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Evaluation of the Impact of Sustainable Architecture on Reducing Environmental Pollution and Improving Energy Efficiency in Residential Buildings

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A B S T R A C T

The present study aimed to evaluate the impact of sustainable architecture on reducing environmental pollution and improving energy efficiency in residential buildings through a comparative analysis of physical-spatial and environmental components in selected urban neighborhoods. This study employed a mixed-methods approach combining qualitative and quantitative analyses to assess sustainability indicators in two neighborhoods, El-Goli and Khiyaban, in Tabriz. Data were collected through structured questionnaires, expert interviews, field observations, and document analysis. The Analytic Hierarchy Process (AHP) was utilized to determine the relative importance of criteria and sub-criteria related to physical-spatial and environmental components. Pairwise comparison matrices were developed using Saaty's 9-point scale, and the data were analyzed using Expert Choice software to compute weights, priorities, and consistency ratios. The evaluation framework included indicators such as accessibility, housing quality, environmental cleanliness, air quality, infrastructure efficiency, and resource management. The results indicate that the El-Goli neighborhood demonstrates significantly higher performance compared to the Khiyaban neighborhood across both physical-spatial and environmental components. The relative weight of the physical-spatial component for El-Goli was 0.723, compared to 0.277 for Khiyaban, while in the environmental component, El-Goli achieved a weight of 0.766 versus 0.234 for Khiyaban. The consistency ratios of the AHP analysis were below 0.10, confirming the validity of the comparisons. Mean scores of environmental and physical-spatial indicators were also higher in El-Goli, indicating superior environmental quality, better infrastructure efficiency, and improved spatial organization. The findings confirm that the application of sustainable architectural and urban planning principles significantly enhances environmental quality and energy efficiency in residential areas, and the superior performance of the El-Goli neighborhood highlights the effectiveness of integrated design, modern infrastructure, and sustainable resource management in achieving these outcomes.

Keywords: *Sustainable architecture, environmental pollution, energy efficiency, Analytic Hierarchy Process (AHP), residential buildings*

1. Introduction

The rapid expansion of urbanization and the increasing demand for residential buildings have intensified environmental challenges and energy consumption patterns across the globe. In recent decades, the construction sector has been identified as one of the primary contributors to environmental degradation, accounting for a substantial share of global energy use and greenhouse gas emissions (Tootonchi Aval & Nik Nemat, 2021). This growing concern has led to a paradigm shift toward sustainable architecture as a strategic response aimed at mitigating environmental pollution, enhancing energy efficiency, and improving the overall quality of life in urban environments. Sustainable architecture, as an interdisciplinary approach, integrates environmental, economic, and social considerations into the design, construction, and operation of buildings, thereby offering a comprehensive framework for addressing contemporary urban challenges (Hosseini Mansoub & Barar, 2023; Jamei & Zaman, 2020).

Environmental pollution, particularly in urban areas, is closely linked to inefficient building design, excessive reliance on fossil fuels, and inadequate planning strategies. Buildings consume a significant proportion of total energy resources, and their operational inefficiencies contribute directly to increased carbon emissions and environmental degradation (Nasri et al., 2023; Saadat Jou et al., 2024). In this context, the integration of sustainable architectural principles, such as passive design strategies, energy-efficient materials, and renewable energy systems, has been recognized as an effective means of reducing environmental impacts while optimizing energy performance (Harischian et al., 2019; Rahaei & Poursiah, 2022). The application of these principles not only reduces energy consumption but also enhances indoor environmental quality, which is a critical factor in promoting human health and well-being.

One of the fundamental aspects of sustainable architecture is the use of environmentally compatible materials and advanced construction technologies. The selection of sustainable materials plays a crucial role in minimizing the ecological footprint of buildings, as it directly affects resource consumption, waste generation, and energy efficiency throughout the building lifecycle (Farnam et al., 2022; Najarnezhad Mashhadi & Zafari, 2023). In addition, innovative design solutions such as double-skin façades and smart materials have been increasingly adopted to improve thermal performance, reduce heat loss, and enhance energy conservation in residential buildings (Sasan et al., 2023; Sheikh Louie Bonab & Sheghaghi, 2022). These technological advancements demonstrate the potential of sustainable architecture to address both environmental and economic challenges in the construction sector.

Moreover, the integration of renewable energy sources into building design has become a key component of sustainable development strategies. Solar energy, in particular, has been widely utilized in residential buildings to reduce dependence on non-renewable energy sources and to decrease environmental pollution (Harischian et al., 2019). The implementation of solar chimneys, photovoltaic systems, and other renewable technologies has shown significant potential in improving energy efficiency and reducing operational costs (Rahaei & Poursiah, 2022; Tamimi & Farhang, 2025). Furthermore, recent advancements in energy management systems and intelligent building technologies have enabled more efficient monitoring and optimization of energy consumption, thereby enhancing the sustainability of residential environments (Vitalii, 2025).

In addition to technological innovations, urban form and spatial organization play a critical role in determining the energy performance and environmental quality of residential areas. The configuration of urban spaces, building orientation, and density significantly influence microclimatic conditions, thermal comfort, and energy consumption patterns (Murathan & Manioğlu, 2025; Sharston & Singh, 2025). Studies have demonstrated that well-planned urban environments with appropriate spatial arrangements can reduce urban heat island effects, improve air circulation, and enhance overall environmental quality. This highlights the importance of integrating sustainable urban planning principles with architectural design to achieve optimal environmental outcomes.

Recent research has also emphasized the role of advanced analytical methods and predictive models in improving building energy performance. The application of machine learning techniques and multi-objective optimization models has enabled more accurate prediction of energy consumption and identification of optimal design solutions for sustainable buildings (Vaisi et al., 2025; Xia et al., 2025). These approaches provide valuable insights into the complex interactions between various design parameters and environmental factors, thereby facilitating evidence-based decision-making in sustainable architecture. In parallel, policy instruments such as subsidies and regulatory frameworks have been recognized as important drivers in promoting energy-efficient building practices and accelerating the transition toward sustainable construction (Rieksta et al., 2025).

Despite the growing body of research on sustainable architecture, there remains a need for context-specific studies that evaluate the effectiveness of sustainable design principles in different urban settings. Local climatic conditions, cultural factors, and urban development patterns can significantly influence the performance of sustainable architectural solutions (Nasri et al., 2023; Saadat Jou et al., 2024). Therefore, comparative analyses of different residential environments are essential to identify best practices and to develop tailored strategies for enhancing environmental quality and energy efficiency. In particular, examining the physical-spatial and environmental characteristics of urban neighborhoods can provide valuable insights into the relationship between architectural design and sustainability outcomes.

In the context of Iranian cities, rapid urban growth and increasing energy demand have intensified the need for sustainable architectural solutions. Many urban areas face challenges such as air pollution, inefficient energy use, and inadequate infrastructure, which necessitate the adoption of innovative design approaches and sustainable planning strategies (Abbaszadeh et al., 2022). The evaluation of existing residential neighborhoods in terms of their environmental performance and spatial characteristics can contribute to a better understanding of the strengths and weaknesses of current urban development practices. Such analyses can also inform future planning and design decisions aimed at improving environmental sustainability and enhancing the quality of life for urban residents.

Accordingly, this study aims to evaluate the impact of sustainable architecture on reducing environmental pollution and improving energy efficiency in residential buildings through a comparative analysis of the physical-spatial and environmental components of selected neighborhoods.

2. Methods and Materials

The research method of this study is based on the qualitative analysis and comparison of physical-spatial and environmental conditions in two neighborhoods of Tabriz, namely El-Goli and Khiyaban, using data collected from questionnaires and interviews. The evaluations in this study were conducted using a Likert scale to measure various environmental and physical-spatial criteria. The data were processed using Expert Choice software to perform pairwise comparison analyses and to determine the relative importance coefficients of sub-criteria and criteria. Furthermore, the Analytic Hierarchy Process (AHP) was employed to analyze the relative importance of components and to calculate the final weights. This method was particularly utilized to assess the impact of sustainable architecture on reducing environmental pollution and improving the quality of life in the studied neighborhoods.

3. Findings and Results

Tabriz, the capital of East Azerbaijan Province, is located in northwestern Iran at a longitude of 46 degrees and 15 minutes east and a latitude of 38 degrees and 8 minutes north. The city lies at an elevation of 1,300 meters above sea level, situated on the Tabriz plain and along the bed of the Talkheh-Rud (Aji-Chay) River. It is bordered by Marand and Ahar counties to the north, Maragheh and Hashtrud to the south, Sarab and Mianeh to the east, and Lake Urmia to the west. With an area of approximately 11,800 square kilometers, Tabriz is the largest city in the northwestern region of the country and the fourth most populous city in Iran. It functions as an administrative, commercial, industrial, cultural, and political hub of the region. Tabriz has a cold and dry climate, characterized by long winters and relatively short summers. The majority of the population belongs to the Aryan Median ethnic group and speaks Azerbaijani Turkish. From an urban planning perspective, the urban fabric of Tabriz is divided into several types, including historical, traditional, organic, and planned textures. Traditional neighborhoods such as Maqsoudiyeh, Charandab, and Bagh Shomal are characterized by narrow, winding alleys with predominantly residential land use. In contrast, planned neighborhoods such as Parvaz Town, Zafaraniyeh, and Kouy-e Ferdows exhibit more regular structures and better accessibility for vehicles. Among the neighborhoods examined in this study are Khiyaban and Parvaz Town. Khiyaban is one of the old and organic neighborhoods of Tabriz, historically significant due to its role in the Constitutional Revolution and located in the central part of the city. Parvaz Town, on the other hand, is a planned neighborhood in the southeastern part of Tabriz, within the El-Goli district, originally designed to accommodate air force personnel and characterized by a regular geometric layout and planned urban amenities.

Based on the examination of physical-spatial components in the Khiyaban and El-Goli neighborhoods of Tabriz from the perspective of sustainable architecture, significant differences are observed. The El-Goli neighborhood, as a newly planned urban fabric, performs better than Khiyaban in most objective indicators such as permeability, compatibility, diversity, and functional concentration. The only exception is the human scale indicator, in which Khiyaban shows a relative advantage due to its organic formation and pedestrian-oriented proportions. In subjective components, Khiyaban demonstrates stronger performance in indicators such as activity vitality, identity of public buildings, and authenticity, owing to its historical background and stronger neighborhood identity. However, El-Goli achieves higher scores in other subjective indicators such as legibility and sense of place. In the functional dimension, no significant difference is observed between the two neighborhoods in terms of access to facilities. Nevertheless, El-Goli shows a more favorable condition in indicators such as flexibility, diversity, and urban infrastructure, indicating the relative success of contemporary urban planning in creating a sustainable environment. Overall, both urban development patterns have their own strengths and weaknesses, and a strategic integration of these features can contribute to the sustainable development of urban neighborhoods.

In examining environmental quality in the Khiyaban (Qotb Square) and El-Goli (Parvaz Town) neighborhoods of Tabriz, key components including cleanliness quality, noise levels, odor and fragrance, quality of the natural substrate and environment, and efficiency were considered. In the Khiyaban neighborhood, cleanliness quality is relatively low due to the presence of waste and dust in streets, sidewalks, and drainage channels. This neighborhood is commonly affected by oil stains from vehicles and scattered waste. In contrast, in the El-Goli neighborhood, streets and drainage systems are regularly maintained, and no visible dust or waste is observed in public spaces. Additionally, green spaces and tall trees in El-Goli contribute to improved acoustic conditions and reduced noise pollution, whereas in Khiyaban, high traffic density and incompatible land uses such as schools result in continuous noise disturbances. Regarding air quality, El-Goli benefits from cleaner air due to its proximity to El-Goli Park, while Khiyaban experiences poorer air quality due to heavy traffic and emissions from chimneys. In Khiyaban, unpleasant odors from domestic sewage are also among the environmental issues observed, particularly in the central parts of the neighborhood. However, in El-Goli, a modern and efficient sewage system is in place, and no unpleasant odors are detected. In terms of waste management, El-Goli utilizes a mechanized waste collection system, with waste bins appropriately located. In contrast, Khiyaban relies on a traditional waste collection system, and in some areas, waste bins are not easily accessible, leading to scattered waste. From an efficiency perspective, El-Goli demonstrates better performance in the preservation of natural resources, particularly vegetation and trees, all of which are marked with protective identification tags. In Khiyaban, due to the lack of natural resources and green spaces, vegetation protection is less effective. Overall, the comparative analysis of these two neighborhoods indicates that El-Goli outperforms Khiyaban across all environmental indicators and provides a cleaner environment, better air quality, lower noise levels, and more efficient waste and sewage management systems.

To evaluate the impact of sustainable architecture on reducing environmental pollution and improving energy efficiency in residential buildings, the Analytic Hierarchy Process (AHP) was employed. In this process, a hierarchical structure of criteria and indicators related to sustainable architecture was first developed. The primary objective of this analysis was to assess the degree to which each principle of sustainable design influences the reduction of energy consumption and the improvement of environmental quality in residential buildings. In the first stage, major criteria such as reduction of energy consumption, use of environmentally compatible materials, optimization of heating and cooling systems, and utilization of renewable energy sources were identified as key indicators. Subsequently, data related to these indicators were collected through expert interviews, document reviews, and observation of sustainable architectural projects and were evaluated both quantitatively and qualitatively. In the next stage, to determine the relative importance of each criterion and sub-criterion, their weighting coefficients were calculated using Thomas L. Saaty’s 9-point scale (Saaty, 1980). Finally, by calculating the relative weights of each sub-criterion and comparing them, the influence of each factor on environmental quality and energy consumption in residential buildings was determined.

Table 1

Saaty's 9-Point Quantitative Scale for Pairwise Comparison of Criteria

Score	Definition	Explanation
1	Equal importance	The two criteria have equal importance in achieving the objective.
3	Slightly greater importance	Experience indicates that criterion A is slightly more important than criterion B in achieving the objective.
5	Greater importance	Experience indicates that criterion A is more important than criterion B in achieving the objective.
7	Much greater importance	Experience indicates that criterion A is much more important than criterion B in achieving the objective.
9	Absolute importance	The much greater importance of criterion A over criterion B has been conclusively demonstrated.

The values 2, 4, 6, and 8 are used when intermediate judgments exist.

Table 2 presents the pairwise comparison matrix of the three main components of the physical-spatial quality of the environment, including "objective environmental components," "subjective environmental components," and "functional environmental components." In this method, pairwise comparisons were conducted to evaluate the relative importance of each component in relation to the others.

Table 2

Pairwise Comparison Matrix of the Three Components of the Physical-Spatial Quality of the Environment Using the AHP Method

Physical-Spatial Environmental Quality	Objective Environmental Components	Subjective Environmental Components	Functional Environmental Components
Objective Environmental Components	1	1	0.33
Subjective Environmental Components	1	1	0.14
Functional Environmental Components	3	7	1

The objective environmental components, as a principal criterion, have greater importance compared with the other components and were assigned a high priority in the pairwise comparison matrix. In comparison with the subjective environmental components, the objective environmental components have a similar priority; however, in comparison with the functional environmental components, their importance coefficient decreases. The subjective environmental components also have relatively lower importance and, in comparison with the functional environmental components, show a coefficient of 1.7, indicating their lower importance relative to the objective components. Finally, the functional environmental components have the lowest importance in comparison with the other components, and in comparison with the subjective environmental components, the coefficient of 7 indicates their superiority.

The values related to the relative weights of the criteria and sub-criteria of the environmental quality component are shown in Table 3. In this table, three principal criteria, including cleanliness quality, sounds, odor and fragrance, quality of the natural substrate and environment, and efficiency, were evaluated and weighted using the AHP pairwise comparison method. This process was carried out precisely in order to prioritize each criterion and sub-criterion.

Table 3

Pairwise Comparison Matrix of the Three Criteria of Environmental Quality of the Environment Using the AHP Method

Environmental Component	Cleanliness Quality, Sounds, Odor, and Fragrance	Quality of the Natural Substrate and Environment	Efficiency
Cleanliness Quality, Sounds, Odor, and Fragrance	1	7	5
Quality of the Natural Substrate and Environment	0.14	1	0.33
Efficiency	0.20	3	1

The criterion of cleanliness quality, sounds, odor, and fragrance, with a relative weight of 0.731, has the highest importance and ranks first. This criterion is identified as the most significant factor in evaluating the environmental quality of the environment. It is followed by the efficiency criterion, with a relative weight of 0.188, which ranks second and indicates its importance in environmental performance. The criterion of the quality of the natural substrate and environment, with a relative weight of 0.081, ranks third, showing that this factor has less importance than the previous two criteria, although it still plays an essential role in the analysis of environmental quality. The inconsistency rate of the pairwise comparisons, obtained as 0.06, is less than 0.10; therefore, the comparisons are acceptable and valid, indicating the precision and accuracy of the AHP analytical process in determining the relative weights of the environmental quality criteria and sub-criteria.

Table 4 presents the evaluation of the importance coefficients of the sub-criteria of the physical-spatial component in the El-Goli and Khiyaban neighborhoods. In this comparison, the El-Goli neighborhood achieved higher scores in most sub-criteria, particularly in the criteria of "accessibility" and "quality of form and fabric," indicating a more sustainable and efficient design in this neighborhood. Furthermore, in the "subjective environmental components" section, El-Goli received higher scores in the criteria of "comfort and convenience" and "residents' vitality," reflecting a more sustainable and attractive living environment for residents. In the "functional environmental components" section, both neighborhoods achieved similar scores in accessibility and public facilities. Analysis of these results indicates that the El-Goli neighborhood, with a more sustainable design and greater harmony among environmental elements, performs better than the Khiyaban neighborhood in various physical-spatial indicators.

Table 4

Pairwise Comparison of the Sub-Criteria of the Physical-Spatial Component in the Studied Neighborhoods Based on Saaty's 9-Point Scale and Determination of Neighborhood Importance Coefficients Using EXPERT CHOICE Software

Main Components	Secondary Components	Factors	Indicators	Mean Score of Sub-Criteria in El-Goli Neighborhood Based on Likert Scale A (Planned Neighborhood)	Mean Score of Sub-Criteria in Khiyaban Neighborhood (Qotb Square) Based on Likert Scale B	Importance Coefficient of El-Goli (A) Relative to Khiyaban (B), A/B	Final Weight of El-Goli (Expert Choice)	Final Weight of Khiyaban (Expert Choice)
Physical-Spatial Component	Objective Environmental Components	Quality of form and fabric	Scale	3.5	4.0	1.4	0.2	0.8
		Quality of accessibility	Accessibility	4.6	2.1	8.0	0.889	0.113
		Housing quality	Construction and architecture	3.57	3.14	4.0	0.8	0.2
		Aesthetic quality	Visual quality	4.3	2.0	8.0	0.88	0.11
	Subjective Environmental Components	Comfort and convenience	Attractiveness	3.02	2.17	5.0	0.83	0.167
		Vitality	Residents' vitality	3.18	2.45	5.0	0.83	0.167
		Identity and mental imageability	Legibility	3.66	3.66	1.0	0.5	0.5
		Authenticity	Reputation and prestige	2.5	4.0	1.6	0.143	0.857
	Functional Environmental Components	Uses and activities	Accessibility	3.25	3.27	1.0	0.5	0.5
		Facilities and services	Public facilities	3.04	3.4	4.0	0.8	0.2

Based on Table 5, the results of the evaluation of the importance coefficients of the sub-criteria of the environmental quality component in the El-Goli and Khiyaban neighborhoods were analyzed in detail. This analysis was conducted using the Likert scale to assess the mean score of the sub-criteria in each neighborhood, and these scores were then used to determine the final weight of each neighborhood through Expert Choice software. The results indicate that the El-Goli neighborhood has higher scores than the Khiyaban neighborhood (Qotb Square) in most sub-criteria. In terms of cleanliness quality, noise, air quality, sewage system, waste, and the quality of the natural substrate, El-Goli performed better and has a higher importance coefficient. In particular, in the sub-criteria of air quality and cleanliness, El-Goli is markedly superior to Khiyaban. Moreover, in the areas of vegetation protection and environmental characteristics, El-Goli continues to have a higher priority. These differences indicate better environmental quality in the El-Goli neighborhood, which may serve as a basis for decision-making aimed at improving and promoting environmental quality in these areas.

Table 5

Pairwise Comparison of the Sub-Criteria of the Environmental Component in the Studied Neighborhoods Based on Saaty's 9-Point Scale and Determination of Neighborhood Importance Coefficients Using EXPERT CHOICE Software

Main Components	Secondary Components	Indicators	Mean Score of Sub-Criteria in El-Goli Neighborhood Based on Likert Scale A (Planned Neighborhood)	Mean Score of Sub-Criteria in Khiyaban Neighborhood (Qotb Square) Based on Likert Scale B	Importance Coefficient of El-Goli (A) Relative to Khiyaban (B), A/B	Final Weight of El-Goli (Expert Choice)	Final Weight of Khiyaban (Expert Choice)
Environmental Components	Cleanliness Quality, Sounds, Odor, and Fragrance	Cleanliness quality	3.66	1.66	7.0	0.875	0.125
		Noise quality	3.65	2.7	5.0	0.833	0.167
		Air quality	4.66	2.33	8.0	0.889	0.111
		Condition of the domestic sewage system	4.33	2.33	7.0	0.875	0.125
		Condition of waste and garbage disposal	3.57	1.57	7.0	0.875	0.125
		Condition of the surface water collection system	4.0	2.0	7.0	0.875	0.125
	Quality of the Natural Substrate and Environment	Vegetation and wildlife landscape	3.2	1.3	7.0	0.875	0.125
		Air and climate	4.0	2.0	7.0	0.875	0.125
	Efficiency	Protection of vegetation cover	5.0	1.0	9.0	0.5	0.1
		Protection of environmental characteristics	3.0	3.0	1.0	0.5	0.5

The results of the weight aggregation analysis and the final ranking of the physical-spatial component presented in Table 6 indicate that the El-Goli neighborhood, with a relative weight of 0.723, has the highest priority in this regard and ranks above the Khiyaban neighborhood, which has a weight of 0.277. This difference in priority reflects the superior quality of the physical-spatial components in the El-Goli neighborhood.

Table 6

Final Score of the Neighborhoods in Relation to the Physical-Spatial Components

Component	Option	Weight	Priority
Physical-Spatial Component	El-Goli	0.723	1
	Khiyaban Neighborhood	0.277	2

The results of the weight aggregation analysis and final ranking of the environmental component in the El-Goli and Khiyaban neighborhoods are clearly shown in Table 7. The findings indicate that the El-Goli neighborhood (A), with a relative weight of 0.766, has the greatest importance in terms of environmental quality and ranks higher than the Khiyaban neighborhood (B). In contrast, the Khiyaban neighborhood, with a relative weight of 0.234, is ranked second, indicating that this neighborhood has been assessed as relatively lower than El-Goli in terms of environmental quality. The overall inconsistency rate of the comparisons is 0.03, which is lower than 0.10; therefore, the comparisons are considered acceptable and accurate. This analysis demonstrates the superiority of the El-Goli neighborhood in environmental dimensions and may serve as a basis for decision-making aimed at improving and enhancing environmental quality in this neighborhood.

Table 7

Final Score of the Neighborhoods in Relation to the Environmental Components

Component	Option	Weight	Priority
Environmental Component	El-Goli	0.766	1
	Khiyaban Neighborhood	0.234	2

The results presented in Table 8 show that the El-Goli neighborhood achieved higher scores than the Khiyaban neighborhood in all sub-criteria of the physical-spatial components, including objective environmental components, subjective environmental components, and functional environmental components. In particular, for the objective environmental components, the El-Goli neighborhood, with a score of 3.69, performed better than the Khiyaban neighborhood, which scored 2.23. These results indicate the higher quality of the physical-spatial components in the El-Goli neighborhood, which may serve as a basis for the design and improvement of sustainable architecture in this area. Overall, the mean score of the El-Goli neighborhood is 3.39, whereas that of the Khiyaban neighborhood is 2.54, indicating the superiority of the physical-spatial components and the implementation of sustainable architecture principles in the El-Goli neighborhood.

Table 8

Mean Scores of the Physical-Spatial Environmental Component in the Studied Neighborhoods

Main Components	Indicators	Mean Score of Sub-Criteria in El-Goli Neighborhood Based on the Likert Scale	Mean Score of Sub-Criteria in Khiyaban Neighborhood Based on the Likert Scale
Quality of the Physical-Spatial Components	Objective Environmental Components	3.69	2.23
	Subjective Environmental Components	3.09	2.85
	Functional Environmental Components	3.41	2.56
Mean Scores		3.39	2.54

Table 9 compares the mean scores of the environmental components in the two neighborhoods of El-Goli and Khiyaban based on the Likert scale. This evaluation includes three principal indicators: cleanliness quality, sounds, odor and fragrance; quality of the natural substrate and environment; and efficiency. According to the results, the El-Goli neighborhood generally achieved higher scores than the Khiyaban neighborhood across all indicators, indicating better environmental quality in El-Goli. In the indicator of cleanliness quality, sounds, odor, and fragrance, El-Goli, with a score of 3.97, is markedly superior to Khiyaban, which scored 2.09. This finding reflects better cleanliness conditions, cleaner air, and more favorable odors in the El-Goli neighborhood. Regarding the quality of the natural substrate and environment, El-Goli, with a score of 3.60, is in a better condition compared with Khiyaban, which scored 1.65. This considerable difference indicates the presence of better green spaces and natural conditions in El-Goli. In the efficiency indicator, El-Goli, with a score of 4, compared with Khiyaban, with a score of 2, demonstrates greater efficiency in environmental resource management. Finally, the overall mean scores are 3.85 for El-Goli and 1.91 for Khiyaban, indicating the superiority of environmental quality and better resource management in the El-Goli neighborhood. This analysis may serve as a basis for reforms in the Khiyaban neighborhood aimed at improving environmental conditions and quality of life.

Table 9

Mean Scores of the Environmental Component in the Studied Neighborhoods

Main Components	Indicators	Mean Score of Sub-Criteria in El-Goli Neighborhood Based on the Likert Scale	Mean Score of Sub-Criteria in Khiyaban Neighborhood Based on the Likert Scale
Quality of the Environmental Component	Cleanliness quality, sounds, odor, and fragrance	3.97	2.09
	Quality of the natural substrate and environment	3.60	1.65
	Efficiency	4.00	2.00
Mean Scores		3.85	1.91

4. Discussion and Conclusion

The findings of the present study demonstrate a clear and consistent superiority of the El-Goli neighborhood over the Khiyaban neighborhood in both physical-spatial and environmental dimensions, reflecting the effectiveness of sustainable architectural and urban planning principles in improving environmental quality and energy efficiency. The results of the AHP-based weighting and ranking indicate that the physical-spatial component achieved a higher relative weight for El-Goli (0.723) compared with Khiyaban (0.277), suggesting that planned urban morphology, structured spatial organization, and integrated design strategies contribute significantly to enhancing the quality of the built environment. These findings align with previous studies emphasizing the critical role of spatial configuration, accessibility, and urban form in shaping environmental performance and energy efficiency in residential areas (Murathan & Manioğlu, 2025; Sharston & Singh, 2025). The structured grid layout, improved accessibility, and optimized land-use patterns in El-Goli appear to facilitate better environmental outcomes, reinforcing the argument that sustainable urban design is a key determinant of environmental performance.

Furthermore, the analysis of sub-components within the physical-spatial dimension reveals that El-Goli outperforms Khiyaban in objective indicators such as accessibility, visual quality, and housing conditions, while also achieving higher scores in subjective indicators such as comfort, vitality, and sense of place. These results suggest that sustainable architecture not only improves measurable environmental attributes but also enhances users' perceptions and experiences of the built environment. This dual impact is consistent with the findings of (Hosseini Mansoub & Barar, 2023) and (Jamei & Zaman, 2020), who highlight the importance of integrating environmental performance with human-centered design principles in sustainable architecture. The higher performance of El-Goli in functional indicators such as infrastructure and service provision further indicates that modern urban planning approaches are more successful in delivering efficient and adaptable environments, which is supported by the work of (Farnam et al., 2022), emphasizing the role of efficient management and planning in sustainable construction.

In terms of environmental quality, the results show that El-Goli achieves a significantly higher relative weight (0.766) compared with Khiyaban (0.234), indicating superior performance across all environmental indicators, including cleanliness, air quality, noise control, and waste management. This finding is particularly important, as it demonstrates the direct relationship between sustainable design practices and environmental outcomes. The improved air quality and reduced noise levels in El-Goli can be attributed to its lower traffic density, better spatial planning, and the presence of green spaces, which act as natural buffers against environmental pollutants. These findings are consistent with the research of (Harischian et al., 2019) and (Rahaei & Poursiah, 2022), who emphasize the role of passive design strategies and natural elements in reducing energy consumption and environmental pollution. Additionally, the higher performance of El-Goli in waste and sewage management reflects the importance of modern infrastructure systems in achieving environmental sustainability, as highlighted by (Tamimi & Farhang, 2025).

Another significant finding of the study is the higher average scores of environmental indicators in El-Goli, particularly in cleanliness (3.97 vs. 2.09), natural environment quality (3.60 vs. 1.65), and efficiency (4 vs. 2), which collectively indicate a more sustainable and well-managed environment. These results suggest that the integration of sustainable materials, energy-efficient systems, and renewable energy technologies in El-Goli has contributed to its superior environmental performance. This interpretation is supported by (Sasan et al., 2023) and (Sheikh Louie Bonab & Sheghaghi, 2022), who demonstrate the effectiveness of advanced building technologies, such as double-skin façades and smart materials, in improving energy efficiency and reducing environmental impacts. Moreover, the role of renewable energy systems, particularly solar-based solutions, in enhancing environmental quality is consistent with the findings of (Nasri et al., 2023) and (Harischian et al., 2019), which highlight the potential of renewable energy integration in reducing dependence on fossil fuels.

The study also highlights the importance of environmental management practices in achieving sustainability outcomes. The use of mechanized waste collection systems, modern sewage infrastructure, and effective resource management strategies in El-Goli has resulted in higher efficiency scores and better environmental conditions. These findings align with the conclusions of (Abbaszadeh et al., 2022), which emphasize the role of integrated building systems and environmental management in optimizing energy consumption and reducing environmental degradation. Furthermore, the application of advanced analytical methods, such as AHP, in this study provides a systematic framework for evaluating the relative importance of different sustainability indicators, which is consistent with the growing use of multi-criteria decision-making approaches in sustainable architecture research.

The comparative nature of this study also underscores the significance of contextual factors in determining the effectiveness of sustainable architecture. The differences observed between El-Goli and Khiyaban can be attributed not only to design and planning approaches but also to variations in infrastructure, socio-economic conditions, and historical development patterns. This finding supports the argument of (Saadat Jou et al., 2024) and (Nasri et al., 2023) that the performance of sustainable architecture is highly context-dependent and requires localized solutions. The results further suggest that the adoption of modern design principles and technologies in newer neighborhoods can lead to substantial improvements in environmental quality, provided that these approaches are appropriately adapted to local conditions.

In addition, the study's findings are consistent with recent advancements in predictive modeling and optimization techniques in sustainable architecture. The improved performance of El-Goli can be interpreted as a result of the effective integration of design parameters that influence energy consumption and environmental quality, which is in line with the findings of (Vaisi et al., 2025) and (Xia et al., 2025). These studies demonstrate the potential of advanced analytical tools in identifying optimal design solutions and improving building performance. Similarly, the role of policy interventions and financial incentives in promoting sustainable construction practices, as discussed by (Rieksta et al., 2025), highlights the importance of supportive institutional frameworks in achieving sustainability goals.

Overall, the results of this study confirm that sustainable architecture plays a crucial role in reducing environmental pollution and improving energy efficiency in residential buildings. The superior performance of the El-Goli neighborhood demonstrates the effectiveness of integrated design, advanced technologies, and efficient management practices in achieving sustainability outcomes. These findings contribute to the growing body of literature on sustainable architecture and provide valuable insights for urban planners, architects, and policymakers seeking to enhance the environmental performance of residential areas (Vitalii, 2025).

One of the main limitations of this study is the reliance on data collected from a limited number of neighborhoods, which may affect the generalizability of the findings to other urban contexts. Additionally, the use of subjective measures, such as Likert-scale evaluations, may introduce bias in the assessment of certain indicators. Another limitation is the lack of longitudinal data, which restricts the ability to evaluate changes in environmental performance over time. Furthermore, external factors such as socio-economic conditions and policy frameworks were not comprehensively examined, which may influence the observed differences between the neighborhoods.

Future research should focus on expanding the scope of analysis to include a larger number of case studies across different climatic and socio-economic contexts. The integration of advanced data analytics, such as machine learning and simulation models, can provide more accurate predictions of energy consumption and environmental performance. Longitudinal studies are also recommended to assess the long-term impacts of sustainable architecture on environmental quality and energy efficiency. Moreover, future studies should explore the interaction between social, economic, and environmental factors in shaping sustainability outcomes.

From a practical perspective, the findings of this study suggest that urban planners and policymakers should prioritize the adoption of sustainable architectural principles in residential development projects. Emphasis should be placed on improving urban infrastructure, promoting the use of renewable energy systems, and enhancing environmental management practices. Additionally, the integration of green spaces, efficient transportation systems, and advanced building technologies can significantly improve environmental quality and residents' quality of life. Finally, the development of regulatory frameworks and incentive mechanisms can encourage the widespread adoption of sustainable design practices in the construction sector.

Authors' Contributions

Authors contributed equally to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

In this research, ethical standards including obtaining informed consent, ensuring privacy and confidentiality were considered.

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