



TRANSFORMING SPACE TO SMART PLACE": HOW SMART INTERIOR TECHNOLOGIES ENHANCE ENERGY EFFICIENCY AND INDOOR ENVIRONMENTAL QUALITY

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KEYWORDS	ABSTRACT
Smart Interior Technologies; Energy Efficiency; Indoor Environmental Quality; Smart Buildings; Occupant Comfort; Sustainability.	The integration of smart technologies into indoor environments has created new opportunities to improve energy efficiency and indoor environmental quality. This study examined the influence of smart interior technologies on energy efficiency and indoor environmental quality, focusing on the role of intelligent monitoring, automated environmental controls, occupancy sensors, and smart lighting in enhancing building performance and occupant comfort. A quantitative research approach was employed, using a structured questionnaire to collect data from users of technology-enabled indoor environments. The collected data were analysed using Partial Least Squares Structural Equation Modelling (PLS-SEM) through SmartPLS. The results revealed a significant positive relationship between smart interior technologies and energy efficiency, indicating that technology-enabled environmental controls support more efficient energy use and reduce unnecessary consumption. The findings also demonstrated a significant positive relationship between smart interior technologies and indoor environmental quality, highlighting their contribution to improving indoor comfort and environmental conditions. These findings emphasise that integrating smart technologies into indoor spaces supports both resource efficiency and occupant well-being. The study contributes to the growing body of knowledge on intelligent built environments by connecting technology integration with environmental performance and indoor quality. Practically, the findings provide useful insights for designers, building managers, developers, and policymakers seeking to promote energy-efficient and occupant-responsive indoor environments, particularly in developing countries where resource constraints and sustainability concerns remain significant. The study recommends the strategic adoption of smart monitoring systems, automated controls, and energy-responsive technologies to support more sustainable and comfortable indoor environments.
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Introduction

Digital technologies have developed at a fast pace and changed the way indoor places are designed and managed. Smart interior technologies combine intelligent monitoring, automated lighting, occupancy sensors and heating, ventilation and air-conditioning (HVAC) controls to make buildings smarter. These technologies can control building operation based on occupancy and environmental conditions, which may lead to better energy efficiency and indoor comfort, compared to conventional systems. Dong et al. (2019) emphasized the importance of smart sensing systems for intelligent building operation, and Dounis and Caraiscos (2009) focused on the advanced control systems for energy saving and comfort management in buildings. The building sector is an important user of energy due to the significant amount of energy used by lighting, heating, cooling and ventilation. Zhang et al. (2025) and Pérez-Lombard et al. (2008) highlighted the need to have an understanding of building energy use for effective energy-saving strategies. Likewise, the International Energy Agency (IEA, 2023) pointed out that building energy performance needs to be enhanced to achieve sustainability goals. Smart interior technologies contribute to reducing unnecessary energy use by adjusting the lighting, temperature and monitoring the environment in real time depending on the presence of people. But their effectiveness is dependent on the system set-up, building attributes and occupant actions.

Indoor environmental quality (IEQ) is also significant as it is essential that the spaces in the interior are suitable for thermal comfort, air quality, lighting and acoustics (Alongi et al. 2025). These factors were found to be significant for occupants' comfort and satisfaction by Frontczak and Wargocki (2011). The continuous environmental monitoring and responsive building operation is enabled by smart sensors and automated controls (Dong et al., 2019). However, the benefits of energy conservation need to be balanced with the needs of the occupants, as inappropriate settings of the systems will result in lower energy savings, but at the expense of ventilation and/or thermal comfort (Dounis & Caraiscos, 2009). Even with the development of intelligent building systems, it is still important to consider the relationship between intelligent building systems and energy efficiency and IEQ. The operational requirements, occupancy and environmental conditions of residential, commercial, educational, healthcare and hospitality settings vary. The advantages of smart interior technologies are thus different in different settings. They are not a guarantee of improved performance, but rather, successful integration and proper system configuration is necessary to yield any positive results.

To tackle this research issue, the present study investigated the linkages between smart interior technologies, energy efficiency and indoor environment quality in a single empirical model. The study employed a quantitative method with the explanatory construct being smart interior technologies, and the outcomes being energy efficiency and IEQ, both measured separately, using Partial Least Squares Structural Equation Modeling (PLS-SEM). The results showed positive correlations between the smart interior technologies and the two outcomes. This study is a contribution to the study of sustainable interior design, as it focuses on the technological integration in the context of two complementary dimensions of the indoor performance: resource efficiency and environmental quality. The results provide practical guidance for interior designers, architects,

building managers and operators who want to design, build and operate responsive and sustainable interior environments. The study emphasizes the need to match the functional and environmental needs of the occupied space with the smart technologies, which helps to transform traditional spaces into smarter, more efficient and space for the people.

Literature Review

Smart Interior Technologies and Intelligent Indoor Environments

Smart interior technologies combine digital devices, environmental sensors, automated controls and connected building systems to optimize the indoor environmental conditions and the operational performance. These technologies include smart lighting, occupancy detection, automated heating, ventilation and air-conditioning (HVAC), and indoor environmental monitoring. They allow interior spaces to react to occupancy and varying environmental needs. Dong et al. (2019) pointed out that smart sensing systems play an important role in monitoring indoor conditions and assisting in intelligent operation of buildings. Likewise, Sivasankari and Rathika (2025) talked about the energy efficiency and comfort of occupants in the building using the Internet of Things (IoT) enabled building automation. Digital twin technologies can also enable the incorporation of building information, environmental monitoring and operational analysis (Venkateswarlu & Sathiyamoorthy, 2025). The success of these technologies, however, is dependent on the accuracy of the sensors, system compatibility, maintenance and proper configuration. So, their contribution should be measured by the measurable performance outcomes, not by technology adoption.

Smart Interior Technologies and Energy Efficiency

In an interior environment, the energy efficiency is a significant factor since the energy consumption is associated with lighting, heating, cooling and ventilation. In conventional systems, they run on a fixed schedule, which means that they consume energy unnecessarily when the environment changes or when they are not in use. Smart interior technologies solve this by using occupancy responsive lighting, automatic temperature control and real-time energy monitoring. Sivasankari and Rathika (2025) highlighted the promise of IoT-driven automation in making buildings more efficient by monitoring and managing them in real-time. In the same way, Venkateswarlu and Sathiyamoorthy (2025) talked about the use of digital twins for energy analysis and building performance optimisation. However, the performance of smart systems depends on the building's type and characteristics, the occupancy, the efficiency of the equipment, and the maintenance regime, among other factors, and can differ from one location to another. Under-designed systems are more energy consuming than well designed systems. The results obtained can be used as a theoretical foundation to analyze the connection between smart interior technologies and energy efficiency.

H1: Smart interior technologies have a significant positive relationship with energy efficiency.

Smart Interior Technologies and Indoor Environmental Quality

Indoor environmental quality (IEQ) relates to thermal comfort, indoor air quality, visual comfort and acoustic conditions. These can affect how comfortable and satisfied occupants are, and are a key consideration in interior design. Smart interior technologies contribute to IEQ by means of environmental sensors and automated controls that measure the temperature, humidity, illumination and indoor air quality. Dong et al. (2019) emphasised the significance of environmental sensing in intelligent building management, and Sivasankari and Rathika (2025) spoke about the role of connected automation in ensuring occupant comfort and environmental monitoring. For instance, temperature sensors can be used for adaptive cooling, carbon dioxide sensors can provide ventilation control information, and smart lighting can be used for occupancy and daylight control. The use of automated systems does not always ensure good indoor conditions, however. The effectiveness of their use is dependent on the accuracy of the sensors, the correct control settings, system maintenance and the needs of the occupant. Furthermore, if systems are not well designed, any improvement in one aspect of the environment will have a detrimental effect on another. Thus, the connection between smart interior technologies and IEQ needs to be assessed independently through empirical research.

H2: Smart interior technologies have a significant positive relationship with indoor environmental quality.

Energy Efficiency and Indoor Environmental Quality

Energy efficiency and IEQ are interrelated aspects of sustainable indoor environments, but they need to be managed. A decrease in ventilation or cooling decreases energy use and decreases air quality or thermal comfort. On the other hand, over-heating, over-cooling and over-lighting keep some comfort conditions, but increase the energy consumption. Sivasankari and Rathika (2025) spoke about the possibilities of IoT-based automation to solve the problem of energy efficiency and occupant comfort at the same time. Likewise, Venkateswarlu and Sathiyamoorthy (2025) highlighted the role of digital twins in integrated building performance analysis. Intelligent systems, such as occupancy responsive ventilation, daylight responsive lighting and adaptive HVAC controls, demonstrate how energy and environmental needs can be balanced. However, the successful integration will be dependent on local climate, room characteristics, occupancy density and system interoperability. The above factors indicate that one should consider energy efficiency and IEQ separately as outcomes of smart interior technologies, and not take it for granted that an improvement in one will also result in an improvement in the other.

Smart Interior Technologies, Sustainability and Occupant-Centred Design.

Smart interior technologies are the extension of the traditional interior design, which includes intelligent monitoring, automatic control of the environment and data-based management decisions. This method integrates spatial functionality, occupant comfort, resource efficiency and environmental sustainability. Sivasankari and Rathika (2025) explained the concept of connected automation for optimizing building operations, and Venkateswarlu and Sathiyamoorthy (2025)

discussed the use of digital twins to integrate environmental data with building operations. Alici (2026) also discussed the importance of smart indoor environments in the context of energy efficiency, user comfort, and environmental sustainability. However, an occupant-centred approach is always critical as smart systems need to be responsive to the needs of the occupants and not just energy issues. System configuration should be based on appropriate temperatures, sufficient illumination, acceptable air quality, usability and preferences of the occupants. Smart interior technologies can thus be used to improve sustainable indoor environments when they are integrated with functional and environmental requirements.

Hypothesis Development

Smart building sensing systems (Dong et al., 2019), IoT-based building automation (Sivasankari & Rathika, 2025), and digital twin applications for building performance (Venkateswarlu & Sathiyamoorthy, 2025) have been studied in the existing literature. These studies demonstrate the feasibility of using intelligent monitoring and automated controls for energy management and indoor environmental control. But the role of smart interior technologies in energy efficiency and IEQ needs further empirical study. These results are usually examined individually, but a combined analysis can give a more holistic view of intelligent interior environments. Moreover, there is no guarantee that technology alone will lead to better performance, as performance will be influenced by the configuration of the technology, the characteristics of the building, and the needs of the occupants. In the light of this, the present study investigates smart interior technologies in the context of energy efficiency and IEQ in a single empirical framework. The following hypotheses are tested in the study:

- H1: Smart interior technologies have a significant positive relationship with energy efficiency.
- H2: Smart interior technologies have a significant positive relationship with indoor environmental quality.

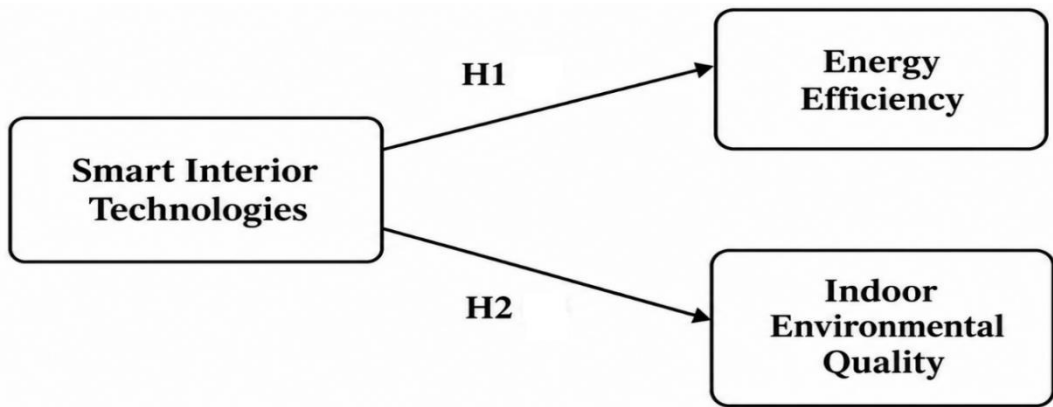


Figure 1. Conceptual Framework

Research Methodology

Research Design

The research design used in this study was quantitative and cross sectional to explore the relationships between smart interior technologies, energy efficiency and indoor environmental quality (IEQ). The study involved the investigation of relationships between defined constructs in the context of structured responses and statistical analysis, which made a quantitative approach appropriate. Smart interior technologies were used as the independent variable and energy efficiency and indoor environmental quality were used as dependent variables in the research model. The methodology was based on the principles of quantitative research and Partial Least Squares Structural Equation Modeling (PLS-SEM) (Creswell & Creswell, 2017; Hair et al., 2021).

Data Collection and Sampling

Structured questionnaires were used to gather data, which included questions to understand the perception of smart interior technologies and their association with indoor environmental performance. The questionnaire was directed to people who are familiar with or use technology in indoor environments such as residential, commercial, educational, and hospitality (as relevant to the sampling frame for this study). Respondents were selected using a purposive sampling method to ensure that those with relevant experience of smart interior features (such as automated lighting, occupancy sensors, intelligent environmental controls and indoor monitoring systems) were included. The respondents were informed of the academic purpose of the research and participation was voluntary. Confidentiality and anonymity were respected and responses were used for research. The questionnaire was structured into four sections: Respondent characteristics, and the three main constructs. The actual fieldwork records should be used to report the final sample size, data collection period, response rate and inclusion criteria.

Measurement of Constructs

All constructs were assessed by multi-item questionnaire scales based on the literature. Smart interior technologies were evaluated using the indicators of intelligent monitoring, automated environmental controls, occupancy sensing and smart lighting. Energy efficiency was assessed using respondents' judgments of efficient energy use, unnecessary energy use and energy responsive operation. Indoor environmental quality was evaluated based on thermal comfort, indoor air quality, lighting and indoor environmental quality indicators. These measures were conceptualised based on previous research on smart-building sensing and indoor comfort (Dong et al., 2019; Dounis & Caraiscos, 2009; Frontczak & Wargocki, 2011). Responses were recorded on a five point Likert scale from strongly disagree (1) to strongly agree (5). Relevance and clarity of the questionnaire items were checked prior to data analysis. If a scale is adapted from a previous validation or pilot study, or if it has been piloted, the procedures used should be described.

Data Analysis

The collected data was analyzed by using Partial Least Squares Structural Equation Modeling (PLS-SEM) using SmartPLS. The analysis was done in two phases. The first step was to test the measurement model to determine the reliability and validity of the constructs. The internal consistency was assessed by Cronbach's alpha and composite reliability, and convergent validity was assessed by indicator loadings and average variance extracted (AVE). The heterotrait–monotrait ratio (HTMT) and other suitable measures (Hair et al., 2019; Henseler et al., 2015) were used to evaluate the discriminant validity. Second, the structural model was evaluated to test the hypothesised relationships. Path coefficients, their statistical significance (bootstrapping), and the explanatory power of the model (coefficient of determination (R^2)) were analyzed. The two hypotheses tested were that smart interior technologies have significant positive relationships with (H1) energy efficiency and (H2) indoor environmental quality. Both relationships were positive and statistically significant as revealed by the results.

Ethical Considerations

The study adhered to the ethical guidelines of research, including informed consent, voluntary participation, confidentiality, and responsible data management. If there is an institutional ethical approval or exemption, this should be reported with the relevant details. Note: Please check the true sample size, sampling sites, collection dates, questionnaire sources and ethical approval information before submitting. This approach should outline the steps you actually took and not be assumed or fabricated.

Results and Discussion

The measurement model assessment, discriminant validity, structural model evaluation and explanatory power of the research model for the study “Transforming Space to Smart Place”: How Smart Interior Technologies Enhance Energy Efficiency and Indoor Environmental Quality are presented in this chapter. The analysis focuses on smart interior technologies as the predictor constructs and energy efficiency and indoor environmental quality as the outcome constructs. The results are analysed in the light of the two hypotheses and literature review on intelligent building systems, energy management and occupant comfort. Before submission, one technical issue needs to be addressed: Composite reliability (CR) values for Table 1 are 0.816, 0.705, and 0.823. The value of 0.705 for energy efficiency is marginal and the reported CR values should be compared to the actual output of SmartPLS. Also, a p-value displayed as 0.000 should be reported as $p < .001$, not $p = .000$.

Measurement Model Assessment

The measurement model was evaluated to check the internal consistency, reliability and convergent validity of the three constructs: smart interior technologies, energy efficiency and indoor environmental quality. Internal consistency was assessed using Cronbach's alpha and composite reliability, and convergent validity was assessed by examining average variance extracted (AVE).

Hair & Alamer (2022) suggest that these measures be assessed collectively instead of using a single reliability coefficient.

Table 1. Construct reliability and convergent validity

Construct	CA	CR	AVE
Smart Interior Technologies	0.784	0.816	0.686
Energy Efficiency	0.861	0.705	0.655
Indoor Environmental Quality	0.793	0.823	0.706

The results showed that Cronbach's alpha values were between 0.784 and 0.861, which are acceptable ranges for internal consistency of the three constructs. The composite reliability values of the smart interior technology and indoor environmental quality were 0.816 and 0.823, respectively. Their AVE values were 0.686 and 0.706, respectively, which were higher than the commonly accepted 0.50, suggesting that these constructs accounted for greater than 50% of the variance of their indicators. The AVE for energy efficiency was 0.655, which was higher than the recommended AVE for convergent validity. There is a reported composite reliability of 0.705; however, this is less than the Cronbach's alpha of 0.861. This discrepancy should be examined with the original SmartPLS output before the measurement model is considered satisfactory, as this is often assumed to be consistent with the other reliability evidence. Remaining results are interpreted based on the values given.

Discriminant Validity

Discriminant validity was assessed using the heterotrait–monotrait ratio (HTMT). This criterion evaluates whether conceptually distinct constructs are empirically distinguishable. Henseler et al. (2015) introduced HTMT as a useful method for assessing discriminant validity in variance-based structural equation modelling.

Table 2. HTMT discriminant validity

Construct relationship	HTMT
Smart Interior Technologies – Energy Efficiency	0.642
Smart Interior Technologies – Indoor Environmental Quality	0.768
Energy Efficiency – Indoor Environmental Quality	0.781

The HTMT values ranged from 0.642 to 0.781. Discriminant validity of constructs was supported by all values being below the threshold of 0.85, which is commonly used. The highest value was between energy efficiency and indoor environmental quality (0.781), which makes sense as both are related aspects of building performance. However, the value was still lower than the threshold, indicating that the constructs could be differentiated empirically. The results confirm that the smart interior technologies, energy efficiency, and indoor environmental quality are distinct constructs in the structural model. The difference is relevant because the study investigates the relationship between

smart interior technologies and two outcomes that are conceptually different, but related: efficient energy use and quality of indoor conditions.

Structural Model and Hypothesis Testing

The structural model was tested to see if there were significant positive relationships between smart interior technologies and energy efficiency and IEQ. Path coefficients (β) and standard error (SE), t-values, and p-values were used to determine the direction and statistical significance of the hypothesised relationships.

Table 3. Structural model and hypothesis testing

Hypothesis	Relationship	β	SE	t-value	p-value	Decision
H1	Smart Interior Technologies $\rightarrow$ Energy Efficiency	0.624	0.058	10.759	0.000	Supported
H2	Smart Interior Technologies $\rightarrow$ Indoor Environmental Quality	0.571	0.064	8.922	0.001	Supported

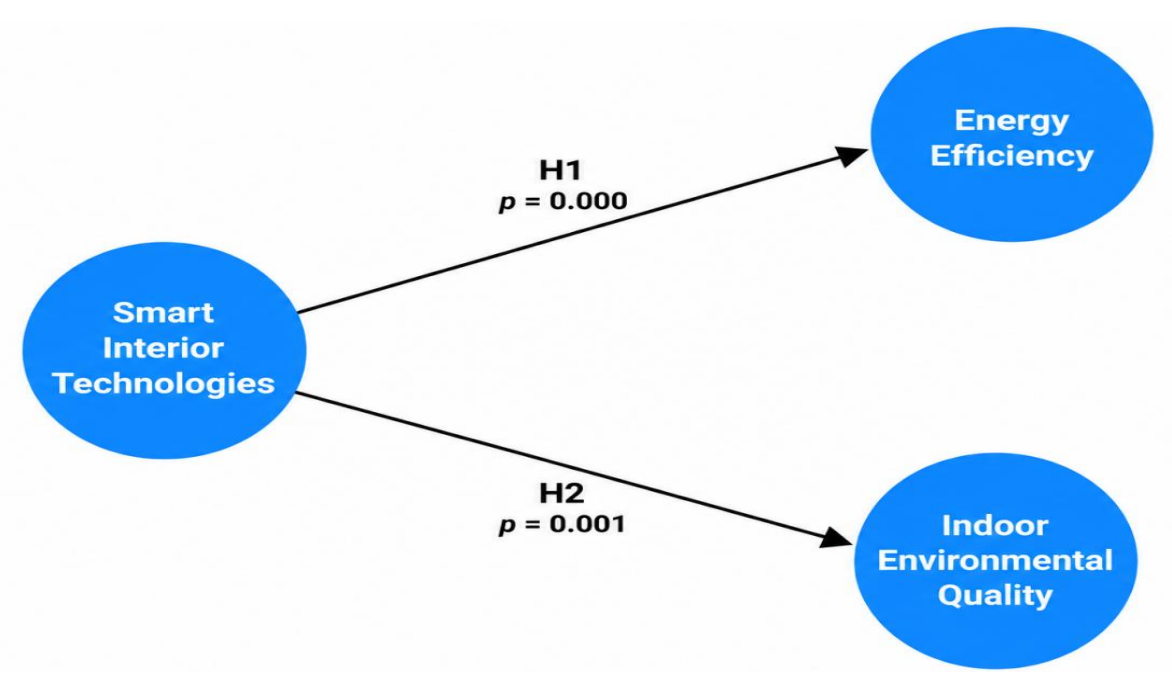


Figure 2. Structural Model

H1 said that there is a significant positive correlation between smart interior technologies and energy efficiency. The hypothesis was supported by the results as the path coefficient was positive ($\beta =$

0.624), the standard error was 0.058 and the t-value was 10.759. The reported significance level was < 0.000 . The positive coefficient shows that in the study model, the more energy efficient the use of smart interior technology, the higher the level of use. This path was the larger of the two tested relationships, in terms of the standardised coefficient. This indicates that the estimated model was more strongly related to energy efficiency than to IEQ when it came to smart interior technologies. In the real world, technologies like occupancy responsive lighting, automated environmental controls and intelligent monitoring enable energy use to match space usage and operating needs. The results, however, do not prove that the electricity consumption has been reduced objectively, but they do provide a statistical relationship. This is in line with the general

trend of smart-building sensing and automated control. Dong et al. (2019) emphasized the importance of sensing systems for building monitoring and control, and Dounis and Caraiscos (2009) spoke about the potential of advanced control strategies to coordinate energy management and occupant comfort. The present results continue this discussion by demonstrating that there is a strong positive relationship between smart interior technologies and energy efficiency in the empirical model presented. In practice, the discovery means that building owners, facility managers, and designers should think about how smart lighting, occupancy detection, and environmental control systems can be integrated into a single functional system when looking for ways to enhance energy performance. However, their effectiveness relies on proper configuration, maintenance and use in relation to building use. The implementation of smart technology should therefore be coupled with careful operational management, not as an energy saving for sure.

H2 reported that there are strong positive relationships between smart interior technologies and the indoor environmental quality. This hypothesis was supported by the results, as the path coefficient was $\beta = 0.571$, the standard error was 0.064, and the t-value was 8.922. The provided p value was 0.001, which is statistically significant and shows a positive relationship. The positive coefficient indicates that the higher the level of smart interior technologies integrated, the higher the level of indoor environmental quality. Intelligent monitoring, automated lighting and responsive environmental controls help to manage indoor conditions, sharing information on temperature, lighting, occupancy and other environmental factors. These capabilities are applicable to indoor comfort since the environment varies depending on occupancy, activities and external conditions. The discovery is consistent with Dong et al. (2019) who highlighted the role of smart-building sensing systems in the monitoring and control of the indoor environment. It is also consistent with the review conducted by Frontczak and Wargocki (2011) which found that thermal, visual, acoustic and air-quality conditions are important influences on occupants' indoor experiences. This literature provides support for the need to address environmental monitoring and responsive control as part of building management for the occupants. The positive correlation also has implications for the practice of interior design. Smart lighting and environmental controls are being considered as part of the design or facility management, in a way that is responsive to the functional needs of individual spaces. However, the use of technology does not guarantee high quality indoor environment. Actual performance is affected by sensor accuracy, control settings, maintenance and user ability to adjust

their environment. The results thus confirm the benefits of smart interior technologies and the need for appropriate implementation.

Explanatory Power of the Structural Model

The ability of the structural model to explain the phenomenon was evaluated by coefficient of determination (R^2) and adjusted R^2 . The statistics show the percentage of variance in each endogenous construct accounted for by the endogenous construct's predictor or predictors in the model.

Table 4. Explanatory power of the structural model

Endogenous construct	(R^2)	Adjusted (R^2)
Energy Efficiency	0.589	0.584
Indoor Environmental Quality	0.426	0.420

The results show that the variance of energy efficiency was 58.9% ($R^2 = 0.589$) explained by smart interior technologies. The adjusted R^2 was 0.584, indicating that the explanatory estimate was not significantly different when adjusted for the complexity of the model. This suggests that there is a significant amount of explanatory power in the estimated model, but the value of the predictive performance would need to be evaluated further. The (R^2) value for the indoor environmental quality was 0.426 and the adjusted (R^2) value was 0.420. Therefore, the model accounted for 42.6% of the variance in the indoor environmental quality, with the help of smart interior technologies. The variance not accounted for is due to other factors not considered in this analysis, including building characteristics, outdoor climatic conditions, maintenance practices, occupant preferences, and the performance of ventilation and air-conditioning systems. The results of the two outcomes show that the model accounted for a higher percentage of the variance in energy efficiency than in IEQ. This pattern is similar to that of energy efficiency, which had a higher path coefficient. The (R^2) values, however, are a measure of the explanatory power of the estimated model, and should not be interpreted as percentages of energy saved or improvements in physical indoor conditions.

The results confirm the two hypothesized relationships between the smart interior technologies and building performance. The two relationships were positive and statistically significant, and the model accounted for 58.9% of the variance in energy efficiency and 42.6% of the variance in indoor environmental quality. The overall results indicate that smart interior technologies can be applied to resource-efficient operation and management of the indoor environmental conditions. The higher relationship with energy efficiency ($(\beta = 0.624)$) shows that the smart interior technologies were more closely related with energy efficiency than with IEQ ($(\beta = 0.571)$). This is a direct consequence of the technologies that play a direct role in the operation of buildings, like occupancy sensors, automated lighting and environmental controls. Dong et al. (2019) explained the significance of sensing and control systems in the operation of smart buildings and Dounis and Caraiscos (2009) analyzed strategies for controlling energy consumption in conjunction with

comfort requirements in smart buildings. The results obtained in the present study support the significance of these technological skills. Second, the strong connection with the indoor environmental quality shows that the impact of smart interior technologies is not just in energy management. Intelligent monitoring and automatic controls enable building operators to determine the indoor condition changes and control environmental systems based on the indoor condition. Frontczak and Wargocki (2011) emphasized that the perception of comfort in the indoor environment is a multidimensional phenomenon and that the environment affects the occupants' experience. The present results underscore the need to take into account technologies that aid in monitoring and managing them.

Third, the explanatory results indicate that smart interior technologies are especially relevant in the field of energy efficiency and that they also help to explain the indoor environmental quality differences. The value of R^2 for energy efficiency was 0.589, which is higher than the value of 0.426 for the indoor environmental quality. A possible explanation is that energy related outcomes are more directly linked to the automated operational controls while the indoor environmental quality is affected by a wider mix of technological, physical and human factors. This interpretation is in line with the multifactorial aspect of indoor comfort mentioned by Frontczak and Wargocki (2011). This explanation should be treated as an interpretation, however, as the present model did not test the individual contribution of these additional factors. The results also have implications for sustainable interior design in developing country context such as Pakistan. Smart systems integration can provide opportunities to enhance operational control in buildings where energy costs, environmental conditions and resource efficiency are significant factors. However, factors such as initial investment, maintenance capacity, system compatibility, electricity infrastructure and the skills needed for operation and maintenance of the technologies should be taken into consideration when making decisions on adoption. The utility of smart interior technologies will rely on the selection of systems suitable to the function of the building, and the proper configuration and maintenance of the systems.

In general, the findings confirm the integrated smart interior design approach in which energy efficiency and indoor environmental quality are seen as complementary performance goals. Building professionals should not only consider the installation of digital devices but also how smart systems work in the context of the indoor environment. This helps to ensure that the technology is selected to meet operational needs and the needs of the occupants. Both hypotheses were supported by the reported structural model results. Smart interior technologies demonstrated positive, statistically significant relationships with energy efficiency and indoor environmental quality. The model also showed greater explanatory power for energy efficiency than for indoor environmental quality. These findings provide a basis for the study's conclusion that smart interior technologies are associated with both resource efficiency and improved indoor environmental conditions. However, because the analysis concerns modelled relationships, claims about actual energy savings or objectively measured environmental improvements should be made only if supported by additional measured data.

Conclusion and Recommendations

Conclusion

This study examined the relationships between smart interior technologies, energy efficiency, and indoor environmental quality (IEQ). The findings demonstrated that smart interior technologies had significant positive relationships with both outcome variables, supporting H1 and H2. The relationship with energy efficiency was stronger ($\beta = 0.624$) than the relationship with indoor environmental quality ($\beta = 0.571$). Furthermore, the structural model explained 58.9% of the variance in energy efficiency and 42.6% of the variance in indoor environmental quality. These findings highlight the potential importance of integrating intelligent monitoring, automated lighting, occupancy sensing, and environmental controls into contemporary indoor environments. The results reinforce the view that smart interior technologies contribute to resource-efficient building operation while supporting the management of indoor environmental conditions. This is consistent with research highlighting the importance of smart-building sensing and automated control systems (Dong et al., 2019; Dounis & Caraiscos, 2009). The findings also align with the multidimensional understanding of indoor comfort, which includes thermal, visual, acoustic, and air-quality considerations (Frontczak & Wargocki, 2011). The study contributes to sustainable interior design research by examining energy efficiency and indoor environmental quality within the same empirical framework. It emphasises that smart interior design should extend beyond the installation of digital devices to consider how technologies support building performance and occupants' environmental needs. However, the findings establish statistical relationships and should not be interpreted as direct evidence of measured energy savings or objectively improved indoor conditions unless supported by corresponding physical measurements.

Recommendations

Based on the findings, several recommendations are provided:

1. Integrate smart control systems: Interior designers and building managers should consider occupancy sensors, automated lighting, and intelligent environmental controls to support efficient building operation.
2. Prioritise indoor environmental quality: Smart systems should be configured to maintain appropriate thermal comfort, lighting, ventilation, and indoor air quality alongside energy-management objectives.
3. Strengthen system monitoring and maintenance: Regular inspection, sensor calibration, and performance monitoring are recommended to ensure that smart technologies operate reliably and respond appropriately to changing indoor conditions.
4. Adopt context-sensitive solutions: Building owners should select technologies according to building function, local climate, operating requirements, installation costs, and maintenance

capacity. In developing countries such as Pakistan, cost-effective and scalable solutions support wider adoption.

5. Improve professional capacity: Training opportunities should be provided for interior designers, facility managers, and building operators to strengthen their understanding of smart systems, environmental monitoring, and energy-responsive design.

6. Encourage further research: Future studies should examine different building types and geographical contexts, incorporate larger and more diverse samples, and combine questionnaire responses with objective measurements of energy consumption and indoor environmental conditions.

In conclusion, smart interior technologies represent a promising approach to creating more resource-efficient and environmentally responsive indoor environments. Their successful implementation requires appropriate technology selection, effective operational management, and continued attention to occupant needs.

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