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Identification and Prioritization of Barriers to the Development of Green Buildings in Existing Buildings Using the DEMATEL-Based Analytic Network Process

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Abstract

The development of green buildings is considered one of the most effective strategies for reducing energy consumption and greenhouse gas emissions in the building sector. However, the implementation of this approach in developing countries faces multiple barriers across economic, social, and politico-legal dimensions. The aim of this study was to identify, structurally analyze, and prioritize the barriers to the development of green construction in existing buildings, with a focus on energy conservation. To this end, eighteen key barriers were extracted based on a review of previous studies and classified into three main criteria: economic, social, and politico-legal. Subsequently, using the hybrid DEMATEL-based Analytic Network Process (DANP) approach, the causal relationships among the barriers and their final weights were determined. The required data were collected through questionnaires and the opinions of experts in the fields of building engineering and energy, and the analyses were performed using RStudio software. The results of the DEMATEL technique showed that the politico-legal criterion, with a positive causality index (+0.759), was identified as the root and principal influential factor in the system, whereas the economic and social criteria were classified as affected factors. Based on the DANP results, the most important barriers to the development of green buildings were the absence of comprehensive and locally adapted green building standards (19.31%), the lack of binding laws and regulations (14.41%), ineffective supervision of the implementation of building regulations (10.02%), the lack of public acceptance of energy consumption standards (8.51%), and non-specialized implementation and the use of traditional construction methods (8.41%). The findings indicate that economic barriers, including high initial costs, are not the primary causes but are rather consequences of weaknesses in legal frameworks, standards, and supportive policies. Accordingly, reforming regulations and legal requirements, strengthening the construction supervision system, establishing financial incentives, and enhancing public awareness are proposed as the most important policy strategies.

Keywords: *green building, energy conservation, DEMATEL, Analytic Network Process, multi-criteria decision-making.*

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1. Introduction

The building sector has become one of the most critical arenas for sustainability-oriented management because it simultaneously affects energy consumption, greenhouse gas emissions, material use, urban resilience, public health, and long-term economic productivity. Buildings are not merely physical assets; they are socio-technical systems shaped by regulations, construction markets, user behavior, technological capacity, professional knowledge, and institutional governance. In this context, the concept of green buildings has emerged as a strategic response to the environmental externalities of conventional construction and operation. Green buildings seek to reduce energy demand, improve resource efficiency, decrease emissions, enhance indoor environmental quality, and align construction activity with broader sustainability goals. Recent scholarship has emphasized that the transition toward greener built environments requires an integrated understanding of energy systems, design technologies, policy instruments, supply chains, organizational capabilities, and user acceptance rather than isolated technical interventions [1-3].

Green buildings are especially important in the context of energy saving because buildings have long operating lives, and inefficient decisions made during design, construction, renovation, or retrofit can lock cities into high levels of energy consumption for decades. Energy conservation in buildings is therefore not simply an engineering concern but also a managerial and policy problem. The adoption of renewable energy systems, energy-efficient envelopes, integrated photovoltaic/thermal technologies, passive design solutions, and intelligent building management systems can substantially reduce energy intensity, yet their diffusion depends on financial feasibility, regulatory enforcement, technical expertise, and cultural acceptance [2, 4, 5]. Studies on advanced green-building technologies show that the future of sustainable buildings is increasingly connected to artificial intelligence, digital twins, optimization algorithms, and smart zero-energy solutions, but the effectiveness of these innovations depends on institutional readiness and the ability of construction stakeholders to translate technical potential into practical implementation [5, 6].

Despite the growing technological maturity of green-building solutions, the transition from conventional construction to green construction remains uneven, particularly in developing countries and emerging urban contexts. Many studies show that green building development is constrained not only by technology costs but also by fragmented regulations, weak enforcement, limited incentives, inadequate professional capacity, poor market awareness, and insufficient integration of sustainability indicators into construction decision-making [7-9]. These barriers are highly interdependent. For example, the high initial cost of green buildings may be intensified by the absence of financial incentives, weak supply chains, limited domestic production of green materials, uncertainty in energy pricing, and the lack of binding standards. Similarly, low public acceptance may arise from limited environmental education, poor communication of long-term benefits, and insufficient trust in green-building certification systems. Therefore, the barriers to green building development cannot be adequately understood as separate obstacles; they must be analyzed as a network of mutually reinforcing economic, social, and political–legal factors.

The literature on sustainability evaluation and rating systems has shown that green buildings require multidimensional assessment frameworks. Rating systems often include energy performance, water efficiency, waste management, materials, indoor environmental quality, site selection, innovation, and social sustainability criteria. However, the scope, depth, and contextual relevance of these indicators vary across countries and institutional settings. Research on sustainability factors in buildings highlights the need to move beyond narrow energy metrics and toward comprehensive evaluation systems capable of supporting greener city environments [1]. Similarly, studies on green building rating systems indicate that waste management, circular economy principles, and environmentally compatible materials must be more systematically incorporated into green-building standards and assessment procedures [10-12]. These findings suggest that the absence of comprehensive and localized standards can itself become a central barrier to green building development.

The policy and legal environment is another foundational determinant of green-building diffusion. In many contexts, the transition to green construction requires enforceable building codes, energy-efficiency regulations, mandatory performance standards, fiscal incentives, urban planning support, and monitoring mechanisms. Studies on urban green infrastructure and policy frameworks show that weak legal structures, limited institutional coordination, and insufficient implementation capacity can reduce the effectiveness of sustainability policies even when environmental goals are formally recognized [13]. Green-building policies must therefore be understood not only as technical guidelines but as governance mechanisms that influence market behavior, construction practices, investor confidence, and public acceptance. In the absence of strong political–legal frameworks, economic barriers tend to become more severe, because private actors face uncertainty, limited incentives, and unclear performance expectations.

Economic and financial barriers have also received considerable attention in the green-building literature. Higher initial investment, perceived cost premiums, limited access to finance, uncertain payback periods, and weak demand-side valuation often reduce the willingness of developers, owners, and consumers to adopt green-building solutions. However, recent studies indicate that economic barriers are rarely independent; they are shaped by institutional structures, supply-chain capabilities, market maturity, and strategic orientation. Research on green supply chain management demonstrates that sustainable performance depends on coordination across suppliers, contractors, organizations, and regulatory stakeholders [14]. Likewise, research on green building supply chain resilience shows that risks, capabilities, and influence mechanisms interact dynamically, meaning that weak supply chains can increase costs and reduce confidence in green construction [15]. These insights support the need to evaluate green-building barriers within a networked decision-making framework rather than through linear ranking methods.

The social dimension of green building development is equally important. Sustainable construction cannot succeed without professional understanding, citizen awareness, user acceptance, and behavioral adaptation. Studies on green-building practitioners' understanding of sustainability show that even professionals may interpret sustainability unevenly, which can lead to implementation gaps and inconsistent application of green principles [8]. Similarly, research on social sustainability indicators emphasizes that green buildings must respond not only to environmental and technical criteria but also to social expectations, user well-being, community needs, and long-term livability [9]. Public understanding of energy conservation, willingness to pay for environmental benefits, and awareness of indoor environmental quality are therefore essential to the successful promotion of green buildings.

Education and capacity building are central mechanisms for overcoming these social and professional barriers. Studies on virtual reality-aided green building education show that project-based learning and immersive pedagogies can improve students' understanding of sustainable building design and strengthen the connection between theoretical knowledge and practical decision-making [16]. Broader studies on organizational resilience and curriculum development also suggest that integrating standards, risk management, disruption planning, and business continuity into education can improve institutional capacity to respond to complex sustainability challenges [17]. Even research outside the technical green-building domain points to the importance of early and structured educational interventions in shaping social behaviors and institutional norms, a principle that can be extended to sustainability awareness and environmental responsibility in the built environment [18]. Therefore, the social acceptance of green buildings depends not only on market signals but also on systematic learning, professional development, and public communication.

Technological innovation offers significant opportunities for reducing energy consumption and improving building sustainability, but technology alone is insufficient. Studies on green building energy patents and analytic hierarchy process evaluation indicate that technological development in green-building energy systems is expanding, but prioritization and adoption require structured decision-making tools [19]. Similarly, studies on building-integrated greenery systems and urban greenery demonstrate that nature-based and building-integrated solutions can enhance building performance, reduce environmental stress, and support urban sustainability, yet their implementation depends on design standards, maintenance systems, stakeholder coordination, and policy support [3, 20]. These findings reinforce the argument that green-building development is a complex managerial problem involving interactions among technology, policy, economics, and society.

From a strategic management perspective, green building development can be interpreted as a form of organizational and sectoral transformation. Construction firms, real-estate developers, municipalities, and regulatory agencies must develop capabilities that allow them to incorporate sustainability into decision-making routines, investment models, procurement systems, and stakeholder engagement processes. Research in related management fields shows that green innovation strategic orientation and green intellectual capital can contribute to competitive advantage, particularly when sustainability is embedded in organizational knowledge and strategic behavior [21]. Similarly, the integration of green human resource management and green marketing highlights the role of workforce engagement, internal sustainability culture, and external brand positioning in building sustainable organizational value [22]. These perspectives are highly relevant to green buildings, because the adoption of green construction practices requires not only technical solutions but also managerial commitment, human capital, and institutionalized sustainability routines.

Citizen participation and environmental governance also play a crucial role in strengthening the legitimacy and effectiveness of sustainability policies. The development of green buildings in existing urban contexts requires cooperation among residents, owners, contractors, municipalities, financial institutions, and policymakers. Institutional capacity-building models for citizen participation in the environmental sector suggest that participatory governance and green human resource management can enhance policy implementation and improve environmental outcomes [23]. In green building development, citizen participation is particularly important because retrofit and renovation projects often involve existing users and property owners whose decisions are influenced by perceived costs, expected benefits, social norms, and trust in regulatory institutions. Therefore, policies that ignore the social and participatory dimensions of green construction may face resistance even when technically sound.

Urban sustainability studies further show that green buildings should be analyzed as part of broader urban and regional systems. Green architecture can support sustainable tourism development, heritage-sensitive regeneration, and place-based environmental management when it is aligned with local culture, climate, and economic activity [24]. Urban greenery also contributes to climate adaptation, thermal comfort, biodiversity, and quality of life, which means that green-building policies should be connected to wider urban planning strategies [20]. In existing buildings, this systemic perspective is especially important because interventions are constrained by older construction methods, existing ownership structures, limited retrofit budgets, and established patterns of energy use. Thus, the development of green buildings in existing building stock requires prioritizing barriers in a way that reflects real-world dependencies among institutional, social, and economic factors.

A key methodological issue in this field is that many studies identify green-building barriers but treat them as independent variables. Conventional ranking approaches can reveal which barriers are perceived as important, but they often fail to show whether a barrier is a root cause or an outcome of other barriers. For instance, high construction costs may appear as a major obstacle, but if those costs are driven by weak regulations, lack of domestic standards, absence of market incentives, and underdeveloped supply chains, then cost reduction policies alone may be insufficient. Methods capable of modeling causal relationships are therefore needed to distinguish driving barriers from dependent barriers. Interpretive structural modeling has been used to analyze barriers to green building labels, demonstrating the value of structural approaches in identifying hierarchical relationships among adoption obstacles [7]. However, for complex systems in which barriers influence one another in multiple directions, a network-based multi-criteria decision-making method can provide a more comprehensive understanding of both causal structure and final priority.

The DEMATEL-based Analytic Network Process (DANP) is particularly suitable for this type of problem because it combines causal analysis with network-based weighting. DEMATEL can identify the direction and intensity of influence among criteria and classify factors into cause and effect groups, while ANP can calculate priority weights under conditions of interdependence. The combined DANP approach is therefore appropriate for analyzing green-building barriers because political–legal, economic, and social dimensions interact dynamically rather than independently. In the context of existing buildings, where policy weaknesses can increase costs, social resistance can reduce market demand, and technological underdevelopment can reinforce economic uncertainty, DANP enables researchers and policymakers to identify not only which barriers are important but also which barriers should be addressed first to generate systemic effects.

Although the existing literature provides valuable insights into green-building technologies, rating systems, social sustainability indicators, education, supply-chain resilience, policy frameworks, and organizational sustainability, there remains a need for integrated studies that examine the causal and networked structure of barriers to green-building development in existing buildings. Many studies emphasize specific aspects such as renewable energy optimization, building-integrated photovoltaics, green infrastructure, waste management, or professional education, but fewer studies combine these insights into a decision-making model that identifies root barriers and ranks them according to both direct and indirect effects [2, 4, 10, 16]. Addressing this gap is essential because policymakers often have limited resources and must know whether to prioritize financial incentives, legal reforms, standard development, professional training, or public awareness. Without a structural prioritization model, interventions may focus on visible symptoms rather than underlying causes.

Accordingly, the aim of this study is to identify, structurally analyze, and prioritize the economic, social, and political–legal barriers to the development of green buildings in existing buildings with an emphasis on energy saving using the DEMATEL-based Analytic Network Process approach.

2. Methodology

In terms of objective, the present study is applied research, and in terms of nature and method, it is descriptive–analytical. To identify, causally classify, and dynamically rank the barriers to promoting green buildings in the existing building stock and to explain their influence on the energy-saving driver, the hybrid multi-criteria decision-making approach of DEMATEL-based Analytic Network Process (DANP) was used. In the real world, economic, social, and political barriers do not operate independently; rather, they have reciprocal relationships and a complex network structure. Although the traditional ANP method considers internal dependencies, because it requires extensive and independent pairwise comparisons in large matrices, it is time-consuming and prone to inconsistency errors. The hybrid DANP approach resolves this complexity by integrating the DEMATEL technique into the Analytic Network Process; in this way, the total-relation matrix is first extracted through DEMATEL and then directly used to construct the weighted supermatrix in ANP.

The statistical population of this study consisted of experts and senior specialists in the field of urban management, as well as experienced construction engineers working in the area of green buildings. The sampling method was purposive. The mathematical implementation process of the hybrid DANP algorithm in this study included the following steps.

The DANP approach is an intelligent combination of the DEMATEL technique and the Analytic Network Process. This method first obtains the total-relation matrix through DEMATEL and then directly uses it to construct the weighted supermatrix in ANP. The mathematical stages of this process are as follows.

Step 1: Formation of the Initial Direct-Relation Matrix ($\boldsymbol{M}$)

After collecting expert opinions using a scale from zero, indicating no influence, to 4, indicating very high influence, the initial direct-relation matrix with dimensions $n \times n$is formed, in which m_{ij}represents the degree of influence of criterion $i$on criterion j.

Step 2: Normalization of the Direct-Relation Matrix ($\boldsymbol{X}$)

The normalized matrix $X$is calculated using the following formula, in which all elements fall between zero and one:

$$X = kM$$

$$k = \frac{1}{\max\left(\max_{1\le i\le n} \sum_{j=1}^{n} m_{ij},\ \max_{1\le j\le n} \sum_{i=1}^{n} m_{ij}\right)}$$

Step 3: Calculation of the Total-Relation Matrix ($\boldsymbol{T}$)

By extending the normalized direct-relation matrix toward infinity, the total-relation matrix, which reflects all direct and indirect effects, is obtained as follows, where Idenotes the identity matrix:

$$T = X(I - X)^{-1}$$

Step 4: Extraction of Causal Indices ($\boldsymbol{R}$+$\boldsymbol{D}$)and ($\boldsymbol{R}$−$\boldsymbol{D}$)

The row sum (R)and column sum (D)of matrix Trespectively indicate the degree of influence exerted and the degree of influence received by each criterion:

$$R = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1} = (r_1, \dots, r_n)^T$$

$$D = \left[\sum_{i=1}^{n} t_{ij}\right]_{1\times n} = (d_1, \dots, d_n)$$

The $R + D$index indicates the degree of interaction and importance of a criterion within the network, while the $R - D$index indicates causality. Positive values of $R - D$are classified as the cause group, whereas negative values are classified as the effect group.

Step 5: Formation of the Unweighted Supermatrix

In the DANP method, the DEMATEL total-relation matrix (T)is directly used to weight the network relationships. Accordingly, each section of matrix Trelated to cluster interactions is normalized and placed as the submatrices of the unweighted supermatrix:

$$W = (T_c)^X$$

Step 6: Calculation of the Limit Supermatrix and Final Weights

By raising the weighted supermatrix to powers until complete convergence is achieved, $\lim_{k\to\infty} W^k$, the limit and stable weights of the main criteria and subcriteria are extracted. These weights determine the final priority of the barriers to promoting green buildings.

3. Findings and Results

This section presents the results obtained from implementing the hybrid DEMATEL–Analytic Network Process model (DANP) to structurally analyze and prioritize the barriers to developing green buildings in existing buildings. This section is organized in three stages. In the first stage, using the DEMATEL technique, the causal relationships among the three main criteria of the study, including economic, social, and political–legal barriers, were identified. In the second stage, the total-relation matrix obtained from DEMATEL was used as the structural basis of the network in the Analytic Network Process, and through calculating the limit supermatrix in RStudio, the final weight and rank of each subcriterion were extracted. In the third stage, to ensure the validity of the results, the consistency of expert judgments was evaluated through the consistency ratio (CR).

The results of this section, in addition to determining the relative priority of the barriers, provide a clear picture of the structure of their reciprocal influence and indicate which categories of barriers play a root role in the formation of other problems. Such an analysis provides an appropriate basis for formulating effective policies and executive actions for the development of green buildings.

Table 1. Barriers to Green Buildings

Subcriteria	Main criterion
High cost of green building construction	Economic
Low price and abundant availability of fossil fuel resources	Economic
Increase in the final purchase price	Economic
High initial capital requirement	Economic
Lower maintenance cost	Economic
Optimal energy consumption	Economic
Lack of appropriate standards in the building industry	Social
Absence of a modern construction industry in the building sector	Social
Non-specialized implementation and non-standard materials	Social
Slow improvement of transparent construction standards	Social
Slow improvement of contractors' execution quality	Social
Reduction of greenhouse gases and control of global warming	Social
Indoor environmental quality	Social
Lack of strict supervision during implementation	Political
Absence of appropriate regulations in the building sector	Political
Inevitable substitute for fossil fuels	Political
Formulation of national building regulations	Political
Removal of government subsidies and increase in energy prices	Political

To uncover the structure of reciprocal relationships among the macro-level criteria, DEMATEL indices were extracted and reported in Table 2. In addition, to provide a geometric explanation of these relationships, the output values were transferred onto a Cartesian coordinate plane, the result of which is shown in Figure 1.

To identify the internal structure of the relationships among the macro-level criteria of the study, the direct-relation matrix was first formed based on the average opinions of the experts. This matrix was then normalized, and the total-relation matrix $(T)$was calculated using it. Based on the total-relation matrix, four main indices were extracted for each criterion: degree of influence exerted (R), degree of influence received (D), importance and interaction $(R+D)$, and causal role $(R-D)$.

The Rindex indicates the total effects that each criterion exerts on other criteria, whereas the Dindex indicates the extent to which that criterion is affected by other factors. The value of $R + D$indicates the importance and centrality of each criterion in the overall network, while the $R - D$index specifies the type of its role. If the value of $R - D$is positive, the criterion is placed in the group of causal factors; if this value is negative, the criterion is classified in the group of effect factors. Table 2 shows the final results of the DEMATEL analysis for the three main criteria of the study.

Table 2. Final DEMATEL Indices for the Main Criteria of the Study

No.	Macro-level criteria of the study	Total influence exerted $(\boldsymbol{R})$	Total influence received $(\boldsymbol{D})$	Importance and interaction index $(\boldsymbol{R+D})$	Causal role index $(\boldsymbol{R-D})$	Nature of the criterion in the network
1	Political criteria	1.684	0.925	2.609	+0.759	Cause
2	Economic criteria	1.420	1.846	3.266	-0.426	Effect
3	Social criteria	1.045	1.378	2.423	-0.333	Effect

Based on the results of Table 2, the political–legal criterion is the only factor with a positive value for the $R - D$index and is therefore identified as the net cause of the system. This result indicates that policies, laws, standards, and supervisory mechanisms play a fundamental role in shaping and intensifying other barriers. In other words, changes in governance structures can directly affect economic and social conditions.

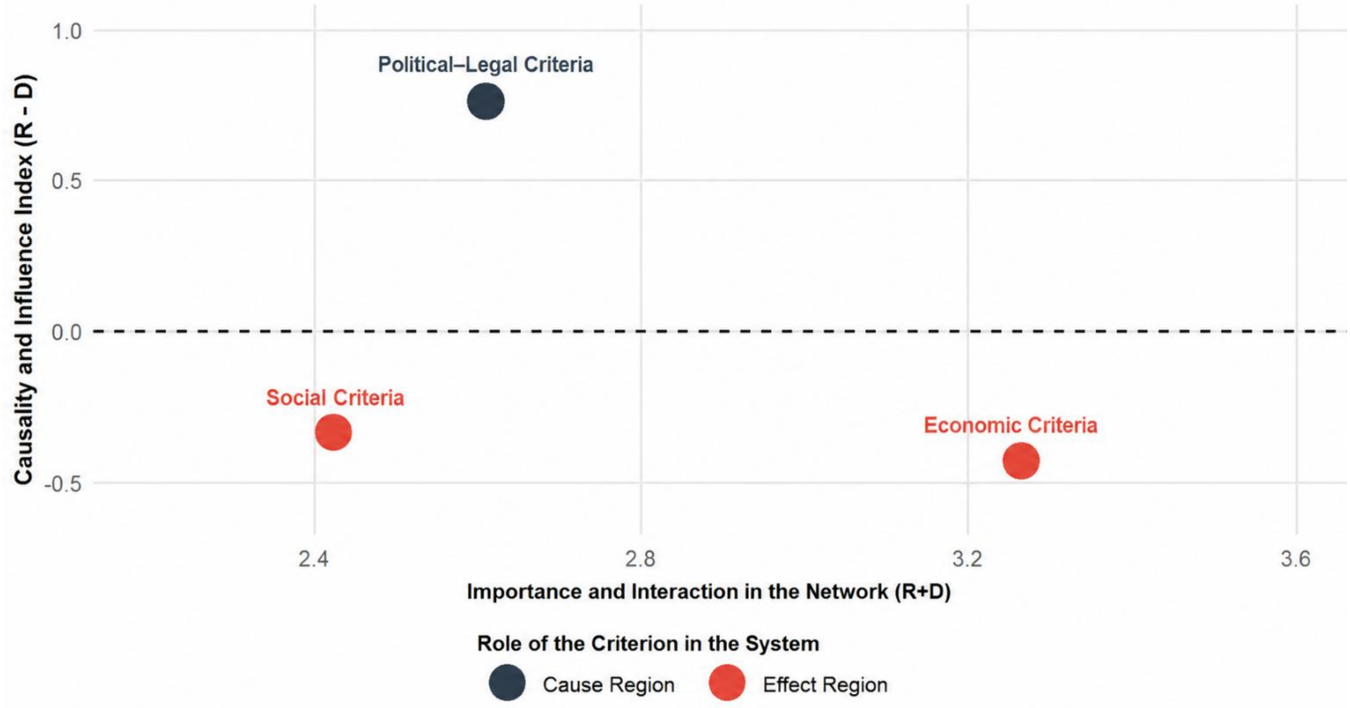

Figure 1. Geometric Map of the Relationships among the Main Criteria

In contrast, although the economic criterion has the highest value of the $R + D$index, it has a negative causal index. This indicates that economic issues, although they have the highest level of interaction and involvement in the overall network, are mainly consequences of conditions created in the political and social domains. Therefore, problems such as high initial costs, high final prices, and low economic efficiency are mostly regarded as outcomes of structural weaknesses in the legal and policymaking system.

The social criterion, with a negative value of the $R - D$index, is also placed in the group of effect factors. This result indicates that weak public awareness, cultural resistance, and non-specialized implementation are largely influenced by governance policies and economic conditions.

As shown in Figure 1, the horizontal dashed line at the zero position determines the boundary separating the relationships. The placement of the political–legal criteria at the highest point of the vertical axis proves that this layer is the only root cause and independent driver in the entire system. In contrast, the economic criteria are positioned at the farthest point on the horizontal axis; this geometric arrangement shows that financial challenges have the highest degree of interaction and involvement in the construction chain, but because they are located in the negative area of the vertical axis, they are entirely effect-oriented in nature, and their intensity depends on the performance of policy variables.

Overall, the results of the DEMATEL analysis show that the most effective strategy for developing green buildings is to focus on reforming legal structures, formulating localized standards, and strengthening supervision and control, because these actions can reduce many economic and social barriers in a chain-like manner.

By injecting the DEMATEL total-relation matrix into the network supermatrix in RStudio, the model reached convergence. The precise priority of the top 10 barriers in the system is reported in Table 3. In addition, to avoid fragmented analyses and to understand the contribution of each upstream dimension across the entire network, the limit weights of all 18 barriers examined in the study are integrated and illustrated in Figure 2.

After determining the causal relationships among the criteria, the total-relation matrix obtained from DEMATEL was used as the structural basis of the Analytic Network Process. At this stage, the unweighted supermatrix was first formed. Then, by applying the cluster weights, the weighted supermatrix was obtained. Finally, by repeatedly raising the weighted supermatrix to successive powers until reaching a stable state, the limit supermatrix was calculated and the final weight of each subcriterion was extracted.

The resulting limit weights indicate the actual relative importance of each barrier by considering the reciprocal relationships as well as the direct and indirect effects among all factors. This feature is the most important advantage of the DANP method over traditional multi-criteria decision-making methods, because the final ranking is not based solely on experts' subjective evaluations but also reflects the network structure of interactions. Table 3 shows the ranking of the top ten barriers in the study.

Table 3. Final Weights and Ranking of the Top Ten Barriers to the Development of Green Buildings: RStudio Output

Rank	Barrier title / subcriterion	Final weight / priority	Upstream criterion
1	Absence of comprehensive and codified standards	0.19306	Political
2	Lack of binding governmental laws and regulations	0.14411	Political
3	Lack of strict supervision over the construction process	0.10016	Political
4	Slow formulation/implementation of energy consumption standards	0.08513	Social
5	Non-specialized implementation and use of traditional materials	0.08406	Social
6	Underdevelopment of the modern construction industry and green technologies	0.06559	Economic
7	Existing deficiencies in national building regulations	0.06366	Political
8	High final building price for consumers	0.06306	Economic
9	Low economic efficiency and low return on energy investment	0.03839	Economic
10	High initial costs of green design and construction	0.03569	Economic

The results of Table 3 show that the most important barrier to the development of green buildings is the absence of comprehensive and codified standards, which alone accounts for more than 19% of the total weight of the system. This result indicates that the absence of a standard and localized framework for defining, evaluating, and rating green buildings is the most fundamental barrier to the development of this approach.

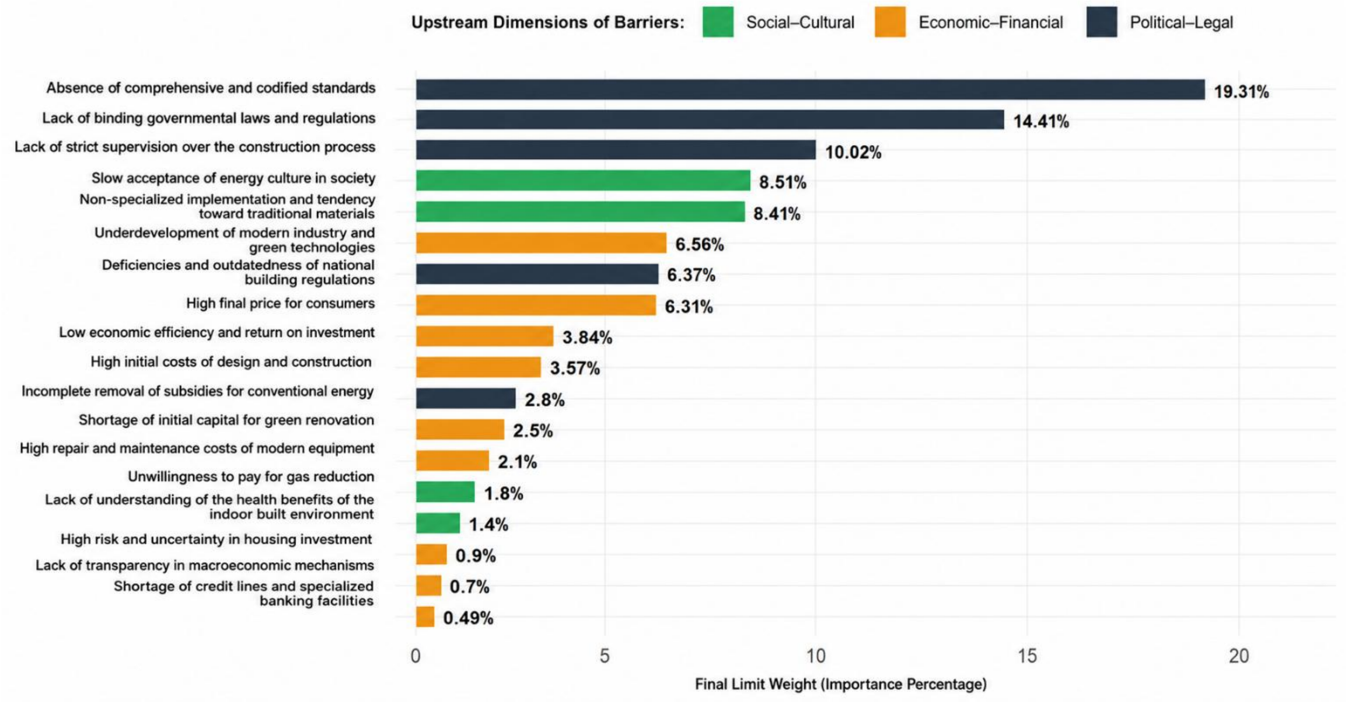

Figure 2. Share and Ranking of Barriers to the Promotion of Green Buildings

The next two barriers, namely the lack of binding laws and regulations and the lack of strict supervision over the construction process, also fall under the political–legal factors. The placement of these three factors in the top ranks indicates that the development of green buildings depends more on the quality of governance, legislation, and supervisory mechanisms than on technical limitations.

Moreover, the presence of two social factors in the fourth and fifth ranks shows that even if legal frameworks are reformed, the success of policies will require improving the specialized knowledge of implementers and increasing social acceptance of energy consumption standards.

In the economic dimension, factors such as the underdevelopment of the modern construction industry, high final price, and low economic returns were placed in the subsequent ranks. This finding confirms that economic problems are largely the result of weaknesses in legal and institutional infrastructures.

An integrated analysis of Table 3 and Figure 2 shows that the main inhibitory force of the system is concentrated in political barriers, which occupy the first to third ranks and account for nearly 44% of the total system weight. These weight peaks confirm that the lack of codified standards and the absence of binding laws are the main barriers in the system. A look at the end of Figure 2, namely barriers ranked 11 to 18, shows that micro-level financial challenges, such as the shortage of banking facilities or the maintenance costs of equipment, despite the initial perception of the market, have the lowest importance weights within the network layers. This finding demonstrates that if policy reform and proper institutional path-setting are carried out, automatic market mechanisms will be activated, and the barriers at the end of the chart will be automatically resolved.

To ensure the validity and rationality of expert judgments, the consistency ratio (CR)was calculated for all pairwise comparison matrices. Based on the criterion proposed by Saaty, if the value of $CR$is less than 0.10, the level of consistency is considered acceptable.

Table 4. Consistency Ratio (CR)of the Pairwise Comparison Matrices of the Study

No.	Pairwise comparison matrix	Random index ($\boldsymbol{RI}$)	Consistency ratio ($\boldsymbol{CR}$)	Consistency status
1	Main criteria: economic, social, and political	0.58	0.0043	Fully consistent / acceptable
2	Subcriteria with respect to the economic criterion	1.51	0.0791	Consistent / acceptable
3	Subcriteria with respect to the social criterion	1.49	0.0684	Consistent / acceptable
4	Subcriteria with respect to the political criterion	1.41	0.0512	Consistent / acceptable

According to the results of Table 4, the consistency ratio of all matrices is below the threshold of 0.10. The lowest inconsistency value belongs to the matrix of the main criteria (0.0043), which indicates the very high coherence of expert responses in determining the relative importance of the three main criteria. Furthermore, despite the relatively large dimensions of some submatrices, the inconsistency values still remain within the acceptable range.

These results indicate that the collected data have an appropriate level of stability and validity and that the final weights extracted from the DANP model are highly reliable. Therefore, the findings of this study can serve as a valid basis for scientific analysis and policy decision-making in the field of green building development.

4. Discussion and Conclusion

The present study aimed to identify, structurally analyze, and prioritize the barriers to the development of green buildings in existing buildings with an emphasis on energy saving using the DEMATEL-based Analytic Network Process. The findings revealed that the political–legal dimension is the only causal and driving criterion in the system, with a positive causal index of (R-D=+0.759). In contrast, the economic and social dimensions were positioned in the effect group, indicating that they are more strongly shaped by upstream institutional, regulatory, and governance-related conditions than by their own independent force. This result demonstrates that the development of green buildings in existing buildings is primarily constrained by deficiencies in policy architecture, regulatory enforcement, building standards, and supervisory mechanisms. Therefore, although economic issues such as high initial costs, low return on investment, and high final prices are visible barriers in the market, the structural analysis suggests that these challenges are largely consequences of weak political–legal frameworks. This finding is consistent with studies emphasizing that sustainable building transformation depends not only on technological readiness but also on governance capacity, regulatory clarity, and institutional coordination [1, 7, 13].

The identification of the political–legal dimension as the root cause aligns with the argument that green-building development requires mandatory standards, enforceable regulations, coherent policy instruments, and effective monitoring systems. In many developing and emerging contexts, green construction remains voluntary or weakly regulated, which reduces the motivation of developers, contractors, and consumers to adopt energy-efficient practices. The findings of this study show that when political–legal systems fail to define clear performance requirements, market actors tend to prioritize short-term cost minimization over long-term energy efficiency. This result is supported by research on policy and legal frameworks for urban green infrastructure, which shows that environmental goals cannot be achieved without institutional enforcement and implementation capacity [13]. Similarly, studies on green building labels indicate that the absence of robust certification, monitoring, and regulatory support weakens adoption, even when technical solutions are available [7]. Therefore, the present findings confirm that legal and regulatory reform should be viewed as the primary intervention point for accelerating green-building development.

The DANP results further showed that the absence of comprehensive and codified standards was the most important barrier, with a final weight of 19.31%. This finding is highly meaningful because standards provide the operational language through which green buildings are defined, measured, evaluated, certified, and monitored. Without localized and comprehensive standards, stakeholders face ambiguity regarding design requirements, material selection, energy performance, indoor environmental quality, and construction supervision. This result corresponds with previous research emphasizing the centrality of sustainability assessment systems and green building rating frameworks in guiding the transition toward greener urban environments [1, 3]. It is also consistent with studies showing that green building rating systems must incorporate energy, waste management, materials, circular economy principles, and social sustainability indicators to become effective decision-making tools [9-11]. Accordingly, the lack of codified and context-sensitive standards can create uncertainty across the entire green construction chain and intensify both economic and social barriers.

The second-ranked barrier was the lack of binding governmental laws and regulations, with a weight of 14.41%. This result indicates that voluntary guidelines alone are insufficient for mainstreaming green-building practices in the existing building stock. When green-building adoption depends only on individual willingness or market preference, implementation remains selective and inconsistent. Binding laws are particularly necessary in the renovation of existing buildings, where owners and investors may avoid energy-saving interventions unless clear legal obligations or strong incentives are in place. This finding aligns with research showing that policy instruments and institutional mechanisms are essential for transforming sustainability objectives into practical building-sector outcomes [13, 23]. It also supports studies that conceptualize green buildings as part of broader urban sustainability strategies rather than isolated construction projects [20, 24]. Therefore, the development of green buildings requires legal mandates that connect building codes, energy standards, urban planning, financial incentives, and environmental governance.

The third-ranked barrier was the lack of strict supervision over the construction process, with a weight of 10.02%. This result shows that even when standards and regulations exist, their effectiveness depends on inspection, enforcement, and accountability mechanisms. Weak supervision allows deviations from approved designs, the use of non-standard materials, poor workmanship, and superficial compliance with sustainability requirements. This finding is consistent with studies emphasizing that sustainable performance depends on the alignment of design, implementation, supply-chain coordination, and operational control [14, 15]. In green construction, supervision is not merely administrative; it is a quality-assurance mechanism that determines whether energy-efficient designs are translated into actual building performance. Research on environmentally compatible materials and green-building performance also highlights that material quality, execution accuracy, and technical compliance are central to the real-world effectiveness of green construction [12]. Therefore, the high rank of supervision-related barriers confirms that governance must extend beyond rule formulation to practical enforcement during design, construction, renovation, and operation.

The placement of social barriers in the fourth and fifth ranks also provides important insight. The slow acceptance of energy culture in society accounted for 8.51% of the total weight, while non-specialized implementation and tendency toward traditional materials accounted for 8.41%. These findings show that green-building development is not only a regulatory or financial matter but also a cultural and professional transformation process. The slow acceptance of energy-saving culture may reduce demand for green buildings, weaken willingness to pay for long-term energy benefits, and limit user cooperation in building operation and maintenance. This finding is consistent with studies indicating that social sustainability, user well-being, and public acceptance are integral components of green-building success [8, 9]. Moreover, the problem of non-specialized implementation aligns with research showing that practitioners' understanding of sustainability is often incomplete or inconsistent, which can lead to weak execution and limited performance outcomes [8].

The importance of social and professional capacity is further supported by studies on green-building education. Project-based learning, virtual reality-aided education, and professional training can strengthen the practical competencies required for sustainable design and construction [16]. Similarly, broader research on capacity building and organizational resilience emphasizes the importance of integrating standards, risk awareness, and continuity planning into professional and educational systems [17]. Even evidence from educational and behavioral intervention research suggests that early and structured learning environments can shape long-term social behaviors and institutional norms [18]. In the context of the present study, these findings imply that social barriers such as weak energy culture and non-specialized implementation cannot be solved only by regulations; they require sustained education, professional certification, technical training, and public awareness campaigns.

The economic barriers in this study, although not identified as root causes, still occupied important positions in the final ranking. The underdevelopment of modern construction industry and green technologies ranked sixth, followed by high final building price for consumers, low economic efficiency and return on investment, and high initial costs of green design and construction. These findings suggest that economic barriers remain highly visible and practically significant, but they are embedded within broader institutional and technological systems. This result is consistent with studies showing that green-building technologies, renewable energy systems, building-integrated photovoltaic/thermal systems, and AI-powered digital twins can improve energy performance, but their adoption depends on cost structures, technical readiness, investment capacity, and policy support [2, 4, 5]. In other words, technology can reduce energy consumption, but weak markets and insufficient policy support can prevent its diffusion.

The finding that modern industry and green technologies remain underdeveloped also aligns with patent-based and technology-prioritization studies, which show that green building energy innovations are expanding but require structured evaluation and adoption mechanisms [19]. Similarly, optimization-based research on thermal comfort and energy-related design indicates that computational methods can improve environmental performance, but successful implementation requires integration with local design traditions, occupant needs, and construction capacities [6]. These studies support the present finding that economic and technological barriers are inseparable from institutional and professional systems. Therefore, a lack of modern construction technologies should not be interpreted only as a market failure; it also reflects weaknesses in regulation, education, investment incentives, supply chains, and innovation governance.

The relatively lower rank of micro-financial barriers, such as shortage of credit lines, uncertainty in housing investment, and maintenance costs, is another important finding. This result does not mean that financial support is unimportant. Rather, it indicates that financial barriers are less fundamental than the upstream political–legal and standardization barriers that shape market confidence. When standards are unclear and regulations are weak, investors face higher uncertainty, consumers may distrust green-building claims, and financial institutions may hesitate to design specialized lending products. This interpretation is supported by research on green supply chain resilience, which shows that risks and capabilities are interconnected and that structural weaknesses can amplify operational and financial barriers [15]. It is also compatible with studies on green supply chain management and sustainable performance, which show that organizational and inter-organizational coordination is required to transform sustainability intentions into measurable outcomes [14].

From a management perspective, the findings show that green-building development should be understood as a strategic transformation of the construction ecosystem. Organizations involved in green construction must develop green intellectual capital, innovation orientation, employee engagement, and sustainability-based decision-making routines. Research on green innovation strategic orientation demonstrates that sustainability-related knowledge and innovation capabilities can become sources of competitive advantage [21]. Similarly, studies linking green marketing and green human resource management show that workforce engagement and internal sustainability culture can strengthen sustainable brand value and organizational performance [22]. These insights support the present study's emphasis on the interaction between institutional, social, and economic factors. Green buildings cannot be scaled through technology alone; they require managerial capabilities, trained human resources, credible standards, and organizational commitment.

The results also highlight the importance of integrating green buildings with broader environmental and urban development policies. Building-integrated greenery systems, urban greenery, and green architecture contribute not only to energy efficiency but also to thermal comfort, public health, climate adaptation, and urban livability [3, 20]. In tourism and heritage contexts, green architecture can also support sustainable development while preserving local identity and cultural continuity [24]. These perspectives suggest that green building development in existing buildings should not be treated as a narrow technical retrofit agenda. Instead, it should be integrated into urban renewal, environmental planning, public health, energy policy, and sustainable economic development. The prioritization pattern obtained in this study supports this systemic view, because the highest-weighted barriers are not isolated project-level issues but institutional and social conditions that influence the entire construction ecosystem.

Overall, the findings confirm that the most effective pathway for promoting green buildings in existing buildings is to intervene first at the level of political–legal structures, especially through the development of comprehensive standards, binding regulations, and strict supervision mechanisms. Once these root barriers are addressed, social and economic barriers can be more effectively reduced. The results support a causal logic in which clear standards reduce ambiguity, binding laws increase compliance, supervision improves implementation quality, professional training strengthens technical execution, and financial mechanisms become more effective in a more predictable market environment. Therefore, the present study contributes to the literature by showing that the barriers to green-building development are not merely a ranked list of independent problems but a networked system in which political–legal factors act as the dominant drivers of economic and social constraints.

The present study has several limitations. First, the data were collected from a purposive sample of experts, and although this approach is appropriate for decision-making models such as DEMATEL and DANP, the findings may reflect the judgments of specialists within a specific institutional and market context. Second, the study focused on existing buildings and energy-saving barriers; therefore, the findings may not be fully generalizable to new construction projects or to green-building goals beyond energy conservation. Third, the model prioritized barriers based on expert perceptions and network relationships, but it did not directly measure the actual cost savings, emission reductions, or behavioral changes that may result from removing each barrier. Fourth, the classification of barriers into economic, social, and political–legal dimensions provided analytical clarity, but some barriers may overlap conceptually across dimensions in real-world construction systems.

Future research should expand the model by applying it in different cities, regions, and building types to compare whether the causal structure of barriers changes across institutional, climatic, and economic contexts. Future studies can also combine expert-based DANP models with empirical performance data from actual green retrofit projects to examine whether the prioritized barriers correspond to measurable energy-saving outcomes. Comparative research between developing and developed countries would help clarify how legal maturity, financial systems, public awareness, and construction technologies influence the ranking of barriers. In addition, future research may integrate fuzzy methods, scenario analysis, system dynamics, or structural equation modeling to examine uncertainty, feedback loops, and longitudinal changes in green-building adoption. It is also recommended that future studies investigate the perceptions of residents, building owners, contractors, investors, and policymakers separately to identify possible differences among stakeholder groups.

In practice, the findings suggest that policymakers should prioritize the formulation of comprehensive and localized green-building standards, the enactment of binding regulations, and the strengthening of supervision mechanisms before focusing solely on financial subsidies. Municipalities and regulatory agencies should establish transparent criteria for green-building evaluation, create inspection systems for construction and renovation processes, and connect building permits to energy-efficiency requirements. At the same time, professional training programs should be developed for engineers, contractors, inspectors, and construction workers to reduce non-specialized implementation and dependence on traditional materials. Financial incentives, credit facilities, and tax benefits should be designed after standards and enforcement mechanisms are clarified so that market actors can invest with greater certainty. Public awareness programs should also communicate the long-term economic, environmental, and health benefits of green buildings to increase social acceptance and demand.

Authors' Contributions

Authors equally contributed to this article.

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Declaration of Interest

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Ethical Considerations

All procedures performed in this study were under the ethical standards.

References

[1] L. W. Park, K. Cho, and M.-i. Choi, "A Sustainability Evaluation of Buildings: A Review on Sustainability Factors to Move Towards a Greener City Environment," *Buildings,* vol. 14, no. 2, p. 446, 2024, doi: 10.3390/buildings14020446.

[2] F. Bai and J. Xing, "Application of Renewable Energy in Green Buildings and Energy Consumption Optimization," *EAI Endorsed Transactions on Energy Web,* 2024, doi: 10.4108/ew.5830.

[3] M. Reyes, G. Pérez, and J. Coma, "The Role of Building-Integrated Greenery Systems in Building Sustainability Rating Systems," *Land,* vol. 13, no. 8, p. 1114, 2024, doi: 10.3390/land13081114.

[4] C. Şirin, J. Goggins, and M. Hajdukiewicz, "A review on building-integrated photovoltaic/thermal systems for green buildings," *Applied Thermal Engineering,* vol. 229, p. 120607, 2023, doi: 10.1016/j.applthermaleng.2023.120607.

[5] S. E. Bibri, "AI and AI-powered Digital Twins for Smart, Green, and Zero-Energy Buildings: A Systematic Review of Leading-Edge Solutions for Advancing Environmental Sustainability Goals," *Environmental Science and Ecotechnology,* vol. 28, p. 100628, 2025, doi: 10.1016/j.ese.2025.100628.

[6] P. Lotfinejad, A. Tarkashvand, and H. Sanaieian, "A computational approach for integration of greenhouse and “Shanashir” to enhance thermal comfort of occupants, utilizing NSGA-II algorithm," (in English), *BUILDING AND ENVIRONMENT,* vol. 273, 2025, doi: 10.1016/j.buildenv.2025.112717.

[7] W. B. Santana, L. M. Pereira, F. G. M. Freires, and L. M. F. Maués, "Analysis of the barriers to the adoption of green buildings labels in Brazil by the validated Interpretative Structural Modeling (VISM) technique," *Journal of Cleaner Production,* vol. 137642, 2023, doi: 10.1016/j.jclepro.2023.137642.

[8] C. T. M. Kowet and A. Ozumba, "Green Building Practitioners’ Understanding of the Concept of Sustainability: South African Perspective," *Iop Conference Series Earth and Environmental Science,* vol. 1101, no. 6, p. 062027, 2022, doi: 10.1088/1755-1315/1101/6/062027.

[9] M. L. Tseng, S. X. Li, C. W. R. Lin, and A. S. Chiu, "Validating green building social sustainability indicators in China using the fuzzy delphi method," *Journal of Industrial and Production Engineering,* vol. 40, no. 1, pp. 35-53, 2023, doi: 10.1080/21681015.2022.2070934.

[10] A. Jorge-Ortiz, M. Braulio-Gonzalo, and M. D. Bovea, "Exploring how waste management is being approached in green building rating systems: A case study," *Waste Management & Research,* vol. 41, no. 6, pp. 1121-1133, 2023. [Online]. Available: https://journals.sagepub.com/doi/abs/10.1177/0734242X221143952.

[11] N. Karami and S. Heydari, "Evaluation of Green Building Indicators within the Circular Economy Framework to Reduce Environmental Impacts," (in English), *Applied Research in Civil Engineering,* vol. 6, no. 1, pp. 105-120, 2022.

[12] M. Mokhber Takmeh Dash, F. Syadati, S. Safari, M. R. Podratchi Asl, M. Yari, and N. Zareh Aqdaraq, "Analyzing the performance of green buildings in the construction industry and environmentally compatible materials," 2023. [Online]. Available: https://civilica.com/doc/1944888/.

[13] K. Keita and S. Kourouma, "Assessment of Policy and Legal Frameworks of Urban Green Infrastructure Development: Republic of Guinea," *Buildings,* vol. 13, no. 8, p. 1945, 2023, doi: 10.3390/buildings13081945.

[14] M. El Mokadem and M. Khalaf, "Building sustainable performance through green supply chain management," *International Journal of Productivity and Performance Management,* vol. 74, no. 1, pp. 203-223, 2025, doi: 10.1108/IJPPM-02-2024-0113.

[15] Y. Jiang, Y. Zhang, A. J. Yeganeh, and D. Zhao, "Resilience of Green Building Supply Chain: Capabilities, Risks and Influence Mechanism," *Journal of Green Building,* vol. 19, no. 3, pp. 41-69, 2024, doi: 10.3992/jgb.19.3.41.

[16] C. Hou, J. H. Lai, and H. Wu, "Project-Based Learning and Pedagogies for Virtual Reality-Aided Green Building Education: Case Study on a University Course," *International Journal of Sustainability in Higher Education,* vol. 24, no. 6, pp. 1308-1327, 2023, doi: 10.1108/ijshe-06-2022-0197.

[17] L. Greenwood, J. Schneider, D. Hess, and Y. Abraham, "Capacity Building for Organizational Resilience: Integrating Standards on Risk, Disruption and Business Continuity in the Curriculum," in *Proceedings of IConSES 2022--International Conference on Social and Education Sciences*, 2022, pp. 157-163. [Online]. Available: https://www.nist.gov/document/greenwood-et-al-capacity-building-org-resilience.

[18] K. M. McGoey, A. Aberson, B. Green, and S. Bandi Stewart, "Building foundations for friendship: Preventing bullying behavior in preschool," *Perspectives on Early Childhood Psychology and Education,* vol. 7, no. 1, p. 9, 2023, doi: 10.58948/2834-8257.1038.

[19] O. Alharasees, U. Kale, J. Rohács, D. Rohács, M. A. Éva, and A. Boros, "Green Building Energy: Patents Analysis and Analytical Hierarchy Process Evaluation," *Heliyon,* vol. 10, no. 8, p. e29442, 2024, doi: 10.1016/j.heliyon.2024.e29442.

[20] R. Aslanoğlu *et al.*, "Ten questions concerning the role of urban greenery in shaping the future of urban areas," *Building and Environment,* vol. 267, p. 112154, 2025, doi: 10.1016/j.buildenv.2024.112154.

[21] V. T. Dang and J. Wang, "Building competitive advantage for hospitality companies: The roles of green innovation strategic orientation and green intellectual capital," *International Journal of Hospitality Management,* vol. 102, p. 103161, 2022, doi: 10.1016/j.ijhm.2022.103161.

[22] A. Shah, S. A. Siddiqui, S. Ilyas, A. Usman, and A. Mahmood, "Green Marketing Meets Green HRM: Building a Sustainable Brand Through Workforce Engagement," *Ijss,* vol. 4, no. 3, pp. 200-214, 2025, doi: 10.63544/ijss.v4i3.158.

[23] Salarian, Abbasi, and Rangriz, "Proposing an Institutional Capacity-Building Model for Citizen Participation Policy in the Environmental Sector: A Green Human Resource Management Approach," *Human Resource Excellence,* vol. 2, no. 5, 2024. [Online]. Available: https://ensani.ir/fa/article/author/277616.

[24] S. Yuliani and W. Setyaningsih, "Green Architecture in Tourism Sustainable Development: A Case Study at Laweyan, Indonesia," *Journal of Asian Architecture and Building Engineering*, vol. 24, no. 1, pp. 27-38, 2023.