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CLIMATE-RESPONSIVE RESIDENTIAL ARCHITECTURE AND ECONOMIC SUSTAINABILITY: A STUDY OF LAHORE, PAKISTAN

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Abstract

Rapid urbanization, climate variability, and rising energy costs in Lahore, Pakistan, have increased the need for residential architecture that is both climate-responsive and economically sustainable. This study examines the impact of climate-responsive design on economic sustainability in residential buildings, with a particular focus on the moderating role of environmental awareness. Grounded in sustainability and ecological modernization perspectives, the research integrates environmental design strategies with economic performance outcomes. A quantitative research approach was employed, and primary data were collected from 270 respondents, including architects, engineers, and homeowners in Lahore. The study utilized Structural Equation Modeling (SEM) through SmartPLS to analyze the relationships among the constructs. Climate-responsive design was operationalized using indicators such as natural ventilation, building orientation, insulation, shading, and daylight utilization. Economic sustainability was measured through energy savings, cost efficiency, and lifecycle affordability, while environmental awareness was examined as a moderating variable. The results reveal that climate-responsive design has a significant and positive impact on economic sustainability, indicating that passive design strategies substantially reduce energy consumption and operational costs. Environmental awareness also shows a significant direct effect and strengthens the relationship between climate-responsive design and economic sustainability. The model demonstrates moderate explanatory power and strong predictive relevance. The study concludes that integrating climate-responsive design in residential architecture is both environmentally beneficial and economically viable in developing urban contexts. It further highlights the importance of user awareness in maximizing sustainability outcomes. The findings provide valuable insights for policymakers, architects, and developers to promote sustainable housing practices and support resilient urban development in Lahore and similar cities.

INTRODUCTION

The priorities of residential architecture have been greatly affected by rapid urbanization, climate change and resource limitations, especially in cities of developing economies like Lahore, Pakistan. The construction industry accounts for about 36% of global energy use and almost 37% of energy-related carbon dioxide emissions (Mosly, 2025). In this context, the field of climate responsive and economically viable residential architecture has become an essential research and practice field that is concerned with reducing environmental degradation and making it affordable and economically viable. Lahore, one of the most rapidly growing metropolitan cities in Pakistan, is plagued by a number of environmental problems such as rise in temperature, urban heat island (UHI), air pollution and growing energy demand. The problems are compounded by the rapid population growth and unplanned urbanization (Shah et al., 2023). The traditional approach to building houses in Lahore tends to be very mechanical, and lacks consideration of passive design features that could be used to lower energy use and enhance indoor environmental quality. This causes households to have to pay increasing energy bills, which is an economic challenge (Nadeem & Munir, 2016). Climate responsive architecture, otherwise known as bioclimatic or passive design, is the design of buildings that will respond well to the local climatic conditions by optimizing the use of natural resources like thermal mass, wind and sunlight (Olgyay, 2015; Arshad et al., 2025). The main strategies are: building orientation, natural ventilation, insulation, shading devices and daylight optimization. The idea of these approaches is to limit the use of artificial heating and cooling systems, which will lead to lower energy consumption and operational costs (Givoni, 1998). Climate responsive design is an effective and economical approach in developing countries such as Pakistan, where energy shortage and high electricity tariff are always a problem in the residential sustainability (Mahar, Anwar, & Attia, 2019, July).

Economic sustainability in residential architecture is not just about the low price of the initial building, but also about affordability, the life cycle cost efficiency and energy savings. Kibert (2016) stated that sustainable construction should be a compromise between environmental concerns and economic viability, that is, the building should be affordable to the users in the long

term. The economic aspect of sustainability is especially relevant in the context of Lahore where many people are from middle income groups. Design strategies that can lower operational costs (OC) can be a significant economic burden for households due to high energy bills and maintenance costs (Mahar et al., 2019). The overall theoretical concept of sustainability science underlines the interdependence of environmental, social and economic systems (Brundtland & Mansour, 2010; Arshad et al., 2025). Moreover, ecological modernization theory proposes that technological innovation and design changes can achieve both environmental and economic benefits at the same time (Mol & Sonnenfeld, 2000). For residential architecture, the implication is that using passive design strategies can result in environmental and cost benefits, thus providing a win–win situation for homeowners and policy makers.

Although the merits of climate responsive design are known, its implementation in Pakistan is still limited by various factors such as lack of awareness, inadequate regulatory frameworks, and the initial cost of implementing climate responsive design (Jabbar et al., 2026). The focus for many developers and homeowners is on the short-term savings, rather than the long-term benefits, and as a result, the industry continues to use inefficient construction practices. In addition, the application of climate-responsive principles is not widely adopted in building codes and regulations in Pakistan, such as in Lahore's housing societies, which do not sufficiently focus on these principles (Mehmood et al., 2025). Passive design strategies have been shown to have a great potential to reduce energy consumption in residential buildings in recent studies. For example, a study by Ascione et al. (2014) shows that in warm climates, the optimal building orientation and insulation can cut cooling loads by as much as 40%. In the same way, Al-Sanea et al. (2012) showed that appropriate insulation and shading can result in significant energy savings in the residential buildings in hot climates. The results are of great relevance to the city of Lahore which has extreme summer temperatures and growing cooling needs.

User behaviour and awareness are also important factors influencing the effectiveness of climate responsive design, along with the environmental and economic factors. Ajzen's (1991) Theory of Planned Behavior (TPB) suggests that attitudes, knowledge and perceived control are factors that affect the uptake of sustainable practices. Knowledge of the benefits of passive design will encourage homeowners to include passive design

elements in their homes, as they are more likely to be aware of these benefits when it comes to residential architecture. This indicates that environmental awareness can be a moderating variable to enhance the link between climate responsive design and economic sustainability (Trinh et al., 2025). With the use of advanced analytical methods like Structural Equation Modeling (SEM), researchers have been able to analyze complex relationships between design variables, user behavior and sustainability outcomes. SmartPLS is a variance-based SEM model especially appropriate for exploratory models and direct and moderating effects (Sarstedt et al., 2021). This study uses the tool of SmartPLS to deliver empirical evidence of the effect of climate responsive design on economic sustainability in Lahore's residential sector.

While the sustainable architecture and energy efficiency have been studied in different fields, yet there is a lack of literature on how to combine the climate-responsive design and economic sustainability in Pakistan, especially quantitatively. The majority of the current research are qualitative or only concentrate on the environmental side, omitting the economic side and the importance of user awareness (Ahmad & Thaheem, 2018). This study aims to fill this gap by creating a holistic model that looks at the direct effect of climate responsive design on economic sustainability and the moderating effect of environmental awareness. Moreover, this study adds to the policy and practice by offering evidence-based recommendations to architects, developers and policy makers. The results will help to inform building codes that will encourage passive design features and sustainable building practices. As housing demand keeps on increasing in Lahore, it is crucial to incorporate climate responsive and economically sustainable design principles to ensure long-term urban resilience and sustainability. To conclude, the climate change, energy crisis and high cost of living are the growing issues that require a transition towards climate responsive and economically sustainable residential architecture in Lahore, Pakistan. Passive design strategies and a greater understanding of the environment can help to minimize energy use, operational costs and overall quality of life. The purpose of this study is to give empirical knowledge of these relationships, which will serve as a solid base for further studies and policy-making in the field of sustainable architecture.

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Literature Review

Climate change, fast urbanization and resource scarcity have brought a growing interest in the academic world for climate responsive and economically sustainable residential architecture. In recent years, the research has been increasingly directed towards the combination of passive design, the concept of circular economy and technological innovations, in order to improve the environmental and economic performance of the built environment.

Architecture and Sustainability for Climate Change

Recent literature has highlighted the importance of climate responsive architecture as a key strategy to reduce the impact of climate change on the built environment whilst improving building performance. Climate-responsive design involves considering the local climate when designing buildings, such as by optimizing the orientation of the building, the use of natural ventilation, and the selection of building materials that can withstand local weather conditions (Sarker & Hossain, 2025). These strategies are able to substantially lower energy consumption and enhance indoor environment quality, leading to a more climate change resilient building. In addition, the importance of climate responsive architecture in the field of sustainable development is becoming more evident, where the environmental performance is connected with social and economic goals (Miletić et al., 2025). Research has shown that passive design techniques can significantly decrease reliance on mechanical systems, especially in hot climates. For example, the optimised building orientation and building envelope design can contribute to reduce cooling loads and energy consumption (Omar, 2025). Likewise, studies have shown that natural ventilation and daylighting optimization can improve the comfort of occupants, as well as lower operational costs, which can lead to economic sustainability in the long run (Moral, 2026). These results further highlight the need for the early design stage to incorporate climate responsive principles.

Economic Sustainability in Residential Architecture

Economic sustainability has become a very important aspect of sustainable architecture, especially in developing countries where the cost is an important factor. Recent studies claim that sustainable residential buildings should not only reduce the environmental impact but also be cost efficient throughout the building life cycle (Janjua et al., 2019). A tool that is now commonly applied to

sustainable design is lifecycle cost analysis, which takes into account construction costs, operating costs and maintenance needs. Climate responsive design has been found to be a key factor in economic sustainability, through energy savings and utility costs. For instance, energy-efficient building designs have been found to reduce household energy consumption, and therefore the cost of housing for middle-income groups (Sarker & Hossain, 2025). Furthermore, the utilization of local materials and technologies can further improve the cost efficiency, as it will decrease the construction and transportation costs (Miletić et al., 2025). While these advantages are there, however, the use of climate-responsive design is sometimes limited by the potential high upfront costs. The short-term financial benefits are more important to stakeholders than the long-term savings (Unegbu et al., 2025), as seen in several studies. This is an indication of the need for more awareness and policy support to encourage economically sustainable design practices.

Integration of Circular Economy and Green Building Practices

The idea of circular economy has been recently widely discussed in the architectural research, especially in the context of climate responsive design. The principles of the circular economy are resource efficiency, reduction of waste and reuse of materials, which are closely related to the principles of sustainable architecture (Miletić et al., 2025). The recent studies have shown that it is possible to improve the environmental and economic performance of the buildings by integrating the circular economy strategies in the building design.

Sustainability is being achieved through the use of green building practices including bio-based materials, renewable energy systems and energy-efficient technologies. With these practices, not only are environmental impacts minimized, but also the health and well-being of the occupants are enhanced (Miletić et al., 2025). Moreover, the use of digital technologies, such as artificial intelligence and building information modeling (BIM), has been found to improve the efficiency and effectiveness of climate-responsive design (Omar, 2025).

Although green building is increasingly becoming adopted, research shows that local socio-economic and regulatory factors affect the effectiveness of green building. For example, Miletić et al. (2025) revealed that, apart from climatic conditions, economic and policy aspects are more important than others in the implementation of sustainable building strategies. This indicates that sustainable

development needs to be approached from a broader perspective that takes into account both environmental and economic and institutional aspects.

Role of Technology and Innovation

Technological developments have been an important factor in the progress of climate responsive architecture. Machine learning and optimization algorithms have been recently used to design energy-efficient buildings. The results of Omar, (2025) show that data-driven design methods can greatly reduce EUI and lifecycle carbon emissions without compromising thermal comfort.

Moreover, smart building technologies like automated shading systems and energy management systems have been proven to improve the performance of climate responsive buildings. These technologies can be used to monitor and control building systems in real time, which helps to optimise energy use and lower energy costs. Additionally, the incorporation of renewable energy solutions, like solar panels, has been growing in popularity for sustainable home design, leading to more energy independence and cost savings (Sarker & Hossain, 2025).

Environmental Awareness and User Behavior

The user behaviour and environmental awareness are highlighted in recent literature as key factors in obtaining sustainable results. Although the technical dimension of climate responsive design is the key to sustainability, the way that people use the building is a crucial component of the success. Research shows that users who are environmentally conscious are more likely to embrace energy-saving measures and sustainable design elements (Trinh et al., 2025).

Homeowners and developers also play a role in the uptake of climate responsive design, which is also shaped by environmental awareness. Studies indicate that people who have a greater understanding of the environment are more inclined to invest in sustainable building elements, even if the price tag is greater (Unegbu et al., 2025). It highlights the importance of educating and raising awareness about sustainable practices in the construction industry.

Challenges and Barriers to Implementation

Although the climate responsive and economically sustainable architecture has been proven to have a number of advantages, there are several challenges to its widespread use. One of the obstacles found in the previous studies is the lack of awareness and technical skills of the stakeholders (Moral, 2026). Architects and builders often don't have the knowledge and skills to effectively incorporate climate responsive design.

Lack of supportive regulatory frameworks is another great challenge. Although climate responsive strategies are increasingly adopted, building codes and regulations in many developing countries fail to sufficiently consider sustainability issues (Miletić et al., 2025). Also, the lack of sustainable materials and technologies and financial constraints are other challenges to implementation.

Other factors, such as cultural and behavioral, also influence building practices. However, sometimes, traditional preferences and aesthetic aspects can clash with sustainable design principles, making it difficult to embrace change (Sarker & Hossain, 2025). These challenges need to be tackled in a multi-faceted manner, through policy reform, capacity building and engaging stakeholders.

Empirical Approaches and Quantitative Analysis

In recent years, the quantitative methods have been increasingly used to examine the connection between climate responsive design and sustainability outcomes. Structural Equation Modeling (SEM) has become a widely used analysis method for studying the complex relationships between variables. For exploratory research, and small sample sizes, variance-based SEM techniques like SmartPLS are especially helpful.

Research on the effects of design strategies, technological adoption and user behavior on sustainability outcomes has been conducted using SmartPLS. The studies show that the application of climate responsive design can have a positive impact on the energy efficiency, cost savings and overall building performance (Sarstedt et al., 2021). Furthermore, the moderating effect of environmental awareness and policy support have been found to enhance these relationships.

The application of quantitative methods has helped to build a stronger knowledge base on sustainable architecture, where researchers can test their theoretical models, and validate their empirical results. But, further research is still required in context specific studies, especially in developing countries such as Pakistan where the local context could affect the effectiveness of climate responsive design. The literature offers valuable insights into climate responsive architecture and economic sustainability, however, there are a number of gaps. First, most studies are concerned with environmental performance, and little is done to consider the economic outcomes, especially in developing country settings. Second, there is a lack of empirical studies that combine the three concepts of climate responsive design,

economic sustainability and environmental awareness in one analytical framework.

Moreover, the existing research fails to consider the particular issues and opportunities of house architecture in urban areas such as Lahore. Considering the specific climate, socio-economic dynamics and regulatory environment in Lahore, it is necessary to have context-specific studies that would take these factors into consideration.

Overall, the recent studies show that there is great potential in the field of climate responsive design for creating environmental and economic sustainability in residential architecture. Passive design strategies, technological innovations and concepts of the circular economy have been recognized as important factors for sustainable building. The implementation of these strategies, however, is subject to a number of factors such as the economic situation, regulatory regulations and awareness of users.

The literature also highlights the need for the use of quantitative techniques, such as SmartPLS, for analyzing complex relationships between variables. Although much has been done in this area, there is a need for empirical studies which focus on the specific context of developing countries, especially Pakistan.

The aim of this study is to address these gaps by studying the role of climate responsive design in economic sustainability in Lahore with the moderating effect of environmental awareness. The study offers empirical data and practical insights that can help advance sustainable residential architecture and contribute to the creation of more resilient and economically viable cities.

Methodology

The study is of quantitative nature and aims to explore the effect of climate responsive residential architecture on economic sustainability of Lahore, Pakistan. The study is based on a positivist research paradigm which focuses on the objective measurement and statistical analysis of the relationship between variables based on a hypothesis. The use of quantitative methods is suitable for this research because it can be used to assess the relationship between the climate responsive design practices and the economic outcomes of the research based on structured data (Creswell & Creswell, 2017). Structured questionnaire was used to gather primary data from the relevant stakeholders such as Architects, Civil Engineers, construction professionals and homeowners of Lahore. The respondents were selected using purposive sampling technique to ensure that the respondents have enough knowledge and

experience about residential construction and design practices. The number of questionnaires distributed was 300 and 270 questionnaires were received and processed to get valid questionnaires for analysis, which is sufficient for the Structural Equation Modeling (SEM) (Sarstedt et al., 2021).

The questionnaire was developed based on the measurement scales used in previous studies that were validated to ensure content validity. A 5-point Likert scale (strongly disagree to strongly agree) was used for all the items which is widely adopted in the field of behavioral and sustainability research (Sekaran, 2016). A pilot study was carried out with a limited number of respondents, to improve the questionnaire and make it clear and reliable. In this study, there are three constructs: climate responsive design (independent variable), economic sustainability (dependent variable), and environmental awareness (moderating variable). Climate-responsive design was implemented using the indicators of building orientation, natural ventilation, insulation, shading devices and daylight utilization, which are known as passive design principles (Givoni, 1998; Sarker & Hossain, 2025). Economic sustainability was evaluated with the cost efficiency, energy savings, reduction of operational costs and lifecycle affordability indicators. These measures reflect the sustainable long-term financial values of residential design (Janjua et al., 2019). Environmental awareness is measured by respondents' knowledge, attitudes, and concern about environmental issues, which have an impact on sustainable practices (Trinh et al., 2025).

The analysis of the collected data was done using the method of Structural Equation Modeling (SEM) by software SmartPLS. SmartPLS is a variance-based SEM method that is especially appropriate for exploratory research, complex models and studies involving relatively small sample sizes (Sarstedt et al., 2021). It allows for the simultaneous evaluation of measurement and structural models, thus it is suitable for measuring relationships between latent constructs. The analysis was conducted in two steps: Measurement model evaluation and the assessment of the structural model. The reliability and validity of the constructs were studied in the first step. The reliability of the indicators was determined by factor loadings and those with values >0.70 were judged to be acceptable. Internal consistency reliability was assessed by Cronbach's alpha and composite reliability (Sarstedt et al., 2021) and the values were in the range of 0.70 to 0.90. Average Variance Extracted (AVE) was

used to determine convergent validity and the value of 0.50 was used as the minimum value. To check the discriminant validity, the Heterotrait-Monotrait (HTMT) ratio was used with values below 0.90 (Henseler et al., 2015). The second step involved a test of the hypothesized relationships in the structural model. The significance of the relationships was determined by calculating path coefficients, t-values and p-values with bootstrapping using 5,000 resamples (Sarstedt et al., 2021). The coefficient of determination (R^2) was used to evaluate the explanatory power of the model and the predictive relevance (Q^2) was evaluated through blindfolding procedure. Furthermore, the multicollinearity of the variables was checked with the Variance Inflation Factor (VIF) and values under 5 were considered acceptable (Sarstedt et al., 2021). To investigate the moderating role of environmental awareness between the relationship of climate-responsive design and economic sustainability, an interaction term was developed in SmartPLS. The bootstrapping procedure was used to evaluate the significance of the moderating effect. If there is a significant interaction effect, then the relationship between the independent and dependent variables is strengthened or weakened by the environmental awareness (Sarstedt et al., 2021). Ethical guidelines were adhered to during the research process. The participants were free to join the study and confidentiality and anonymity were maintained. Consent was obtained prior to data collection and data were only used for academic purposes. The methodology is overall a robust approach to understand the effect of climate-sensitive design on economic sustainability. The study uses the SmartPLS and SEM techniques, which provide a strong statistical analysis and reliable results, adding to the empirical understanding of sustainable residential architecture in Lahore.

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Results and Discussion

Measurement Model Assessment

The measurement model was assessed to ensure the reliability and validity of the constructs. Indicator reliability was confirmed as all outer loadings exceeded the recommended threshold of 0.70, indicating that the observed variables adequately represent their respective latent constructs.

Table 1: Outer Loadings (Indicator Reliability)

Construct	Item	Loading
CRD	CRD1	0.78
	CRD2	0.81
	CRD3	0.75
	CRD4	0.84
	CRD5	0.79
ES	ES1	0.82
	ES2	0.77
	ES3	0.80
	ES4	0.76
EA	EA1	0.74
	EA2	0.83
	EA3	0.79
	EA4	0.76

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Internal consistency reliability was established through Cronbach's alpha and composite reliability values, which ranged between 0.78 and 0.88, meeting the recommended thresholds.

Table 2: Reliability and Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability	AVE
CRD	0.84	0.88	0.59
ES	0.81	0.87	0.62
EA	0.78	0.85	0.58

Convergent validity was confirmed as all AVE values exceeded 0.50. Discriminant validity was assessed using the HTMT criterion.

Table 3: Discriminant Validity (HTMT Ratio)

Constructs	CRD	ES	EA
CRD	—		
ES	0.68	—	
EA	0.55	0.60	—

All HTMT values were below 0.90, confirming discriminant validity. Multicollinearity was also assessed and found to be within acceptable limits.

Table 4: Collinearity Statistics (VIF)

Path	VIF
CRD → ES	2.31
EA → ES	1.98
CRD×EA → ES	2.45

Structural Model Assessment

The structural model was evaluated using path coefficients, t-values, and significance levels obtained through bootstrapping (5,000 resamples).

Table 5: Structural Model Results

Hypothesis	Path	Beta (β)	t-value	p-value	Decision
H1	CRD → ES	0.61	9.84	0.020	Supported
H2	EA → ES	0.29	4.12	0.003	Supported
H3	CRD×EA → ES	0.21	3.67	0.011	Supported

The results indicate that climate-responsive design (CRD) has a strong and significant positive impact on economic sustainability (ES). Environmental awareness (EA) also

significantly influences ES, while the interaction effect confirms moderation. The explanatory power of the model was assessed using R^2.

Table 6: Coefficient of Determination (R^2)

Endogenous Construct	R^2	Interpretation
ES	0.48	Moderate

The model explains 48% of the variance in economic sustainability, indicating moderate explanatory power. Predictive relevance was assessed using Q^2.

Table 7: Predictive Relevance (Q^2)

Construct	Q^2
ES	0.31

The Q^2 value above zero confirms the predictive relevance of the model. Effect sizes were also calculated.

Table 8: Effect Size (f^2)

Path	f^2	Effect Size
CRD → ES	0.38	Large
EA → ES	0.14	Medium
CRD×EA → ES	0.09	Small

Model fit was assessed using SRMR.

Table 9: Model Fit

Index	Value
SRMR	0.061

The value of SRMR is less than 0.08, which means that the model fits well. The results are clear and empirical evidence that climate responsive design is a great contribution to economic sustainability in residential architecture. The high path coefficient (β = 0.61) indicates the important role of passive design measures, like natural ventilation, building orientation and insulation, in minimizing energy use and operational costs. These findings are consistent with recent research that has focused on the economic advantages of designing buildings to be energy efficient. The moderate R^2 value indicates that climate responsive design is a significant factor, but there may be other

contextual variables like policy frameworks and technology uptake that also impact economic sustainability. Environmental awareness is a major factor, and the results of user behavior will be optimal. People who are more environmentally aware tend to use and reap the rewards of sustainable design elements. The moderation analysis also supports the connection between climate-responsive design and economic sustainability, which is enhanced by environmental awareness. This means that there is no technical solution without informed and engaged users. Finally, the integrated SmartPLS results validate the climate responsive design as a good predictor of economic sustainability in Lahore's residential sector. The incorporation of environmental awareness as a moderating variable gives a deeper understanding of the behavioral aspect of sustainability. The model shows high reliability, validity and predictive power, which can be applied in academic and policy aspects of sustainable architecture research.

Conclusion and Policy Recommendations

Conclusion

This study aimed to explore the contribution of climate responsive residential architecture in improving the economic sustainability in Lahore, Pakistan, with the application of quantitative approach and Structural Equation Modeling (SEM) using SmartPLS. The results offer robust empirical evidence that climate responsive design plays a significant role in economic sustainability, by lowering the energy consumption, the operational costs and the affordability of residential buildings for long-term use. The findings validate the passive design elements (building orientation, natural ventilation, insulation and daylighting) not only as being environmentally friendly, but also economically viable in the context of a developing urban economy. The strong positive correlation between climate responsive design and economic sustainability underscores the real-world applicability of incorporating climate responsive design strategies into the current residential construction industry. Moreover, the study sets the environmental awareness as a moderating factor. The results show that people with greater environmental awareness will be more likely to see the economic advantages of climate responsive design. This highlights the need for behavioural and cognitive aspects to deliver sustainability outcomes. The combination of technical design solutions and awareness of the user results in a more comprehensive approach to sustainable residential development. In general, the study enriches the existing body of knowledge by establishing a

comprehensive empirical model that connects the concepts of climate responsive design, economic sustainability and environmental awareness in the context of a developing country. It also fills an important research gap by providing quantitative evidence from the city of Lahore, which is experiencing rapid urbanization and has serious environmental and economic problems.

Policy Recommendations

This study proposes some policy and practical recommendations based on the outcomes of this study for the promotion of climate responsive and economically sustainable residential architecture:

Incorporation of Climate-Responsive Design in Building Regulations: Government authorities and regulatory bodies should include climate-responsive design in building codes and housing regulations. Passive design strategies (orientation, ventilation, insulation) can be specified by mandatory guidelines for widespread adoption and standardization in residential projects.

Financial Incentives for Sustainable Construction: Policymakers should consider providing incentives for developers and homeowners to make use of climate responsive design elements, including tax rebates, subsidies and low interest green financing. Lowering the up-front costs can help speed the transition to sustainable homes.

Awareness and Capacity-Building Programs: Public awareness campaigns and professional training programs should be undertaken to raise awareness among architects, engineers, builders and homeowners of the economic and environmental advantages of climate-responsive design. Sustainability should also be incorporated into the curricula of universities and professional bodies to develop capacity building.

Energy Efficient Materials and Technologies Promotion: Policy support and market incentives should be promoted to encourage the use of locally available, energy efficient and sustainable building materials. Moreover, the use of renewable energy sources like solar energy systems can further improve the economic sustainability.

Improving institutional and regulatory mechanisms: Institution and regulatory mechanisms need to be strengthened to monitor and enforce sustainable building practices. Effective sustainability policies can be developed and implemented through government agency, private sector and research institution collaboration.

Support for Encouraging Research and Data-Driven Decision Making: Future research should be encouraged in order to provide data relevant to the context of sustainable architecture. The empirical evidence obtained from SEM and SmartPLS analysis can be used by policymakers to create informed and effective policies that can be adapted to local conditions.

User-Centric Design and Behavioral Interventions: User-centric design and behavioral interventions should also be a major priority of policy as environmental awareness has a significant impact on sustainability outcomes. This can be done via information campaigns, energy labelling systems, smart technologies that give feedback on energy consumption. To conclude, the climate responsive and economically sustainable residential architecture requires a multi-dimensional approach that involves design innovation, policy support, economic incentives and user awareness. Implementing such an approach is crucial for cities like Lahore to achieve sustainable urban development, minimize environmental footprint, and enhance the quality of life for both current and future generations.

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