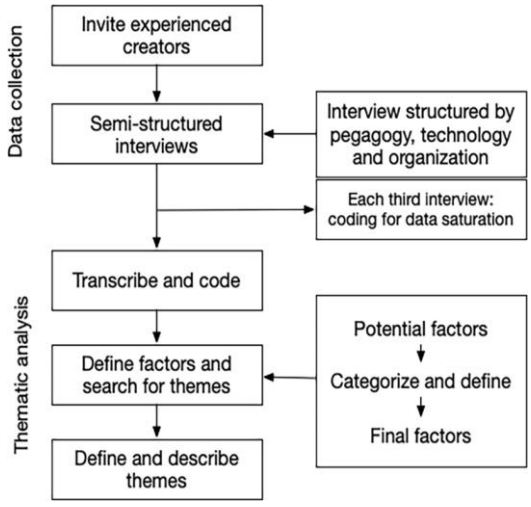

Figure 1. Data analysis diagram

5.5. Study instruments

The study uses a complex of carefully developed tools to comprehensively measure the nature of the environment and user experiences. The Observation Checklist will include a list of sustainability indicators that are predefined, such as the type of materials, the efficiency of lighting, the quality of ventilation, the spatial layout, and thermal comfort. The Environmental Assessment Form has categories that are based on literature of sustainability like indoor air circulation, the interplay of natural and artificial lighting, perception of thermal stability, and interior freshness. The Semi-Structured Interview Guide will include open-ended questions that will cover the comfort level of the residents, their emotional reaction to interior environments, their everyday experience with the interior features, and their perception of the quality of the environment. All these instruments are used to guarantee the methodological consistency of data-collection phases and make it possible to conduct a structured comparative evaluation.

5.6. Validation of study instruments

To guarantee the validity and suitability of the study equipment, all the data collection instruments, such as observation checklist, environmental assessment form, and semi-structured interview guide, were examined by the panel of three professionals chosen separately. The professionals were interior design, sustainable design, and environmental design. The validation was aimed at analyzing the content and face validity, the clarity, relevance, and sufficiency of every instrument in the evaluation of the intended sustainability indicators and dimensions of user

experience. According to the feedback of the experts, there were slight linguistic and structural improvements to make it clear and consistent with the study goals. The instruments were later validated to be acceptable and applicable in the field of study.

5.6. Procedure

The process occurs in six steps. To begin with, the appropriate residential units are identified and selected based on the sampling criteria. Second, preliminary site visitation is done to familiarize the researcher with spatial layouts and environmental conditions. Third, systematic field observations are implemented, where interior attributes are recorded in several sessions to reduce time bias. Fourth, a standardized checklist is used to assess lighting, ventilation, and thermal conditions by conducting environmental assessments. Fifth, semi-structured interviews are carried out with occupants of both units, and they are recorded audio (where allowed), transcribed, and ready to undergo thematic coding. Lastly, thematic, matrix based and indicator-based analyses are used to triangulate all data, which are obtained by observation, assessment and interviews to come up with overall evaluation of sustainable interior design strategies.

6. Results

It should be noted that the following results represent an exploratory, performance-based comparative assessment derived from structured observations and checklist-driven indicators. The reported scores are not instrument-based measurements, but rather standardized evaluative ratings intended to support analytical comparison between the two residential case studies.

The current findings represent a comparative evaluation of the strategies of sustainable interior design implemented in two residential environments, Case A, which implies the combination of several sustainability elements, and Case B, which is a traditional interior design. Systematic field observations, environmental performance checklists and semi-structured interviews with occupants of the two units were used to collect data. The evaluation is a combination of environmental indicators (sufficiency of lighting, quality of ventilation, thermal comfort, and material choice) and the user experience variables (comfort, satisfaction, and emotional state). The current section summarizes the findings as per the research goals and begins with an extensive evaluation of the green building plans in the two settings.

Objective 1: to determine and categorize the major sustainable interior design approaches presented in modern literature and implemented in residential design with special attention paid to the choice of materials, energy conservation, indoor environment, and spatial comfort. The comparison analysis demonstrates strong differences in the introduction of sustainable aspects in the two housing environments. In Case A, the choice of environmentally friendly materials, the addition of natural lighting, the use of biophilic furniture, the use of LED-based lighting systems, and the use of thermal comfort technologies have been chosen deliberately. On the contrary, Case B mainly involves the use of standard materials, artificial lighting, simplified ventilation systems, and simple environmental additions. These differences demonstrate that the existence or lack of sustainable elements can affect the ecological nature of residential interiors (see Table 3. and Table 4. that captures the presence and the nature of sustainable strategies in each unit).

Table 3. Sustainable interior design strategies identified in Case A and Case B

Sustainable Strategy Category	Case A (Sustainable Unit)	Case B (Conventional Unit)
Material Selection	Low-emission, environmentally responsible finishes	Standard commercial materials
Ventilation Quality	Multiple natural ventilation pathways	Moderate airflow; limited openings
Lighting Strategy	LED lighting + optimized natural lighting	Conventional fluorescent/incandescent lighting
Thermal Comfort Interventions	Insulation features; controlled heat gain	Minimal thermal modifications
Biophilic Integration	Indoor plants; natural textures	No biophilic features
Spatial Organization	Arrangement supporting airflow and daylight penetration	Standard layout without sustainability considerations

Comparative Semi-Quantitative Assessment (1–3 Scale)

Scoring system: 1 = Low performance | 2 = Moderate performance | 3 = High performance

Table 4. Comparative Environmental Performance Scores of Case A and Case B

Environmental Indicator	Case A (Sustainable Unit)	Case B (Conventional Unit)
Natural Lighting Performance	3 (High)	1 (Low)
Artificial Lighting Efficiency	3 (High)	1 (Low)
Ventilation Effectiveness	3 (High)	2 (Moderate)
Thermal Comfort Stability	3 (High)	1 (Low)
Material Sustainability	3 (High)	1 (Low)
Biophilic Contribution	3 (High)	1 (Low)

The semi-quantitative comparison of the two residential units on environmental performance as shown in Table 4 reveals that there are distinct and consistent differences in the performance of the two residential units on environmental performance. Case A has a high score (3) on all of the evaluated environmental indicators, which demonstrates the proper adoption of sustainable interior design strategies. Contrary, in Case B, most of the performance scores were low (1) to moderate (2), which demonstrates low environmental optimization.

Case A had high (3) in natural lighting because of the optimized location of windows, unhindered entry of daylight in the room and space organization to maximize distribution of daylight. On the other hand, Case B had low scores (1), because it was very dependent on the artificial lighting and there was limited access to natural lighting.

Case A scored highly (3) in terms of artificial lighting efficiency because of the application of energy-efficient LED systems combined with the natural lighting plans. Case B had a low score (1) due to the reliance on traditional lighting systems that are not very energy efficient.

The effectiveness of ventilation in Case A was high (3), and it was backed by the presence of several natural airflow pathways and cross-ventilation between significant interior spaces. Case B portrayed moderate performance (2) with an open ventilation that was present though restrictive in scope and effectiveness.

Case A had a high score (3) again on the stability of thermal comfort due to the existence of insulation strategies and controlled heat gain, which led to the consistency in indoor temperature conditions. Comparatively, Case 2 had a low score (1) because the thermal fluctuations were noticed by virtue of the low environmental control measures.

In terms of material sustainability, Case A (3) scored high using low-emission materials that are environmentally friendly. Case B had a low score (1) as it was mainly based on commercial material without any sustainability in mind.

Lastly, the biophilic features of Case A led to high performance score (3), which led to enhancements in air freshness and visual comfort. Case B, which does not include any biophilic integration, received a low score (1) on this indicator.

Altogether, the comparative scoring proves that the systematic implementation of the strategies of the sustainable interior design strategies in Case A contributed to the situation when the environmental performance was consistently high whereas in Case B, this situation was not observed, and the results were rather weak in all assessed indicators.

Figure 2 results illustrate that Case A is a holistic approach to sustainable interior design strategies. Materials which are more environmentally friendly, have more ventilation paths and biophilic elements are also used to achieve a healthier and more environmentally conscious interior.

Case A relies on the maximization of natural lighting and its supplement with energy saving LEDs, but Case B is heavily reliant on artificial lighting that is not environmentally efficient. Case A has the presence of thermal comfort properties, including insulation and regulated heat gain, whereas Case B has them usually. Furthermore, Case A demonstrates the spatial organization of the objects and that the air movement, daylight distribution, and comfort of the inhabitants are considered, and the Case B organization is traditional with no alterations in terms of sustainability. Combined, these findings prove the validity of sustainable policies in the development of the interior environmental Figure 2. quality and form the foundation of further analysis of their impact on comfort and user experience in the rest of the objectives.

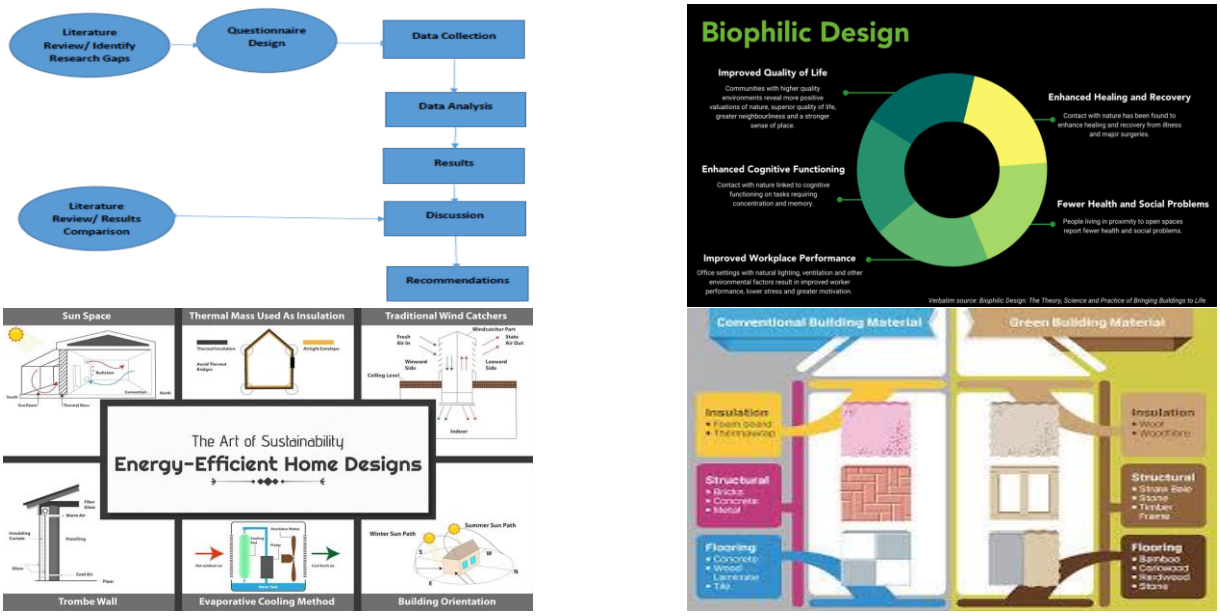

Figure 3. Descriptive visual diagram illustrating objective 1 findings

Objective 2: To assess the potency of these sustainable strategies in a real residential environment to determine how they affect environmental performance, comfort of users, and the quality of interior spaces in general.

6.1. Environmental performance differences narrative description

The comparative analysis of the environmental performance of the two residential units shows definite differences due to the inclusion, or not, of the sustainable interior design strategies. Case A, that incorporates environmentally friendly materials, increased natural ventilation routes, and energy efficient lighting, had better environmental performance in all the indicators that were studied. The greater number of openings in the natural ventilation contributed to the better quality of airflow, alleviating the conditions of indoor stagnation and enhancing the perceived air freshness. Case A made better use of natural daylighting because spatial was well planned and there were no windows blocked by objects and this minimized the need of artificial lighting in the daytime. The use of LED-based lighting also increased the efficiency of energy and did not reduce visual comfort. Thermal comfort in Case A was also better, which was aided by the use of insulation material and moderation of heat gain design which helps in attaining more stable temperature conditions.

Case B on the contrary exhibited poorer environmental performance because of the lack of natural ventilation, traditional lighting systems, and little thermal comfort interventions. The use of artificial lighting was the cause of uneven light levels, and the absence of insulation caused the thermal conditions to be observed to vary significantly. The quality of the air was moderate, with less natural air exchange routes, which

significantly decreased freshness and further increased reliance on mechanical ventilation habits. Collectively, these results, as shown in Table 5, Table 6. indicate that the introduction of sustainable interior design solutions is a key factor that contributes to the performance of the environment in residential spaces, and that Case A has been performing better than Case B on all of the assessed indicators.

Table 5. Comparative environmental performance indicators in Case A and Case B

Environmental Indicator	Case A (Sustainable Unit)	Case B (Conventional Unit)
Natural Lighting Efficiency	High penetration; strategic window placement	Limited natural light; reliance on artificial lighting
Artificial Lighting Type	Energy-efficient LED systems	Conventional fluorescent/incandescent
Indoor Air Quality	Enhanced through improved ventilation paths	Moderate; fewer ventilation openings
Airflow Circulation	Strong cross-ventilation across main living areas	Restricted airflow movement
Thermal Comfort	Controlled heat gain; insulation supports stable temperatures	Temperature fluctuation due to lack of insulation
Environmental Material Impact	Low-VOC, sustainable materials used	Standard materials; no sustainability focus
Biophilic Impact	Presence of plants enhances air freshness and visual comfort	No biophilic elements present

User Comfort and Satisfaction Results
Semi-Quantitative Comparative Assessment (1–3 Scale)
Scoring system: 1 = Low | 2 = Moderate | 3 = High (performance-based evaluative ratings derived from interviews and structured observations)

Table 6. Comparative User Comfort and Satisfaction Scores of Case A and Case B

User-Centered Indicator	Case A (Sustainable Unit)	Case B (Conventional Unit)
Visual Comfort	3 (High)	2 (Moderate)
Thermal Comfort Perception	3 (High)	1 (Low)
Perceived Air Freshness	3 (High)	2 (Moderate)
Emotional Well-Being	3 (High)	1 (Low)
Overall Satisfaction	3 (High)	2 (Moderate)

The semi-qualitative analysis of user-oriented results observed in Table 6 shows that there are dramatic differences in the level of comfort, satisfaction, and emotional reaction between the two residential units. Case A showed high scores (3) on all the user-experience indicators assessed, and Case B showed moderate (2) to low (1) scores.

Case ʻA scored highly (3) on visual comfort, with residents indicating the presence of balanced daylight, decreased glare, and effective use of natural and artificial lighting. Case B scored moderately (2) with regards to the lighting conditions as being acceptable yet less optimised and more dependent on artificial lighting.

In terms of thermal comfort perception, Case A received a high score (3) as occupants reported that the interior temperatures were stable, and the thermal discomfort was lower. Conversely, Case B scored low (1) because residents mentioned that there were visible changes in temperature and limited thermal regulation.

Case A showed a high rating of perceived air freshness (3): the ventilation pathways were enhanced and biophilic elements were present, which supported the feeling of freshness and respiratory comfort. Case B showed medium performance (2) with insufficient and ineffective airflow and minimal natural ventilation.

Concerning emotional well-being, the respondents in Case A were found to have positive emotional reactions, such as relaxation, lower stress, and enhanced sense of belonging to the living environment, which gave them a high score (3). On the other hand, Case B scored low (1) because the occupants reported a neutral or slightly negative emotional reaction to environmental stagnation and a lack of sensory stimulation.

Lastly, the general satisfaction with the interior environment was also high (3) in Case A, demonstrating the overall beneficial impact of sustainable design measures on everyday life. Case B scored moderately (2) because the interior was seen to be functionally satisfactory but without environmental and emotional enrichment.

Overall, the findings suggest that not only the overall environmental performance of the interior design strategies implemented in Case A was improved but also the human comfort, emotional state, and satisfaction, which supported the human-centered concept of sustainability in residential interior design.

Figure 3 shows that the environmental indicators have a greater positive distribution around the sustainable residential environment (Case A) and it has a higher performance in lighting quality, air movement, thermal stability, and material environmental impact. The environmental performance gap between the two units indeed shows that sustainable interior design strategies play a central role in enhancing the quality of the environment.

The real benefits of sustainable design methods in making residential environments healthier and more sustainable can be traced in Case A with the high-quality air, more efficient lights, and thermal stability. The use of energy-efficient lighting and the use of natural lighting as much as possible in Case 0 can contribute to reducing the energy use and, at the same time, to making the visual experience more comfortable.

The improved design of ventilation will result in more comfortable and healthier indoor environment, and the choice of materials and insulation will be used to define the stability of temperatures and air quality. This evidence supports the hypothesis that a sustainable interior strategy

produces a direct positive impact on the environmental performance of residential settings and preconditions the further studies of the topic of comfort and user satisfaction discussed in the next objective.

Objective 3: To examine the variables that promote or impair effective adoption of the interior strategies that promote sustainability in residential settings and to offer evidence based on comparative case studies.

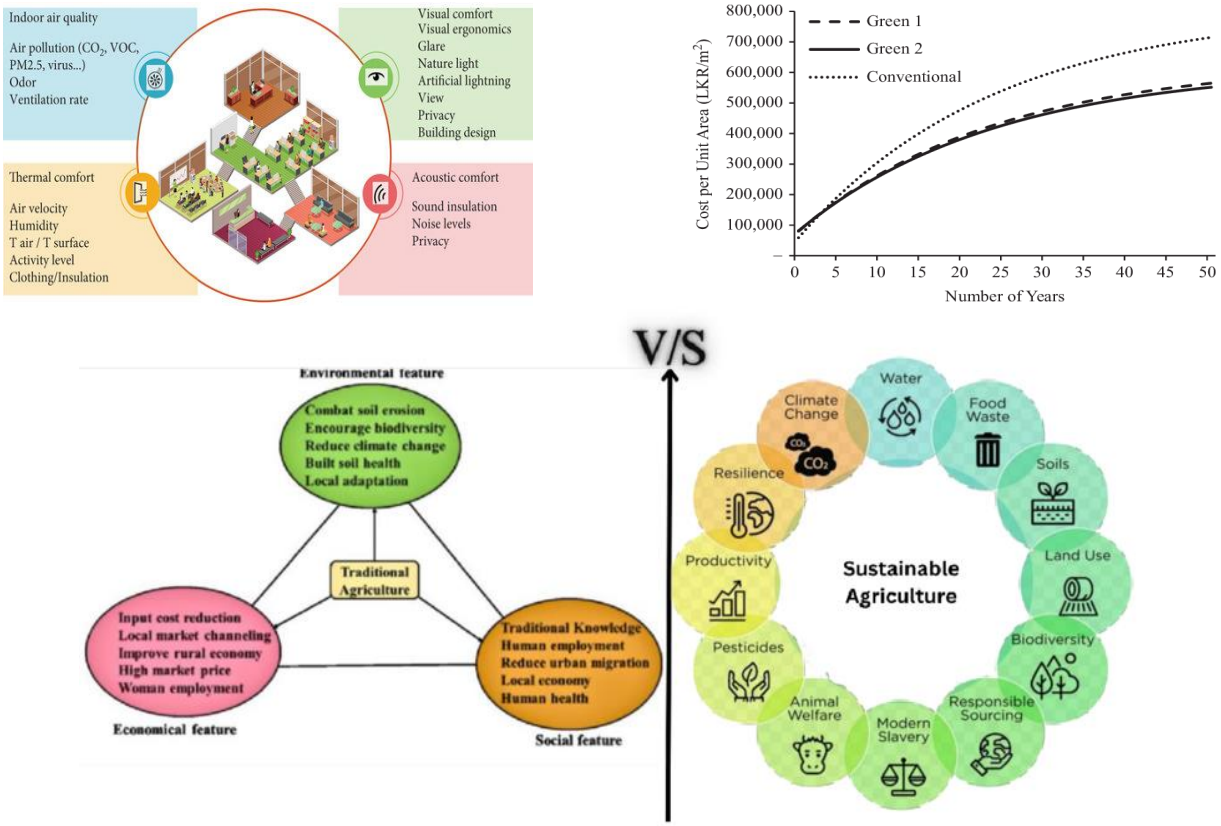

Figure 4. Descriptive environmental performance diagram

6.2. Narrative description user comfort & satisfaction differences

The comparative analysis of user-centered outcomes helps to prove that the representatives of the sustainable residential unit (Case A) expressed significantly greater rates of comfort and emotional satisfaction in comparison with the residents of the traditional setting (Case B). Interviews also revealed that occupants of Case A enjoyed improved visual comfort, which could be attributed to the successful integration of natural daylighting, which reduced the level of glare and helped to achieve even light all day and night. Similarly, better ventilation and the use of biophilic features created the impression of freshness, psychological relaxation, and an overall more desirable indoor environment.

In Case, thermal comfort was always felt to be more stable and less fertigating, which was due to better insulation and space organization, which reduced the effect of temperature variations. The perceived environmental characteristics were seen to positively affect emotional well-being; the participants said they felt calmer and less stressed and attached to the residential environment. In contrast, the residents of Case B indicated that they experienced reduced levels of comfort in various dimensions. They referred to excessive use of artificial lighting, changing thermal conditions, and a general feeling of environmental stagnation which could be attributed to poor air exchange. Lacking natural features and sustainable materials also added to the spatial experience that was said to be neutral or even monotonous. Taken together, these qualitative results Table 7. highlight the fact that sustainable interior design practices have a significant positive effect on the comfort and quality of life of the users.

Table 7. Comparative User Comfort and Satisfaction Indicators in Case A and Case B

User Experience Indicator	Case A (Sustainable Unit)	Case B (Conventional Unit)
Visual Comfort	High due to daylighting + efficient artificial lighting	Moderate; heavy reliance on artificial lighting
Thermal Comfort	Stable; insulation reduces fluctuations	Fluctuating; minimal environmental control
Perceived Air Freshness	Strong due to enhanced ventilation and biophilic elements	Moderate; limited airflow
Acoustic Comfort	Improved due to material finishes and spatial organization	Not optimized; noise not mitigated
Emotional Well-Being	High; sense of relaxation, reduced stress, positive mood	Lower; neutral or slightly negative emotional responses
Satisfaction with Interior	Strong sense of comfort and attachment to environment	Limited satisfaction; space perceived as functional but unremarkable

As Figure 4 demonstrates, the user-friendly advantages of sustainable interior design are well-supported using the empirical findings. The better day lighting, better thermal management, better air circulation, and the use of natural elements and most especially biophilic elements all help to give a holistic feeling of psychological and physical comfort in Case A. These findings coincide with the previous literature highlighting the emotional and experiential influence of sustainable interiors and, thus, proves that sustainability is not only a technical or environmental characteristic but also a factor of well-being and satisfaction.

Conversely, the lack of sustainable plans in Case B led to lower levels of comfort, an increased number of environmental discrepancies, and less emotional connection with the residential environment. The traditional interior, though functional enough, did not produce an equivalent level of comfort or the psychological advantage that Case A had.

Thus, the results support the idea that sustainable interior design solutions have a significant positive impact on comfort, satisfaction, and emotional state and, therefore, confirm the hypothesis of the research and prove the necessity to implement these solutions in the modern residential design practice.

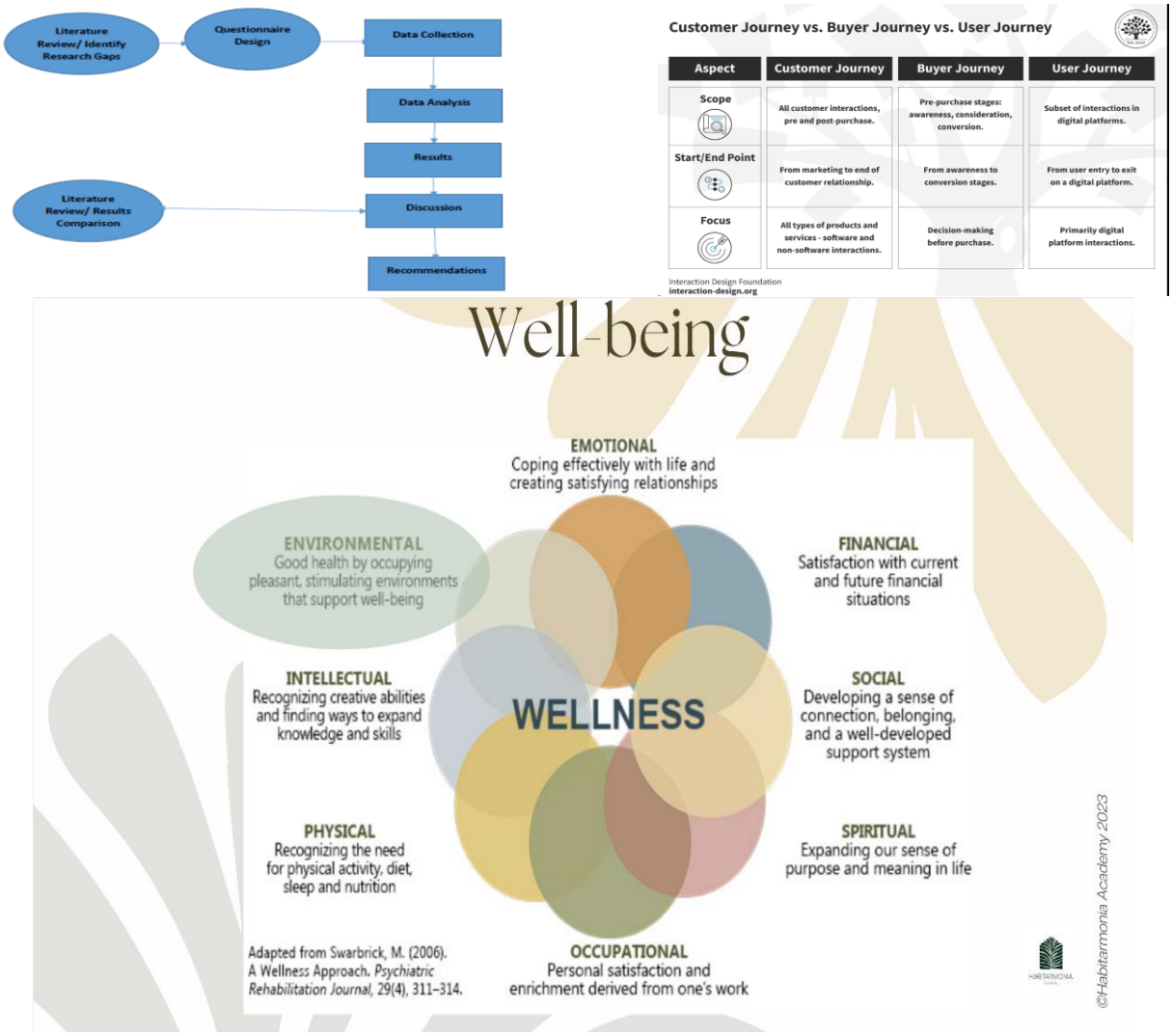

Figure 5. Descriptive diagram: user comfort & satisfaction comparison

7. Discussion

7.1. Interpretation of the findings

The interpretation of these findings should be viewed within the exploratory and case-based nature of the study, as the results are derived from a limited number of residential units and performance-based evaluative indicators.

The findings of the present research suggest that the use of sustainable interior design methods has a great positive effect on environmental performance and user-related outcomes in residential settings. The comparative study of the sustainable unit (Case A) and the traditional unit (Case B) reveals that the indicators of the environmental parameters including the quality of lighting, efficiency of ventilation, and thermal stability is much better when sustainable approaches are applied consciously. Such benefits are not limited to the technical advantages; they are also going to be converted into the increased level of comfort, satisfaction, and emotional wellbeing of the residents. Case A has biophilic aspects, less toxic materials, and natural ventilation aisles that make the interior environment healthier, more relaxed and hospitable. Furthermore, the results indicate that sustainable design measures interact in a cumulative way: natural lighting, air quality, space organization

and thermal moderation are combined to develop interior conditions that are felt to be steadier and emotionally reassuring. In Case B, however, where these measures were not taken, lighting inconsistencies, uncontrolled thermal environment, and insufficiency of fresh air were noted, which made the house living experience less comfortable and more emotionally neutral. This observation highlights the fact that any decision made in the design that is based on sustainability will not only impact on the performance of the environment, but also how people live, perceive and have emotional responses to the environments in which they live.

7.2. Comparison with previous research

The current findings are very much in line with theoretical expectations and the previous empirical evidence. [4] highlighted the socio-technical essence of sustainable residential interiors, how material selections, ventilation, and embedded design aspects constitute interdependent systems. The existing results confirm this opinion by demonstrating how sustainable approaches in Case 1 jointly enhanced the environmental situation, thus contributing to the interdependence model offered by [4] colleagues. Likewise, [13] has already proved the emotional and psychological effects of sustainable interior, stating that spatial characteristics, including lighting, ventilation, and material features, influence emotional conditions of residents. These findings are directly reflected in the improved emotional state and comfort felt in Case A , which substantiates the hypothesis that sustainability contributes to the positive affective experiences. The research that is attitudes-oriented- [15] also finds the current study to agree with their findings: the authors of the article focused on the fact that sustainable decision-making of designers has a direct impact on the interior results. Their argument that sustainable practices can produce quantifiable changes in user experience is proven by the strong environmental and experiential benefits in Case A. Lastly, [16] discovered that interior design techniques have an impact on comfort and perceptual well-being, especially in sensitive users, which is consistent with the high scores of comforts, relaxation, and satisfaction that residents of Case A reported. All these comparisons, in turn, support the fact that the findings of this study are consistent with literature and support theoretical expectations concerning the environmentally and psychologically positive role of sustainable interior design.

8. Conclusion

The findings used in the study reveal that integration of environmentally friendly procedures into interior design is a conclusive factor in improving the physical setting as well as the quality of experience of residential buildings. Comparative studies have found that a sustainably retrofitted residential unit performs better than conventional ones in several key environmental indicators such as natural lighting efficiency, ventilation quality and thermal stability and the environmental impact of the materials used in building it. These excellent environmental features are then linked to better user-focused performances because residents of the sustainably planned units indicate greater degrees of comfort, emotional state, and general contentment of their living environments. According to the authors, sustainability-oriented interior design is not only about environmental performance; it has a significant impact on occupants and how they perceive their spaces, experience them, and feel attached to them.

The results support the suggestion that sustainable interior design is a different paradigm and not an extension of the conventional residential design practices. In this respect, the designers, architects, and policymakers are advised to focus on the encouragement of natural ventilation, biophilic formalism, energy-saving light, and other environmentally friendly materials as the first design priorities. The practices enable the establishment of residential spaces that promote healthy living, reduce stress, and promote emotional engagement of the occupants to spatial arrangements. The general conclusion of this work is that interior design with references to the principles of sustainability plays a tangible role in the creation of residential environments that are comfortable ecologically, psychologically, and holistically.

Despite its contributions, there are several limitations to the study. To begin with, the study is grounded on just two case studies thus restricting the generalizability of the findings to the larger residential settings. Second, environmental performance measures were based on systematic checklists of observations as opposed to quantitative measures, which can limit the accuracy of environmental performance values. Third, the interviews did not use standardized psychometric scales to assess user experiences, and that is why the qualitative analysis of user experiences was obtained. Fourth, the cross-sectional design of the study does not allow addressing seasonal changes and long-term changes in behavior and comfort levels of occupants, and thus, it does not allow making longitudinal inferences.

Future studies can build on these findings by adding more residential units to the sample and using a wide range of architectural typologies to allow generalizing and conducting more detailed comparative analyses. More precise information on lighting, air quality and thermal performance would be provided with the implementation of quantitative environmental measurement instruments, including lux meters, CO 2 sensors, or thermal imaging. Longitudinal studies would be a possibility to address the impacts of sustainable interior strategies on occupant comfort and wellbeing with time and season. Further, the incorporation of behavioral, physiological, or psychological measures would also offer more empirical evidence on the connections between sustainable design interventions and occupant health and emotional performance. Lastly, economic cost benefit analysis of sustainable residential design might educate developers and policymakers on whether such strategies can be scaled up and be economically viable on a large scale.

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