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Developing effective components in the design of residential apartments in the temperate and humid climate of Iran in order to reduce energy consumption in Mazandaran Province

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Abstract

Background and Objective: Buildings are considered the leading energy consumers, representing 40% of global energy usage. In Iran, due to insufficient focus on energy issues by both the population and authorities, over 40% of total energy consumption is allocated to this sector. The primary aim of this research is to assess the influence of each design parameter (form, envelope, openings, and roof) from the viewpoint of professionals in this field, focusing on residential apartment designs for energy reduction in Iran's humid and moderate climate. The secondary goal is to rank these components (form, envelope, openings, and roof) in terms of their energy-saving potential, as advised by experts.

Methodology: This research adopts an applied methodology, utilizing both qualitative and quantitative techniques based on the nature of the data. In the qualitative phase, thematic analysis was employed to prioritize the components and define the critical design elements for reducing energy consumption. Initially, 41 indicators were identified for the four main parameters (form, envelope, openings, and roof). The quantitative phase involved using a questionnaire, with expert feedback ensuring the accuracy of the findings, leading to the identification and ranking of 37 final indicators.

Results and Findings: The results reveal that, from the experts' point of view, to reduce energy consumption in residential apartments in Iran's humid and moderate climate, the envelope and openings components received the highest rankings, with weights of 0.383 and 0.312, respectively. Among envelope elements, the highest weight was given to avoiding metal materials. For openings, the most significant factor was the optimal placement of windows. In terms of roof design, the most valued element was the use of sloped roofs, while for form, the spacing between buildings ranked the highest. Experts in this field suggest that following the prioritization proposed in this study could effectively contribute to lowering energy consumption in residential apartments in the target climate.

Keywords: Mazandaran Province, residential apartments, temperate and humid climate, residential, climatic architecture, energy consumption.

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EXTENDED ABSTRACT

Introduction

The building sector is one of the largest consumers of energy worldwide, accounting for approximately 40% of total energy use and a significant share of greenhouse gas emissions. In Iran, the residential sector represents a major portion of national energy consumption, largely due to rapid urbanization, increasing demand for thermal comfort, and insufficient integration of climate-responsive design strategies in contemporary buildings. The excessive reliance on fossil fuels for heating and cooling has intensified environmental concerns, including carbon dioxide emissions and resource depletion.

The temperate and humid climate of northern Iran, particularly Mazandaran Province, presents unique environmental challenges and opportunities for energy-efficient residential design. High humidity levels, considerable rainfall, warm summers, and relatively cool winters require architectural solutions that respond effectively to local climatic conditions. Traditional architecture in this region historically utilized passive design strategies, such as natural ventilation, appropriate building orientation, climate-adapted openings, and lightweight construction materials. However, many contemporary residential apartment buildings have neglected these principles, resulting in increased energy demand and reduced environmental performance.

Previous studies have investigated various aspects of energy-efficient building design, including building orientation, façade characteristics, roof technologies, ventilation strategies, and material selection. Nevertheless, comprehensive research focusing specifically on the prioritization of effective design components for residential apartments in the temperate and humid climate of Mazandaran remains limited. Therefore, this study aims to identify and prioritize the most influential architectural design components contributing to energy reduction in residential apartment buildings. The research focuses on four principal categories: building form, envelope, openings, and roof design. The findings are intended to provide a practical framework for architects, designers, and policymakers seeking to improve energy performance in residential developments within this climatic region.

Methodology

This study employed an applied research approach using a mixed qualitative–quantitative methodology. In the qualitative phase, a thematic analysis method was adopted to identify the most important design indicators influencing energy consumption in residential apartment buildings. A comprehensive review of Persian and international literature related to climate-responsive architecture, building energy efficiency, passive design strategies, and residential building performance was conducted.

Initially, 85 scientific publications published between 2010 and 2024 were examined. After a screening process based on relevance to the research objectives, 45 studies (20 Persian and 25 English publications) were selected for detailed analysis. Using thematic coding techniques supported by MAXQDA software, four major design categories were identified: form, envelope, openings, and roof. These categories included 41 preliminary indicators associated with reducing energy consumption in residential apartments located in temperate and humid climates.

To validate the extracted indicators, a panel of 26 architectural experts and university faculty members from Mazandaran Province evaluated the initial framework. Based on their feedback,

four indicators were removed due to insufficient relevance, resulting in a final set of 37 indicators.

In the quantitative phase, a structured questionnaire was distributed among 48 specialists with academic and professional experience in architecture, building design, and energy-efficient construction. Participants evaluated the significance of each indicator using a six-point Likert scale ranging from “no effect” to “very high effect.” Statistical analyses were conducted using SPSS software. Data normality was assessed using the Kolmogorov–Smirnov test, while one-sample t-tests examined the significance of each design component. The Friedman test was used to rank the components according to their relative importance.

Furthermore, the Analytic Hierarchy Process (AHP) was applied to determine the relative weights of the design categories and their corresponding indicators. Pairwise comparison questionnaires were completed by ten highly experienced experts holding doctoral degrees and possessing more than ten years of professional experience in architecture and building design. The Expert Choice software was utilized to calculate final priorities and weights.

Results and Findings

The statistical analysis demonstrated that all four design categories significantly contribute to reducing energy consumption in residential apartment buildings located in the temperate and humid climate of Mazandaran Province. Results of the one-sample t-test indicated that the mean scores for form, envelope, openings, and roof were all significantly higher than the reference value, confirming their importance in energy-efficient residential design.

The Friedman ranking test revealed significant differences among the four categories. The building envelope achieved the highest priority rank, followed by openings, roof design, and building form. These findings indicate that the thermal and material characteristics of the building envelope play the most critical role in controlling energy losses and improving overall building performance in the study area.

The AHP analysis further confirmed this prioritization. The envelope category received the highest weight (0.383), followed by openings (0.312), while roof and form each obtained lower weights (0.116). These results emphasize the dominant influence of façade and wall-related design decisions on energy conservation.

Within the envelope category, the most important indicators included the avoidance of metallic materials, the use of materials with low thermal capacity, and the implementation of double-skin façades. Experts considered the reduction of heat transfer through exterior walls a fundamental strategy for minimizing both heating and cooling demands.

For the openings category, appropriate window placement received the highest priority, followed by external horizontal shading devices and double-glazed windows. These findings highlight the importance of balancing daylight access, natural ventilation, solar control, and thermal performance. Properly designed openings can significantly improve indoor environmental quality while reducing mechanical cooling and heating requirements.

In the roof category, sloped roofs achieved the highest ranking, reflecting their suitability for regions with high rainfall and humidity. Green roofs, reflective roofing materials, and cool roof technologies were also identified as beneficial strategies for enhancing energy performance.

Among the form-related indicators, outward-oriented architecture, appropriate spacing between buildings, and east–west building orientation received the highest priorities. These features improve natural airflow, reduce unwanted heat gain, and facilitate passive environmental control.

Overall, the results indicate that passive design measures associated with envelope optimization and opening design provide the greatest potential for reducing energy consumption in residential apartment buildings located in northern Iran's temperate and humid climate.

Conclusion

This study developed and prioritized a comprehensive set of architectural design components for reducing energy consumption in residential apartment buildings in Mazandaran Province, Iran. Through a combination of thematic analysis, expert evaluation, statistical testing, and AHP modeling, the research identified the most influential factors affecting building energy performance within a temperate and humid climate.

The findings demonstrate that building envelope design and opening configuration are the most effective categories for energy reduction. Specifically, avoiding metallic façade materials, selecting low-thermal-capacity materials, optimizing window placement, incorporating shading devices, and using high-performance glazing systems were identified as key strategies. Additionally, sloped roofs and appropriate building spacing contribute to improved climatic responsiveness and energy efficiency.

The study provides a practical framework for architects, urban planners, developers, and policymakers involved in residential construction within northern Iran. By integrating the prioritized design recommendations into future projects, it is possible to reduce energy demand, decrease dependence on fossil fuels, improve thermal comfort, and mitigate environmental impacts associated with carbon emissions.

Furthermore, the proposed framework may serve as a foundation for future research investigating the quantitative impact of these design parameters through building energy simulations and performance-based assessment methods. Such investigations could further refine climate-responsive design guidelines and contribute to the development of more sustainable residential environments in Iran and similar climatic regions worldwide.

Declarations

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Authors' Contribution

Authors contributed equally to the conceptualization and writing of the article. All of the authors approved the content of the manuscript and agreed on all aspects of the work declaration of competing interest none.

Conflict of Interest

The authors declare no conflict of interest.

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