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Saeed Kamranfar [1,2], Yousef Azimi [2], Mohammad Gheibi [3], Amir M. Fathollahi-Fard [4,5,*] and Mostafa Hajiaghaei-Keshteli [1]

[1] Tecnologico de Monterrey, Escuela de Ingeniería y Ciencias, Puebla 4500, Mexico
[2] Environment and Sustainable Development (RCESD), Department of Environment, Tehran 15367, Iran
[3] Department of Civil Engineering, Ferdowsi University of Mashhad, Mashhad 456732, Iran
[4] Department of Electrical Engineering, École de Technologie Supérieure, University of Québec, 1100 Notre-Dame St W, Montreal, QC H3C3P8, Canada
[5] Peter B. Gustavson School of Business, University of Victoria, P.O. Box 1700, Victoria, BC V8P5C2, Canada
* Correspondence: amirmohammad.fathollahifard.1@ens.etsmtl.ca

Abstract: There is a great deal of interest in analyzing construction development barriers to identify and rank them based on sustainability criteria and have less environmental pollution. Due to the importance of construction projects in developing countries such as Iran, this study implements a green construction development paradigm to identify and rank barriers for a case study in Tehran, Iran. The main novelty of this paper is the development of a new decision-making method using the DEMATEL and Delphi techniques and the ANP. In this regard, first of all, data collection is performed through a literature review and survey studies using questionnaires, interviews, and observations. The applied method for experts' agreement was integrated through brainstorming and the classical Delphi method. By analyzing different economic, environmental, cultural, and social criteria using a hybrid decision-making framework, the results show that the main economic barrier with a weight of 0.2607 is ranked first, while the main feature of economic assessment is connected to the risk of investment. The cultural and social barriers, with a weight of 0.2258, ranked second, and the managerial barrier, with a weight of 0.2052, ranked third. In the social and managerial aspects, the main barriers were related to looking at green construction as luxurious and the uncertainty of green construction performance due to the climate and texture of the local area, respectively. According to the findings and results, the proposed barriers and sub-barriers in this study can be used to develop and create planning at the strategic level for the development of green construction for our case study in Tehran, Iran. With a concentration on the outcomes of the present research, the sustainable green building framework can be implemented by the application of a prioritized knowledge management concept.

Keywords: green construction development barriers; identification of barriers; ranking of barriers; DEMATEL; ANP

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1. Introduction

Over-consumption of natural resources has been regarded as the foremost peril toward global sustainability [1]. UN programs have defined global sustainable development for more than two decades. Most developed and developing countries have adopted these programs to achieve the 2030 Agenda, which is currently shaped by 17 Sustainable Development Goals (SDGs) [2]. Since the population in urban areas and in big cities is increasing, resources should be used efficiently and quickly. It is estimated that by 2050, Earth's population displacement will lead to urban areas and the formation of vast cities. Thus, a smart and sustainable infrastructure is needed to properly manage the needs of citizens and provide advanced services [3]. The increasing expansion of the industry has led to the invasion and occupation of nature and the destruction of natural facilities and resources, natural energy mines, and forests. Cities began with the use of traditional ways of living alongside nature, but with the industrialization of urban societies, human beings have unknowingly expanded and transformed their environment to the point where it is now at the stage where we are now. This is the result of negligence and non-exchange that has been performed by humans in this field from the past till now [4]. Therefore, issues such as environmental compatibility and sustainability of human products and activities are among the issues which are not only important for governments but also for academics [5]. On the other hand, creating the necessary conditions for a desirable life has always been the goal of human beings, and this issue has caused more than half of the world's population to live in urban areas, among which more than 80% of this population is in developing countries [6].

The theory of population growth and economic development has led to the expansion of construction activities in these areas [7]. The purpose of designing these sustainable buildings is to reduce damage to the environment in terms of energy and utilization of natural resources, which in modern architecture is a function of a function. In climate architecture, form is a function of price [8–10]. Therefore, climate architecture has been mainly referred to as sustainable architecture since the 1990s, and according to the British Encyclopedia, increasing environmental awareness dates back to the 1960s as a socially active youth movement questioned by many extremists in tent structures and geodesic domes to respect Native American culture and negatively impact the living environment the least [7]. Living in the early 20th century, famous architect Frank Lloyd Wright promoted naturalistic architecture, where renewable and clean energy is used to supply energy to a green building [9–12]. It is a phenomenon that is compatible with the green environment and the sense of land resources throughout the life of the building [8]. From the construction of the building to the design of the building, its maintenance, repair, and destruction are in line with the environment [13–17]. Addressing the present issue is important in that the rapid population growth and lack of attention to nature lead to excessive consumption of fossil fuels and, as a result, irreparable damage to the environment [16–20]. This issue was so important that in the architecture of the new approach, green architecture has been created [9].

According to Figure 1, it is clear that in developed countries such as Germany, the rate of investment in green buildings increased more than that in non-certified buildings from 2008 to 2021. Therefore, this trend will occur in developing countries with delays in the extension of green buildings. Likewise, research on green construction development barriers is assumed to be a hot issue for the execution of green buildings [21–25].

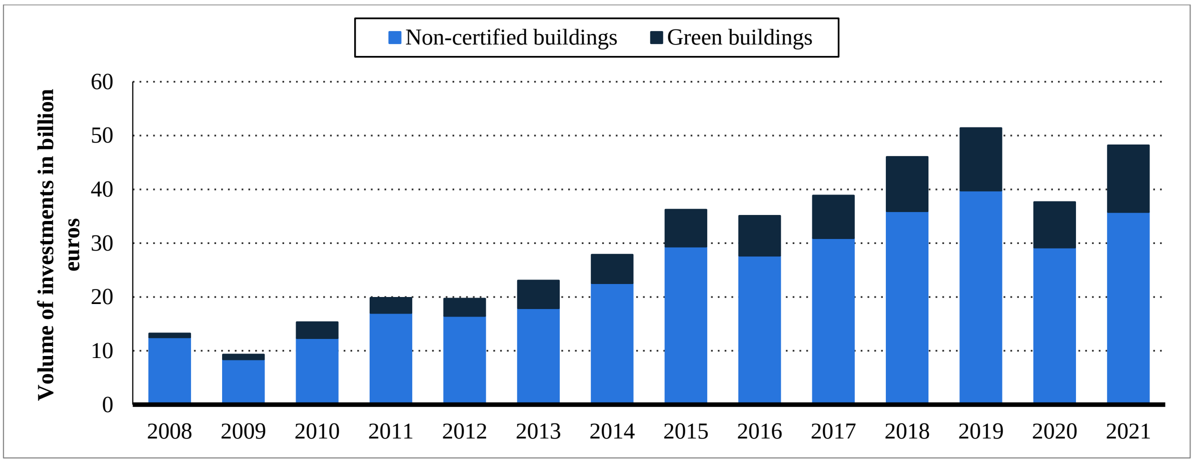

Figure 1. Investments in green and non-certified buildings in Germany from 2008 to 2021. Source: BNP Paribas Real Estate; ID 1294695.

1.1. Relevant Studies on Green Construction Development Barriers

To study the literature review, we focused on the relevant publications from 2015 to now. For example, Yang and Yang [17] classified the barriers to sustainable housing in Australia into technical and design factors, economic factors, sociocultural factors, and institutional factors regarding Spangenberg's sustainability charter. This study identified economic factors as the most important, followed by institutional factors. This confirms that the housing industry in Australia prioritizes economic interests over other softer values, and there is considerable concern over an ineffective policy mechanism [17]. Wilson and Tagaza [19] examined some drivers and barriers to the development of green commercial buildings in Australia based on a series of interviews with key stakeholders in the construction industry concerning business drivers for green construction along with some barriers, including perceived financial risks such as split incentives, initial capital costs, and lack of life cycle costs, as well as perceived construction risks, including project delivery mechanisms, material procurement, site practices, and the current regulatory environment [19]. Later, in 2016, Deng et al. [20] conducted a research project aimed at identifying the key barriers to green building development in Ningbo, China and suggesting policy improvements to the local government based on a research project funded by the World Bank's GEF program. Questionnaires and interviews with relevant stakeholders were conducted in the studied city. Based on the surveys and interviews, the key obstacles to the development of green buildings in the studied city were identified, and recommendations for policy changes were proposed [20].

In 2017, Abraham and Gandimeda [17] studied, investigated, and ranked the barriers to the adoption of green buildings in their country using the hierarchical analysis method. The study identified 20 specific barriers that were classified into four categories: (1) policy and market barriers (PMBs), (2) financial and economic barriers (FEBs), (3) information, promotion, and training barriers (IPEs), and (4) managerial and organizational barriers (MOBs). Seven groups—stakeholder-builders, prospective residents, architects, engineers, project managers, contractors, and government representatives—participated in ranking and prioritizing the barriers. The results of the local and global weight calculations showed that the IPEs ranked the highest and the PMBs ranked second, while the FEBs and MOBs lagged far behind with less global weight. Among the seven main specific barriers, lack of expertise in life cycle costs, lack of awareness of the benefits of green buildings, lack of labeling, and lack of infrastructure and training are barriers that belong to the category of IPEs. Weak implementation of construction regulations, lack of incentives, and high capital costs also found space among the seven main obstacles with high weights [15]. In another study in 2017, Nguyen et al. [16] identified 41 barriers to GBs in Vietnam from the literature and validated them by surveying 215 construction professionals and government officials. Exploratory factor analysis was used for principal component analysis to reveal that while legal and institutional barriers are widely perceived as the most challenging barriers, social and cognitive barriers generally represent the main barriers involved [16]. In this year, Chan et al. [14] identified 15 obstacles in a comprehensive piece of research on the issue of basic obstacles in the adoption of green building technologies in developing countries and the study of Ghana, and after that, by distributing a questionnaire among 46 construction experts, they identified 20 important factors and reduced them substantially. The first three positions among these 20 basic obstacles were placed in the order of (1) the high cost of green buildings, (2) the lack of incentives from the government, and (3) the lack of financial plans and programs, such as loan allocation. The analysis of the results showed that despite the distance of many basic obstacles in preventing the development of green construction in developing countries such as Ghana and with developed countries such as America, Canada, and Australia, one important and effective obstacle was the same between the two: the cost of green building construction, which is one of the most basic obstacles in all countries. The study also found that the most important of the five main groups of barriers were government-related, highlighting the role of government in promoting GBT adoption in Ghana. By analyzing the barriers to the adoption of GBTs in the context of a developing country, this study adds to the green building literature that can help policymakers take appropriate measures to reduce barriers and thus promote the adoption of GBTs [14].

Later, in 2018, Shen et al., [18] revealed the green technical capabilities and barriers of GBs in Thailand from the perspectives of consultants, architects, and engineers using a questionnaire and case study. Obstacles to GBs mainly stem from financial pressure, technical limitations, and insufficient promotion. "Lack of motivation from owners" and "high initial cost" were ranked as the two main barriers to green buildings. Overall, the results show that market demand and technological progress are the main drivers for the GB industry, and government, economic conditions, education, and corporate social responsibility are other drivers for the industry [18].

In another paper in 2018, a residential building was used to evaluate and rank the greenness of the building in the city of Bandung in the country of Indonesia by Firdaus et al. [13]. Although the main goal of this research was to evaluate the greenness of a specific case, it also identified important inhibiting factors in the construction industry. A lack of customer demand, investment costs, lack of awareness, and site conditions are considered important factors in the development process of green construction in Indonesia, and in the end, suggestions to solve these issues were introduced by the authors. The problem of customer demand can be solved by creating relevant policies, a formal evaluation system, and incentives. In the case of contractors, they should be aware of the commercial benefits of the investment, and to increase the contractor's awareness, more socialization about several aspects of green buildings is needed. The obstacle of the site condition should be considered in the development of the green building evaluation model [13]. Darko et al. [22] described the development status of green buildings in cold regions and showed its importance in addition to analyzing the problems facing the development of green buildings in cold regions and offered suggestions [22]. In 2019, Wu et al. [12] investigated and identified possible obstacles through a systematic and semi-structured study through interviews with experienced industry executives, reached 24 obstacles to the development of green construction in China, and collected information and data through a questionnaire. Finally, by describing and analyzing the inferential statistics, they ranked and described the influence of the most important factors. The output of the results showed that the lack of policy and industry guidance, the immature eco-friendly market, and the lack of environmental awareness were the most important reasons for the growth and development of green construction in China [12].

In 2020, Karji et al. [10] addressed the key obstacles to promoting sustainable development in the construction industry of America, which is a developed country and a leader in the green construction industry. The 12 known key barriers were divided into 4 main barrier categories. The most important main obstacle is pre-construction restrictions, such as design restrictions, suppliers' preferences, and lack of trained personnel, and then management restrictions, including insufficient committees for high-level management, legal restrictions such as political effects and financial and investment restrictions, and a lack of plans. Activity was one of the main causes of financial and planning restrictions [10]. In 2020, Yadgari Dehkordi et al. [11] evaluated the sustainability indicators in green construction with a multi-criteria decision-making fuzzy approach. This study, considering the green building index, which is the most practical sustainability rating tool in the country, identified and ranked the sustainability indicators for evaluating green building production in Malaysia. The data were collected from a panel of experts and found using a fuzzy-based decision-making trial and evaluation laboratory (DEMATEL) method to show the level of importance and relationships between the sustainability indicators in green building products. The results showed that "energy efficiency" and the quality of the indoor environment are the most important, while water efficiency and innovation are the least important criteria in the evaluation of green building production in Malaysia [11].

In 2021, Nasereddin and Price [21] conducted a study to address the capital cost barriers for sustainable construction (SC). Concepts and processes related to sustainable construction, value management (VM), and total quality management (TQM) were integrated into a new approach to reduce the total life cost based on a framework and three supporting processes aimed at improving project management understanding and decision-making. Data collection was a triangulated approach in three phases: focus groups (23 participants), the Delphi method (8 participants and 2 rounds), and a validation questionnaire (20 respondents). This research showed that the capital cost of a LEED silver-certified building in Jordan was about 20–25% more than the capital cost of traditional buildings. However, the increased capital cost that customers in Jordan considered acceptable for LEED was 5 to 10 percent, regardless of the savings in operating costs [21]. More recently, in 2022, Joshua [23] found that inadequate training, unfamiliarity with green technologies, and higher initial costs of green building practices and materials are key challenges that hinder the implementation of sustainable construction processes by project management teams. The study also demonstrated significant mitigation strategies such as educating stakeholders about the future benefits of green buildings, engaging staff with green building backgrounds, and setting sustainable priorities and goals early in the feasibility study. The value of this research is helping project management teams understand these challenges and strategies to turn them into opportunities for the construction industry [23]. Hence, green construction development barriers and multi-criterion decision-making (MCDM) were converted into hot issues [24–30], and some of the main research in this field is summarized in Table 1 [31–45].

Table 1. Recent research in the aforementioned field.

Researchers	Tools	Description	Reference
Abadi and Moore (2022)	MCDM and lifecycle circularity assessments	Circular economy assessment in construction	[46]
Ramu et al. (2022)	Analysis network process (ANP)	Implementation of sustainable supply chain in providing construction processes	[47]
Erol et al. (2022)	Multi-criteria decision making, hesitant fuzzy linguistic term sets, and quality function deployment	Evaluation of barriers' roles in circular economy implementation through blockchain concept	[48]
Luo et al. (2022)	Scientometrics methods	Review assessment and research gaps	[49]
Mojumder et al. (2022)	Fuzzy best-worst method (FBWM)	Assessment of barriers in local green construction mitigation	[50]

For trying to design a green building using clean energy and natural spaces, this paper proposes new solutions while reducing environmental problems. As is known to everyone in the world, energy is the crisis of the 21st century. Fossil fuels are the richest oil resources, and world gas will be the richest by the end of the next 30 years. Nuclear energy is considered more dangerous and destructive than as a source of energy production and is being planted day by day in a number of world nuclear power plants in Iran. As such, investigation 19 of the National Building Regulations on Energy Saving has been carried out, and a look at the per capita energy consumption in Iran compared to the global average doubled the importance of using green buildings. In Iran, for example, the per capita annual electricity consumption is three times that of the world. The use of green buildings to develop an approach means eight times more adaptability and more human activities with the environment, reducing the destructive effects on it and the role of current buildings in the production of industrial pollutants, and harm to human health is discussed in the construction of environmentally friendly buildings and energy.

1.2. Network Analysis and Research Gaps

For exact determination of the research gap and trend, with the application of VOSviewer software (https://www.vosviewer.com/, accessed on 1 August 2022) in the Scopus databank, the keyword occurrence of green construction development barriers is demonstrated in Figure 2a. In consideration of the declared scheme, it can be found that the concentration of green construction barriers is assumed as a novel idea due to implementation of sustainable building processes because the concept was not strongly considered by other researchers. Likewise, it can be found that new survey methods were developed in this field, and this research also involves combined analytical and survey techniques. In the following, the most active countries in the mentioned field (green construction barriers) are illustrated in Figure 2b. Based on Figure 2a, China, Australia, and Malaysia are the main recent contributors to this research area.

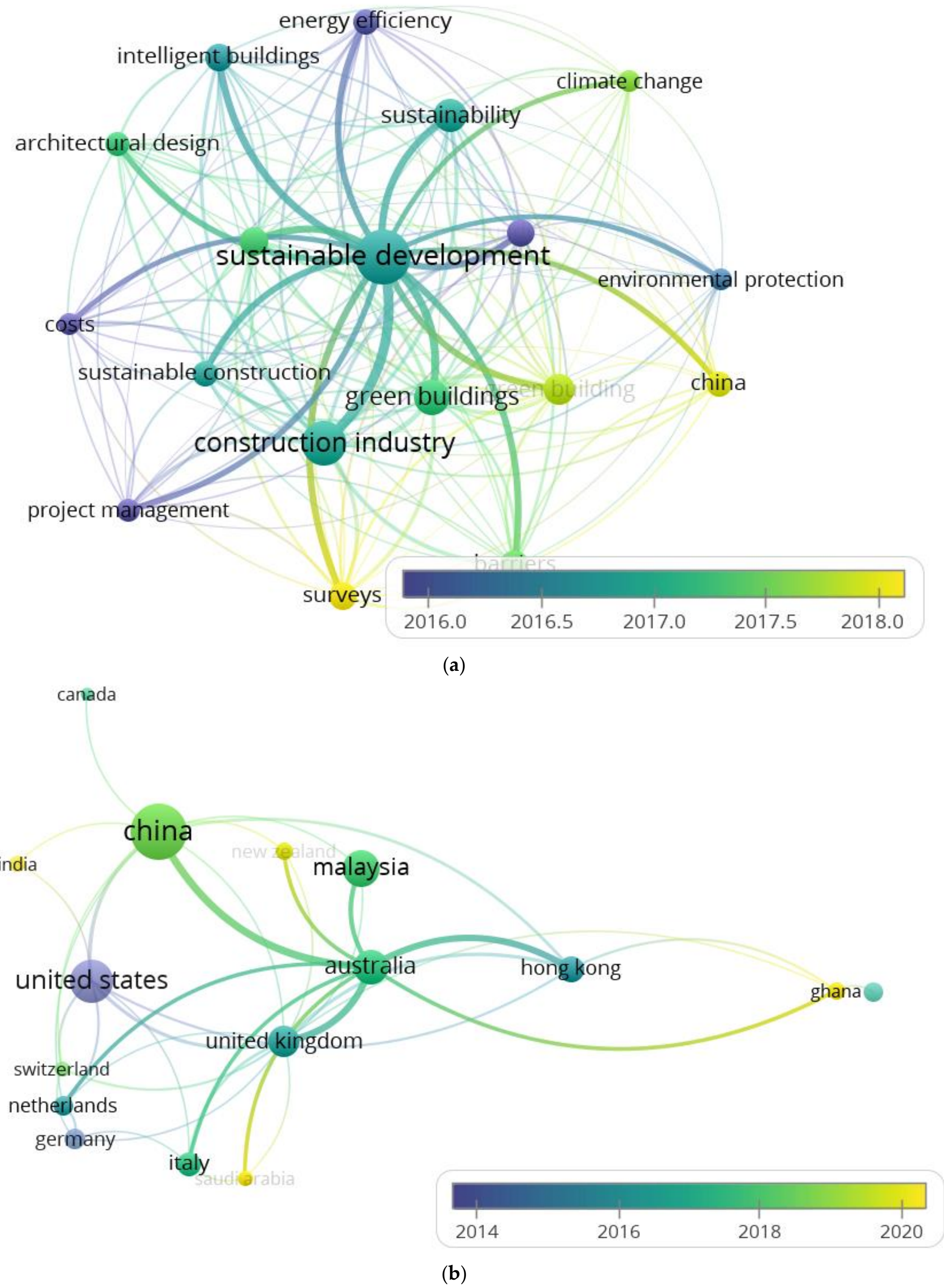

Figure 2. The outputs of network analysis by (**a**) keyword repetition and (**b**) countries' contributions.

To fill such research gaps and address these grand challenges, this study provides an empirical analysis to identify and rank the problems of green building development. In this regard, the main novelty of this research is developing a hybrid decision-making method using DEMATEL and the analytic hierarchy process (ANP). Likewise, an investigation is conducted to identify the barriers to green construction and also provide solutions to remove these barriers with a combined approach. In addition, this research contributes to the knowledge of sustainable building processes by expanding the literature on the challenges facing project management in adopting sustainable building processes and ranking development barriers.

After this introduction, Section 2 identifies mitigation strategies to overcome challenges in the sustainable building process. The methodology used for this study and the tools used for the analysis are described in Section 3, which explains the questionnaires in detail and clarifies the answers of the survey participants. The results and discussions are presented in Section 4, and finally, the conclusions of this study are shown in Section 5.

2. Methods

Here, the main methods and tools for analyzing the construction development barriers are presented. In this regard, we identify and rank the main obstacles to the development of green construction in the construction of District 22 of Tehran by the ANP, which is descriptive-analytical in terms of method and nature and is also in the field of applied research in terms of purpose. The statistical population of this research consists of urban planning and municipal staff and construction engineers. First, a list of experts is prepared, and then, based on the degree and work experience, 20 people were purposefully selected as a sample to identify the criteria based on the amount of work experience and degree.

2.1. Case Study

Here, we introduce our case study in Tehran, Iran, the westernmost urban area of Tehran in terms of location, which is connected to Alborz Heights from the north to Tehran's Area 5 from the east and to the south of Tehran province. The area of this area is 6200 hectares, of which approximately 1300 hectares are dedicated to urban green space. As shown in the geographical map of Tehran in Figure A1, the location of the area has a good level of access. Due to the wind in Tehran, which is generally from west to east, this area of Tehran has a cleaner and more favorable climate than other areas of Tehran. District 22 is the pioneer area of Tehran, with the highest level of tower construction and heights of towers from 10 to 42 floors. Despite many arcs and sensitivities of environmental experts regarding construction restrictions in this area, the strategic position of this area, and its impact on other areas of Tehran, the goals and maintaining a knowledge-based and leisure-oriented pattern with violations and unauthorized construction were ignored.

These violations can be attributed to the high-rise construction of residential and commercial towers that block the wind from the west to the east. This exacerbates air pollution in Tehran, which was previously considered by a treatment plant in Tehran and is now a breathing barrier. It seems that considering a vertical construction and if it follows the design and texture of the city is one of the factors of sustainable development, but this issue has not been observed in District 22. However, in the building itself, good efforts have been made, especially in terms of energy and facilities. Inside the building, the technology of green installations has been applied, which is more toward sustainability than the management and urban policy-making departments of this region. What is clear is that everything that harms the environment is the opposite of sustainable development. Therefore, what is a priority of this region is to review the strategy and long-term goal of this region and, along with it, improve and develop the indicators of green construction development in this region, which has much potential.

2.2. Questionnaire

In this study, a preliminary online questionnaire was first used to select and reject the barriers, which was implemented by the elite and Delphi methods. A number of barriers were removed and the most important criteria were selected by the Minister of Standards [45–48]. In relation to the integrated system, which is a time-consuming task, as well as to improve the quality of the questionnaires and optimize the final calculations of the questionnaire, we defined a new approach, which was a combination of the Delphi method and the ANP as the DANP approach, which was performed with a questionnaire that was answered by 20 experts in the field of green building [49–52]. A sample questionnaire can be found in the Appendix A of this research (Table A1). At the beginning of each questionnaire, a brief description of what needed to be done was provided. In this study, Cronbach's alpha coefficient was used to obtain the reliability of the questionnaire, which is usually acceptable when it is above 0.7. A specification of the barriers in the present research is demonstrated in Table 2.

Table 2. Identification of barriers and experts' agreement during different cycles of classical Delphi method in our research.

Dimension	Code	Barriers	Cycle 1 (%)	Cycle 2 (%)	Cycle 3 (%)
Design, Construct, and Executive	**C1**	Lack of design and construction knowledge	**75**	**65**	**90**
		Insufficient experience of contractors in the construction and implementation of green constructions	**85**	**85**	**100**
		Lack of technology and market for green materials	**60**	**70**	**85**
		Lack of trained manpower in the field of green construction	**75**	**80**	**95**
Managerial	**C2**	Lack of long-term and strategic goals in relation to local urban development	**65**	**85**	**90**
		Conflicts of interest and lack of cooperation between related organizations	**80**	**80**	**85**
		Uncertainty of the performance of green construction according to the climate and regional-local context	**90**	**90**	**90**
Economical	**C3**	Risk of investment	**60**	**60**	**70**
		Lack of an executive plan for green construction with economic justification	**70**	**75**	**95**
		Lack of facilities and tax incentives for public and private building developers	**80**	**85**	**75**
Cultural and Social	**C4**	Lack of awareness of people about the serious consequences of climate change	**70**	**75**	**80**
		Looking at green construction as luxurious	**90**	**100**	**100**
		Lack of proper awareness and knowledge for proper or optimal use of green buildings	**80**	**95**	**90**
Legal	**C5**	Lack of local standards and framework for continuous evaluation of green construction	**80**	**80**	**85**
		Lack of mandatory regulations for creating green buildings	**60**	**75**	**75**

In Table 2, the barriers are shown from the classical Delphi method during three different cycles. The outcomes of experts' agreements in this survey study are demonstrated in the table. Based on the Delphi method, when the agreement percentage was more than

60%, the strategy was accepted until finishing the third cycle [44]. The presented barriers are the selected approaches for green construction development. Based on classical Delphi outputs, it can be found that the barriers' agreement process during the brainstorming of the classical Delphi method had some fluctuations, but the mentioned parameters earned more than 60% agreement. Thus, all of them were approved by the experts' opinions during the process. It should be noted that these indicators and the determination of the Delphi scores were only for appraising the importance of attendance and had nothing to do with their weights. Experts have agreed with the presence of this index to different degrees. Hence, this fact does not mean we determined the weights of the indicators at this stage.

2.3. Data Analytics

Our data analytics were based on the MCDM method, where we provided a combination of the Delphi method and the ANP. In this hybrid method, using the dimethyl matrix of the subcriteria, an ANP supermatrix was formed, and finally, the weights of the criteria, which were the dimensions, and subcriteria, which were barriers, were obtained.

The DANP Technique

The literature shows that during the last two decades, several MCDM methods have been increasingly applied to real-world problems. Among them, some procedures are based on a cumulative function that indicates the closeness to the ideal points, such as VIKOR, the Threat-Oriented Person Screening Integrated System (TOPSIS), DEMATEL, the analytic hierarchy process (AHP), and the ANP. This study defines a hybrid decision-making method based on the DEMATEL, ANP, and Delphi methods known as DANP to focus on determining the evaluation criteria and decision structures based on decision makers' preference weights [24].

During the decision-making process, it is very important to measure the importance of the criteria and structures to increase the quality of decision making. Different from the traditional statistical factor analysis, which usually divides the criteria into groups and considers equal weights of independent criteria to summarize the effectiveness of a factor, the ANP and DANP methods were developed to consider the interrelationship between the influencing criteria in the system [25]. The DANP was created to make a visual impact map of the relationship between the dimensions and criteria with DEMATEL and using the baseline concept to evaluate key factors by considering the influential weights and priorities in the penetration matrix by DEMATEL [26].

An important difference between the classical approach and the modern method is that the clusters are considered the same, while we know that this weight can be non-uniform and it will be fixed. In the new method, the final results are analyzed based on Concept A, where the results obtained from the matrix of complete connections obtained by the DEMATEL method are analyzed [27]. The new approach of this integrated model is more acceptable than the classical method because of the dependence between the criteria that have real problems in the world around us and our decisions. Finally, this method was developed to determine the effective weights of each dimension and criterion by combining DEMATEL with the ANP method [28]. Generally, the steps involved in the DANP method are those given in Figure 3.

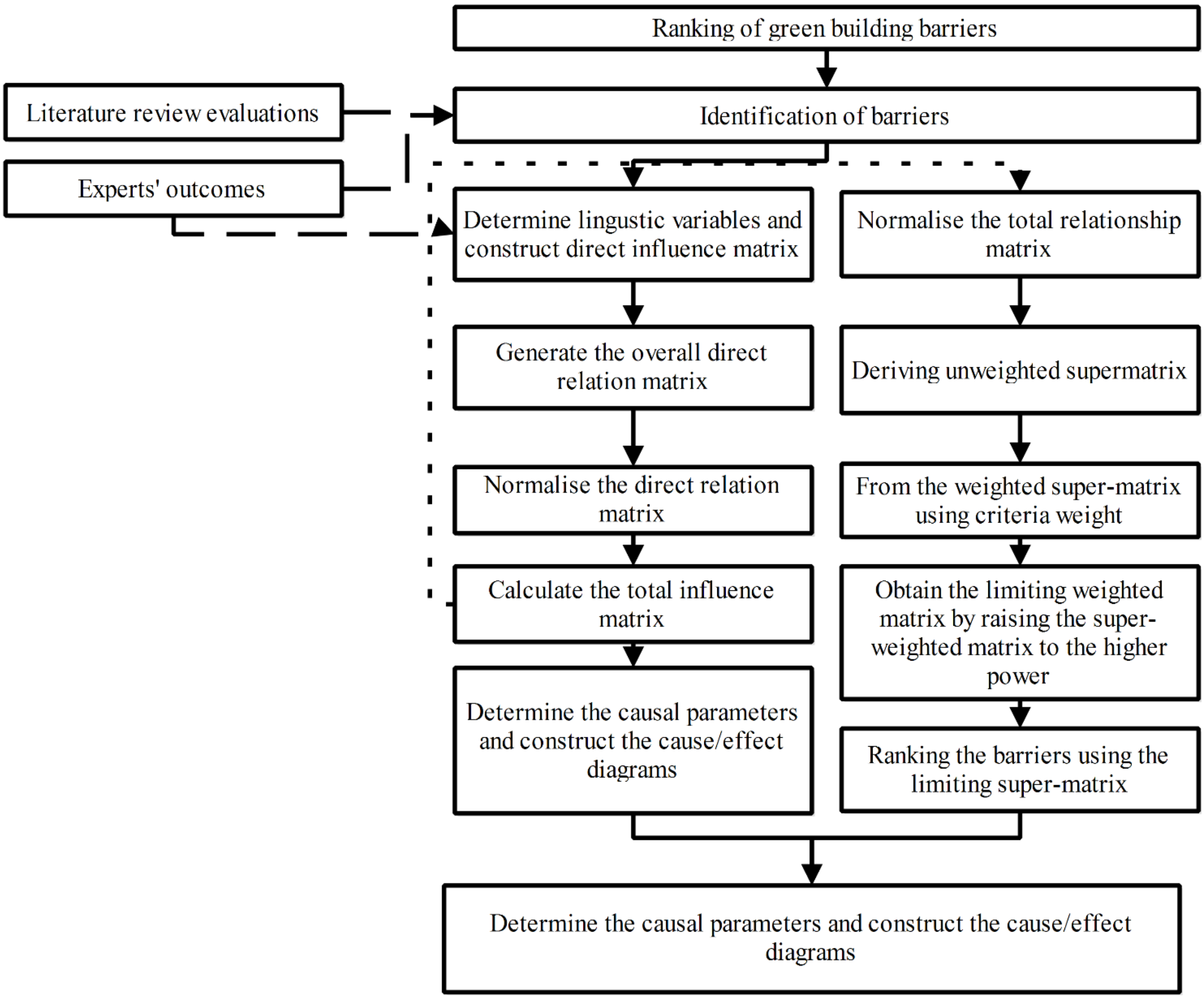

Figure 3. Proposed research framework.

In the present research, the process of ranking by the DANP method is described in 10 different stages, which are summarized in Equations (A1)–(A13) from Steps 1 to 10:

Step 1: Calculate the direct connection matrix. Evaluation of the relations between criteria (the effect of one criterion on another criterion) is based on the opinions of research experts using a rating range from 0 to 4, in which 0 means it is ineffective, 1 means it has a low impact, 2 indicates a moderate impact, 3 indicates a high impact, and 4 indicates a very high impact. The experts were asked to determine the effect of one criterion on another (i.e., if they believed that criterion i affected criterion j, they had to denote it by d_c^{ij} Rhine matrix D = $[d_c^{ij}]$), which is obtained from direct connection (Equation (A1)).

Step 2: Normalize the direct relations matrix. The direct correlation matrix D is normalized using the following equation, and the matrix N is obtained (Equation (A2)).

Step 3: Calculate the total communication matrix. Once the matrix D is normalized and the matrix N is obtained, the total relations matrix will be obtained through the following equation. In this relation, I represents the unit matrix (Equation (A3)).

The complete correlation matrix can be counted by the criteria denoted by T_C (Equation (A4)).

Step 4: Analyze the results in this step. The sums of the rows and columns of the complete relations matrix are calculated separately according to Equation (A5).

The index *r_i* represents the sum of the rows *i*, and *c_j* represents the sum of the columns *j*. The index *r_i* + *c_j* is obtained from the sum of the rows *i* and columns *j (i = j)*. This index indicates the importance of the *i*th criterion. Similarly, the index *r_i-c_j* is the result of the difference between the sum of the rows *i* and columns *j* and indicates the influential or influenced dimensions of the criterion *i*. In general, if *r_i -c_j* is positive (*i* = *j*), then the *i*th criterion is one of the causal or influential criteria. If *r_i-c_j* is negative (*i* = *j*), then the *i*th criterion is part of the set of influential criteria. All charts, known as network relations maps, can be drawn based on the two indicators. According to this map, it can be decided how the dimensions and criteria can be improved.

Step 5: Normalize the total dimensional relations matrix ($T_D^{\propto}$). The matrix T_D is obtained from the mean T_C^{ij}.This matrix will be normalized according to the following method so that the sum of each row is calculated and each element is divided by the sum of the corresponding row elements. The total normalized relations matrix T_D is shown as $T_D^{\propto}$ (see Equations (A6) and (A7)).

Step 6: Normalization of the total criteria matrix ($T_D^{\propto}$). The normalization of T_c with the sum of the degrees of influential and influenced dimensions of the criteria and dimensions for the acquisition of $T_D^{\propto}$ is are as shown in Equations (A8)–(A10).

Step 7: Form the unweighted W matrix. In this step, the transposition matrix of the total normalized relation $T_C^{\propto}$ is calculated, and the matrix *W* is obtained. If, for example, a matrix such as the matrix W^{11} is empty or zero, then this means that the corresponding matrix is independent (Equation (A11)).

Step 8: Formation of a weighted matrix. In order to form a weighted matrix, the complete normalization $T_D^{\propto}$ matrix is transposed to be normal and multiplied by an unweighted matrix (Equation (A12)).

Step 9: Limit the weighted matrix. We limit the weighted matrix by being able to reach a large number Z until the matrix converges and stabilizes. The output of this step will be the effective DANP weights (Equation (A13)).

Step 10: Find the final weights of the criteria and subcriteria. Where the matrix converges, the values of the first column of the matrix will be equal to the final weight of the corresponding subcriterion. The sum of the criteria of each main criterion becomes the relative weight of that criterion. The result of dividing the final weight of each subcriterion by the relative weight of the main criterion is equal to the relative weight of that subcriterion (Equation (A12)).

In this study, the Likert scale was used to score each of the indicators extracted from the classic Delphi method. In fact, after approving the type of indicators in brainstorming, the experts in question used this numerical range for the scoring operations. This process has been used in many different studies and has sufficient accuracy [45]. After interviews with the elites and the identification of possible barriers based on a literature review and research background, 15 barriers affecting the development of green construction were identified and extracted in 5 dimensions. To localize these factors, 20 experts were asked through a questionnaire based on the 1–5 Likert scale (1 = very little importance, 2 = low importance, 3 = moderate importance, 4 = high importance, and 5 = very high importance) to rate each indicator.

3. Computations and Results

The average score of each index was calculated based on integration of the Likert scale and surveying of the experts. If the average score of an index was less than three, then it was removed. The results showed that all indicators were approved by the experts; that is, the average of all indicators was higher than three. The results are given in Tables A2 and A3. It is worth noting that both the research factor evaluation and confirmed barriers are summarized in Tables 3 and 4, respectively.

Table 3. Evaluation of our factors based on different dimensions.

Dimension	Barrier	Average Point
Design	Lack of design and construction knowledge	3.5
	Insufficient experience of contractors in the construction and implementation of green constructions	4
	Lack of technology and market for green materials	3.8
	Lack of trained manpower in the field of green construction	3.35
Managerial	Lack of long-term and strategic goals in relation to local urban development	3.3
	Conflicts of interest and lack of cooperation between related organizations	3.3
	Uncertainty of the performance of green construction according to the climate and regional-local context	3.9
Economical	Risk of investment	3.85
	Lack of an executive plan for green construction with economic justification	3.65
	Lack of facilities and tax incentives for public and private building developers	3.3
Cultural and Social	Lack of awareness of people for the serious consequences of climate change	3.2
	Looking at green construction as luxurious	3.15
	Lack of proper awareness and knowledge for proper or optimal use of green buildings	3.35
Legal	Lack of local standards and framework for continuous evaluation of green construction	3.6
	Lack of mandatory regulations for creating green buildings	3.5

Table 4. Confirmed barriers for research.

	Symbol Dimension		Symbol Barrier
Design	C1	Lack of design and construction knowledge	C11
		Insufficient experience of contractors in the construction and implementation of green constructions	C12
		Lack of technology and market for green materials	C13
		Lack of trained manpower in the field of green construction	C14
Managerial	C2	Lack of long-term and strategic goals in relation to local urban development	C21
		Conflicts of interest and lack of cooperation between related organizations	C22
		Uncertainty of the performance of green construction according to the climate and regional-local context	C23
Economical	C3	Risk of investment	C31
		Lack of an executive plan for green construction with economic justification	C32
		Lack of facilities and tax incentives for public and private building developers	C33
Cultural and Social	C4	Lack of awareness of people for the serious consequences of climate change	C41
		Looking at green construction as luxurious	C42
		Lack of proper awareness and knowledge for proper or optimal use of green buildings	C43
Legal	C6	Lack of local standards and framework for continuous evaluation of green construction	C51
		Lack of mandatory regulations for creating green buildings	C52

According to Tables A2 and A3, all research indicators had an average value higher than three, so they obtained the necessary points and were approved. The verified indicators are given in coded form in Tables A2 and A3.

This study evaluates the barriers to the development of green construction for the study area. The barriers were finalized based on an extensive literature review and then through discussions with experts. In this research, 15 barriers were identified and categorized into 5 dimensions as shown in Table 2.

After finalizing the barriers, a questionnaire was prepared and sent to the experts to assess the effective power of the barriers. The questionnaire included a pairwise comparison matrix that was expected to be completed by the experts. The evaluation of the relationship between the criteria (the influence of one criterion on another criterion) was conducted based on the opinions of the research experts using a rating range from 0 to 4, where 0 meant it lacked impact, 1 meant little impact, 2 meant medium impact, 3 meant high impact, and 4 meant very high impact. The experts were asked to determine the effect of one criterion on another. The pairwise comparison matrix included two-by-two comparisons of all 15 obstacles with each other. The experts' responses were used to develop a network relation map (NRM) using Equations (A1)–(A5).

The total influence matrix could be calculated using the expert responses with Equations (1)–(4). After that, the impact of each of the dimensions as well as the obstacles was determined, and the results are presented in Tables A2 and A3, respectively.

An index that has a positive D-R indicates that it is the cause; that is, it has a high impact. Accordingly, in the dimension of design, construction, and implementation, a lack of design and construction knowledge in the managerial dimension, conflicts of interest and lack of participation between related organizations in the economic dimension, the existence of investment risk in the cultural and social dimension, failure to inform people about the serious consequences of climate change and the legal aspect, and the lack of mandatory codified criteria for creating a green building were the most influential criteria. The internal relationships between the criteria are also shown in Figure 4.

Using Table A3, the influential and influenced dimensions of the main criteria were determined. In a similar way, we calculated the values of D and R. According to Table A3, the legal and managerial criteria had positive D-R values; that is, they had causal aspects and were highly effective. According to Figure 5, the management dimension had the highest value of D + R, so it had the strongest relationship with other system factors.

Using Table A2, the influential and influenced dimensions were determined. We calculated the values of D and R in a similar way. The legal and managerial criteria had positive D-R values; that is, they had causal aspects and high impacts. The management criterion had the highest value of D + R, so it had the strongest relationship with other system factors.

The final weights of the criteria and subcriteria were extracted from the restricted supermatrix (Table A11), and they are given in Table 5. We determined the final weight of each barrier's total influence matrix of demotions generated using Equations (A1)–(A6), and they are shown in Table A4. Similarly, the total influence matrix of the barriers was developed, and it is shown in Table A5. Furthermore, the total influence matrix of the demotions and critical success factors (CSFs) were transformed into a normalized total influence matrix using Equations (A6)–(A9), and they are shown in Tables A6 and A7. The normalized total influence matrix was transposed to generate the unweighted supermatrix (W) using Equation (11), and it is shown in Tables A8 and A9. The weighted super-matrix was generated by multiplying the unweighted matrix (W) by the transpose of the TD norm (refer to Table A6) using Equation (12), and it is shown in Table A10. Finally, the weighted supermatrix was raised to the power of 15 to generate a stable limiting matrix (refer to Table A12), from which we found the final weight for each barrier.

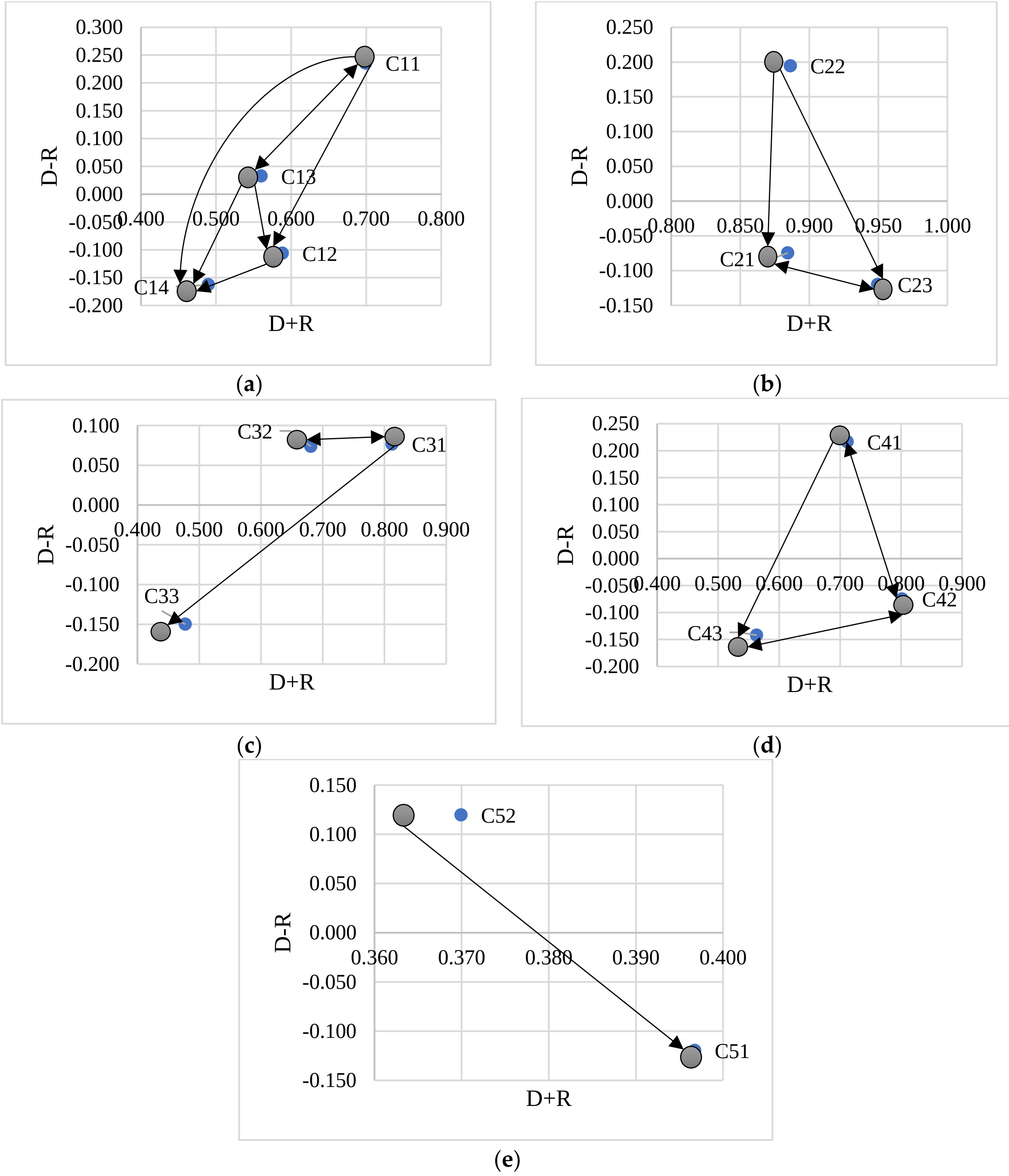

Figure 4. Causal chart of barriers (Symbol criteria are presented in Tables A2 and A3).

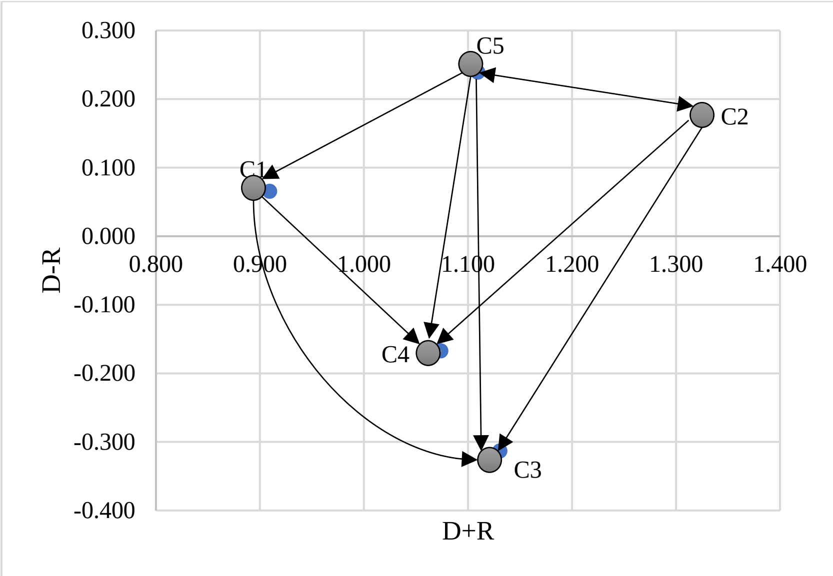

Figure 5. Causal diagram of the main factors (Symbol criteria are presented in Tables A2 and A3).

Table 5. Final weights of criteria and subcriteria.

Benchmark Name	Relative Weight	Final Weight	Rank
Design, construction, and implementation (C1)	0.1518		4
Lack of design and construction knowledge (C11)	0.227	0.0345	3
Insufficient experience of contractors in construction and execution of green constructions (C12)	0.283	0.0429	1
Lack of technology and green material market (C13)	0.217	0.0329	4
Lack of trained manpower in green construction (C14)	0.273	0.0415	2
Managerial (C2)	0.2052		3
Lack of long-term and strategic goals in relation to local urban planning (C21)	0.345	0.0709	2
Conflicts of interest and lack of partnership between related organizations (C22)	0.254	0.0522	3
Uncertainty of green construction performance due to climate and texture of local area (C23)	0.400	0.0821	1
Economic (C3)	0.2607		1
Risk of investment (C31)	0.396	0.1033	1
Lack of an executive plan (C32)	0.317	0.0825	2
Lack of facilities and tax incentives for the public (C33)	0.287	0.0749	3
Cultural and social (C4)	0.2258		2
Lack of awareness people (C41)	0.242	0.0546	3
Looking at green construction as luxurious (C42)	0.467	0.1054	1
Lack of proper awareness and knowledge for proper or optimal use of green buildings (C43)	0.291	0.0657	2
Legal (C5)	0.1566		5
Lack of local standards and framework for continuous assessment of green construction (C51)	0.627	0.0983	1
Lack of mandatory regulations for creating green buildings	0.373	0.0584	2

4. Discussions, Contributions, and Recommendations

The purpose of this study was to rank the barriers of green building development in Tehran. The barriers were weighted and ranked. The results showed that the economic barrier with a weight of 0.2607 was ranked first. The cultural and social barrier had a weight of 0.2258 and was ranked second, and the management barrier had a weight of 0.2052, ranking third. The results of this study are consistent with the prior research [29]. This study also stated that there are vital barriers, government-related barriers, human-related barriers, knowledge and information barriers, market-related barriers, and cost risk barriers. As can be seen, the economic barrier was selected as the most important factor by the experts, which can also be seen in other countries. The economic factor is an integral part of construction projects. This barrier has been considered the most important barrier in the implementation of green buildings. According to the management barrier, the lack of the required new and modern management for the implementation of green buildings in developing countries, in addition to the lack of trained and skilled personnel in this field, has led to a lack of project management as well as motivation and courage to build and implement them. Masrom et al. [30] found that the higher cost and lack of green awareness for reconstruction, the more limited the sustainability of commercial buildings in Malaysia.

Zhang et al. [31] investigated 28 barriers to the development of green construction in China and found that high costs hindered the use of green technologies. Research studies showed that the barriers to sustainable construction in each region have certain commonalities, but they also have unique characteristics, and according to the conditions of each country, different policies and economic levels, as well as people's awareness of environmental protection, are also different. The second most important barrier in the obtained results was the social and cultural barrier. This barrier itself consisted of three sub-barriers, and this factor has been investigated in many past researches works. For example, in 2010, Wu et al. considered the lack of environmental sustainability the third most important obstacle in the development of green construction in China [12]. Additionally, in a study in Pakistan in 2017, Azeem et al. identified the most important obstacle to the adoption of green buildings as "lack of awareness among people about the importance and benefits of adopting green building practices", followed by "lack of government incentives" and "lack of green building rules and regulations". The results showed that the most important action to promote the adoption of green buildings is "creating public awareness of green projects through seminars, workshops and discussions", followed by "availability of green building rules and regulations (mandatory to apply)" and "government financial incentives and penalties (e.g., loans, taxes) to promote green building practices" [32]. Hoffman and Henn stated in a study that the strongest obstacles to the faster deployment of green buildings are psychological and social, and they discussed them at three levels: individual, organizational, and institutional. They proposed two strategies to overcome this obstacle. Entrepreneurial opportunities and challenges for change also described seven specific strategies, namely issue framing, targeting the right demographic, education, structural and incentive change, indemnifying risk, green building standard improvements, and tax reform [33]. The third most important barrier in the ranking was the managerial barrier. This barrier was one of the most important barriers in past research in both developed countries and developing countries, but in terms of ranking and importance compared with other obstacles, this factor in developed countries was a stronger factor than the economic or cultural factors. In 2020, Karji [10] found the second most effective factor to be management restrictions after pre-construction restrictions. Although green buildings have various advantages, there are many obstacles in their implementation. Obstacles such as higher costs, lack of customer interest, delays in technical progress, and lower market demand are considered very important. These critical barriers slow the progress of green buildings. Therefore, to overcome the obstacles and also address the complexity in the design and implementation of green buildings, several modifications to the existing project management methods are needed [34].

The fourth barrier in our study was the barrier of knowledge, design, and implementation. This barrier has been investigated under different headings in past research. Although it seems that this barrier is seen more in developing and less developed countries, in the research conducted in 2020 by Karji in America, this barrier was the most important considered obstacle in the development of sustainable construction. In research conducted in Indonesia in 2016, the findings showed that the main obstacle to the green building movement in Indonesia is insufficient understanding of the concept of green buildings by the building occupants and even other stakeholders. This key issue leads to other problems, such as heavy enforcement, lack of awareness, negligence, and resistance to change to the new green lifestyle [35]. The least important barrier in our research was the legal barrier.

However, at the beginning of the research, this barrier seemed to be important in the development of green buildings in the study area, and according to the opinions of the elites and professors, it was divided into two sub-barriers. Using the obtained results, it was shown that this barrier is less important than other economic, cultural, managerial, and knowledge obstacles in design and implementation. However, this result is consistent with previous studies in other countries. It is interesting that the results often show that it is usually not the most important barrier in developed or developing countries, such as in Karji's research [10] on the case study of the United States. This conclusion also applies to Chan's research [14] for the country of Ghana.

Generally, construction in Iran is performed traditionally, and this method is still accepted by the people. This is due to the culture of construction in Iran. When a new method or new technology enters the construction industry, it faces resistance from the engineering community, and this is due to the lack of accurate knowledge of the benefits of the new method [36]. It is necessary to pay attention to the fact that our country is not facing the problem of standard building materials or a lack of technology, but we have the problem of the culture of correct use of this technology [37]. A clear example of this is the issue of industrialization in buildings, where everyone has been emphasizing for years the need for industrialization of buildings, but this issue is discussed in a cross-sectional manner and in a short time, and in a limited time, it is forgotten again [38]. In addition, there is no comprehensive, general, and strategic view of it. The purpose of green building is to build buildings that are compatible with the environment and conserve energy. Green design is one of the new design methods that has emerged exclusively in the world of architecture, and so far, various buildings have been designed using the style of green design [39]. This type of architecture is moving forward in the field of sustainable development and various other fields (energy, materials, facilities, etc.), along with the use of technology. The key steps in the design of a green building include specifying building materials from local sources for the reduction of transportation costs and the optimization system for the use and production of renewable energy on site [40]. According to the International Energy Agency, which publishes statistics, 40% of the per capita energy consumption is consumed by buildings [41]. The importance of this issue stems from the fact that with the creation of industrial transformation and the existence of many comforts and well-being facilities for human beings, the natural cycle of production and consumption will continue without interruption. With finite energies and resources, instead of the presence of pristine nature alongside man-made industry, we are watching the disappearance of nature and, as a result, the disappearance of energies and resources [42]. In addition, air pollution, light pollution, noise pollution, and other environmental problems have had a direct impact on human health. With this approach and the need to reduce problems, the creation of green and, at the same time, sustainable buildings become more apparent regarding the environmental problems that exist [43].

Nelms et al. [51] evaluated just the economic barriers to green construction in buildings with the application of decision-making techniques [51]. Meanwhile, the managers for decision making need to consider the different aspects of each issue. Therefore, the present research covered this aspect of green construction design and operation characteristics. In another single-object study, Dawood et al. [52] developed a novel idea about the effects of low-carbon construction [52], and it had the same dimension of environmental impact assessment and barriers as our research.

Based on the evaluations made in terms of the use and implementation of green materials in a building, before the contract process, the contractors should take related scientific and executive courses, and based on the opinion of the engineering system, they should have sufficient qualifications for this work. Based on the experts' opinions, the experience of contractors and executors should be evaluated with the help of this approach and be a guarantee for the correct implementation of the application of green materials [53]. With consideration to managerial insights, it is essential to consider the climate issues in each region because environmentally friendly aspects, such as heating, ventilation, and air conditioning, are also justified dimensions [54]. The results of this study show that in the economic dimension, concessions such as tax reduction or low-interest facilities should be given to groups that operate based on green materials. With this approach, the risk of investing in this area is practically reduced, and the desire for this area increases [55]. On the other hand, non-governmental organizations should be more active in the field of informing citizens about the importance of green materials and their environmental benefits. This is the correct direction in the field of increasing people's spontaneous desire in this field [56]. In addition, with the help of social streamlining, the approach of using green materials becomes a social duty instead of an ornamental matter [57].

When the engineers and construction contractors were interviewed about the subject of this research, we often encountered a common issue. Even though the interviewees admitted to being aware of the definition of green and sustainable building, they often had superficial definitions and wrong concepts about this topic. It is suggested that the training and incentive certificates for a designer and executive engineer can become a driving factor for the growth and encouragement of awareness among elite people, because many of the issues of concern for green building certificates are related to correct and sustainable design and implementation and not necessarily the use of facilities and equipment. Special and advanced buildings have been built. Another case is the lack of investment and the construction of government buildings and centers for advertising and a spark for culture, as well as pushing and encouraging people in this direction. The lack of long-term and strategic goals concerning urban-local development, which are specifically related to things such as the classification of the building site, parking, and public transportation, has been neglected in the planning and plans of urban development in this area, and in all these cases, lack of attention had a significant impact on the development of green construction and building construction. According to the author, for the development of green construction in this region, which is one of the new and progressive regions, it is necessary to pay special attention to the context of the region, climate, and density, as well as the division of facilities and public services at the regional level, which can cause many problems in the not too distant future, such as serious damage to the environment of the region and the surrounding areas and the lack of satisfaction and comfort of the users of the region, which contradict the main points of concern for all green certificates.

Even though there is still no general framework or system for the level of sustainability or greenness of a building as a whole, according to the authors, presenting such issues and case studies and even acting case by case and advancing green goals regionally, as foreign experiences have shown, is one of the important factors in the development of green construction, although providing a measurement system requires working groups with different expertise in the field of construction and the environment (similar to what is performed in the formulation of national regulations by forming specialized committees). Studies such as this increase awareness in the first place and promote sustainable development, which of course can be the first very small step in creating motivation and public awareness to develop and promote green construction.

Despite the integration of the two models and the improvement in accuracy and results, which is considered one of the strengths of this method, the existence of two questionnaires and filling them in the way of paired comparisons is a very time-consuming and difficult task that can lead to a decrease in the quality of the data. Therefore, we performed two tasks: first, we changed the approach of the model from the traditional and classic method to a new approach, which could be modeled by completing only one DEMATEL questionnaire, and second, considering the difficult way of filling out the questionnaire, we made the questions of the questionnaire the most comprehensive and inclusive ones and included the lowest possible number of questions.

Finally, one of the theoretical distinctions of the current research with other works was in the questionnaire and model section. To determine the final questionnaire, we did not pay attention to the previous research's literature, and by studying the area in question, interviewing municipal engineers, and surveying and conducting field studies with the residents of that area, the supervisors of the workshop were able to have a more comprehensive view of the problems and challenges in the area under study. In the direction of sustainable development and the development of green construction, we should achieve a special distinction in terms of the quality of the criteria compared to other criteria in similar urban studies. Our second innovation was in the model method, which increased the quality of the model by using a consolidated model, and with a new approach compared to other similar models. One of the other important reasons for using the new approach instead of the traditional and classic approach of the DEMATEL and ANP model is that it is more optimal than the classical method. Additionally, in the literature review of this method, it is pointed out that many relationships and influences after the threshold getting omitted increases the possibility of incorrect answers.

5. Conclusions and Future Works

The aim of this study was identification and ranking of the barriers to green building development in District 22 of Tehran. In this research, for the ranking of the barriers to green building development in building construction to be based on this, the first 15 indicators were extracted in 5 dimensions, which were approved by the research experts. Then, using the DANP method, the influential and influenced barriers were investigated, and finally, the factors were weighted and ranked.

The final results showed that among the 5 categories of the main barriers, the economic barrier with a weight of 0.2607 ranked as the most important barrier to the development and promotion of green construction in this region. The cultural and social barriers had a weight of 0.2258, the administrative barriers had a weight of 0.2052, design, and the design, construction, and implementation barriers had a weight of 0.1518, ranking from second to fourth, respectively. Finally, the legal barriers attained the fifth rank as the least important obstacle. Likewise, the first rank among the various barriers in each category was obtained this way. The following were recognized as the influential barriers. In the economic sub-barrier, it was risk of investment. Among the cultural and social sub-barrier, it was a luxurious view of green construction. Among the managerial sub-barrier, it was the lack of clarity regarding the performance of green construction according to the climate and context of the local area. Among the barriers to design, construction, and implementation, it was the inadequate experience of contractors in the construction and implementation of green constructions. Among the legal sub-barrier, it was the lack of local standards and frameworks for continuous evaluation of green constructions. According to the findings and results, the barriers and sub-barriers used in this research can be used to develop and create a strategic model and policy for the construction and development of green buildings in this district of Tehran and similar cities and countries.

With consideration of the MCDM outcomes, it can be found that for real field implementation of green construction applications in the Iranian megacities, first, a local standard and instructions should be executed. In the next step, the risk of investment should be reduced with some motivational plans and changing the viewpoints of citizens about the declared constructions. Finally, as an improvement of the mentioned plan, some green construction that is adopted by specific climates should be presented with research and development practices.

Regarding future research directions, we can consider the impact of the COVID-19 pandemic on construction projects [58]. The application of system dynamic computations for modeling the barrier effects on green construction development can be attractive in scientific communities [59–62]. In this regard, the application of business-based models such as supply and demand curves, customer journey maps, and value chain analysis for strategy building in green constructions can be useful in the field of sustainability research [63–65].

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Appendix A

$$D = \begin{bmatrix} d_c^{11} & \ldots & d_c^{1j} & \ldots & d_c^{1n} \\ \vdots & & \vdots & & \vdots \\ d_c^{i1} & \ldots & d_c^{ij} & \ldots & d_c^{in} \\ \vdots & & \vdots & & \vdots \\ d_c^{n1} & \ldots & d_c^{nj} & \ldots & d_c^{nn} \end{bmatrix} \tag{A1}$$

$$N = \text{VD};\ \text{V} = \min\left\{1/\sum\nolimits_{j=1}^{n} d_{j.i}\ 1/\sum\nolimits_{i=1}^{n} d_{i.j}\right\},\ i,j \in \{1,2,\ldots,n\} \tag{A2}$$

$$\text{T} = N + N^2 + \ldots + N^h = N(I-N)^{-1},\ when\ h \to \infty \tag{A3}$$

$$\begin{matrix} D1 & D_j & D_n \\ c_{11....}\ c_{1m1} & c_{j1...C_{jmj}} & c_{n1....C_{nmn}} \end{matrix} \tag{A4}$$

$$T_c = \begin{matrix} D_1 & c_{11} \\ \vdots & c_{12} \\ \vdots & c_{1n1} \\ \vdots & \vdots \\ \vdots & c_{21} \\ D_j & c_{22} \\ \vdots & c_{2n2} \\ \vdots & c_{31} \\ D_n & c_{32} \\ & c_{3nnn} \end{matrix} \begin{bmatrix} T_C^{11} & \ldots & T_C^{1j} & \ldots & T_C^{1n} \\ \vdots & & \vdots & & \vdots \\ T_C^{i1} & \ldots & T_C^{ij} & \ldots & T_C^{in} \\ \vdots & & \vdots & & \vdots \\ T_c^{n1} & \ldots & T_C^{nj} & \ldots & T_C^{nn} \end{bmatrix}$$

$$T = [t_{ij}].i,j \in \{1,2,\ldots,n\} \tag{A5}$$

$$r = [r_1]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}$$

$$c = [c_1]_{n\times 1} = \left[\sum_{j=1}^{n} t_{ij}\right]_{n\times 1}$$

$$T_D = \begin{bmatrix} t_{11}^{D_{11}} & L & t_{1j}^{D_{1j}} & L & t_{1m}^{D_{im}} \\ M & M & M & M & M \\ t_{i1}^{D_{i1}} & L & t_{ij}^{D_{ij}} & L & t_{im}^{D_{im}} \\ M & M & M & M & M \\ t_{m1}^{D_{m1}} & L & t_{mj}^{D_{mj}} & L & t_{mm}^{D_{mm}} \end{bmatrix} \begin{matrix} \to d_1 = \sum_{j=1}^{m} t_{1j}^{D_{1j}} \\ \to d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}} \\ \to d_m = \sum_{j=1}^{m} t_{mj}^{D_{mj}} \end{matrix} , d_i = \sum_{j=1}^{m} t_{ij}^{D_{ij}}, i = 1, \ldots, m \tag{A6}$$

$$T_D = \begin{bmatrix} t_{11}^{D_{11}}/d_1 & L & t_{1j}^{D_{1j}}/d_1 & L & t_{1m}^{D_{im}}/d_1 \\ M & M & M & M & M \\ t_{i1}^{D_{i1}}/d_i & L & t_{ij}^{D_{ij}}/d_i & L & t_{im}^{D_{im}}/d_i \\ M & M & M & M & M \\ t_{m1}^{D_{m1}}/d_m & L & t_{mj}^{D_{mj}}/d_m & L & t_{mm}^{D_{mm}}/d_m \end{bmatrix} = \begin{bmatrix} t_D^{\alpha 11} & L & t_D^{\alpha 1j} & L & t_D^{\alpha im} \\ M & M & M & M & M \\ t_D^{\alpha i1} & M & t_D^{\alpha ij} & L & t_D^{\alpha im} \\ M & M & M & M & M \\ t_D^{\alpha m1} & L & t_D^{\alpha mj} & L & t_D^{\alpha mm} \end{bmatrix} \tag{A7}$$

$$\begin{matrix} D_1 & & D_j & & D_n \\ c_{11}\ c_{1m1} & \ldots. & c_{jl}\ , c_{jmj} & \ldots & c_{nl}\ , c_{nml} \end{matrix} \tag{A8}$$

$$T_C^{\alpha} = \begin{matrix} & c_{11} \\ D_1 & c_{12} \\ \vdots & M \\ M & \vdots \\ \vdots & c_{1_{m1}} \\ \vdots & M \\ \vdots & c_{i1} \\ D_j & c_{i2} \\ M & M \\ \vdots & c_{n1} \\ \vdots & c_{n2} \\ D_n & M \\ & c_{n_{mn}} \end{matrix} \begin{bmatrix} t_c^{\alpha 11} & L & t_c^{\alpha 1j} & L & t_c^{\alpha im} \\ M & M & M & M & M \\ t_c^{\alpha i1} & M & t_c^{\alpha ij} & L & t_c^{\alpha im} \\ M & M & M & M & M \\ t_c^{\alpha m1} & L & t_c^{\alpha mj} & L & t_c^{\alpha mm} \end{bmatrix}$$

$$d_{ci}^{11} = \sum_{j=1}^{m_1} t_{cij}^{11}\ , \ i = 1,\ 2,\ \ldots,\ m_1 \tag{A9}$$

$$T_C^{\propto 11} = \begin{bmatrix} t_{c11}^{11}/d_{c1}^{11} & \ldots & t_{c1j}^{11}/d_{c1}^{11} & \ldots & t_{c1m1}^{11}/d_{c1}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{11}/d_{ci}^{11} & \ldots & t_{cij}^{11}/d_{ci}^{11} & \ldots & t_{cim1}^{11}/d_{ci}^{11} \\ \vdots & & \vdots & & \vdots \\ t_{cm11}^{11}/d_{cm1}^{11} & \ldots & t_{cm1j}^{11}/d_{cm1}^{11} & \ldots & t_{cm1m1}^{11}/d_{cm1}^{11} \end{bmatrix} = \begin{bmatrix} t_{c11}^{\propto 11} & \ldots & t_{c1j}^{\propto 11} & \ldots & t_{c1m1}^{\propto 11} \\ \vdots & & \vdots & & \vdots \\ t_{ci1}^{\propto 11} & \ldots & t_{cij}^{\propto 11} & \ldots & t_{cim1}^{\propto 11} \\ \vdots & & \vdots & & \vdots \\ t_{cm1\,1}^{\propto 11} & \ldots & t_{cm1j}^{\propto 11} & \ldots & t_{cm1m1}^{\propto 11} \end{bmatrix} \tag{A10}$$

$$\begin{matrix} D1\ \ldots. & & D_j & & D_n \\ c_{11}\ c_{1m1} & \ldots. & c_{jl}\ , c_{jmj} & \ldots & c_{nl}\ , c_{nml} \end{matrix} \tag{A11}$$

$$W = (T_c^{\alpha})' = \begin{array}{cc} & c_{11} \\ D_1 & c_{12} \\ \vdots & M \\ M & \vdots \\ \vdots & c_{1_{m1}} \\ \vdots & M \\ \vdots & c_{i1} \\ D_j & c_{i2} \\ M & M \\ \vdots & c_{n1} \\ \vdots & c_{n2} \\ D_n & M \\ & c_{n_{mn}} \end{array} \begin{bmatrix} W^{11} & L & W^{i1} & L & W^{n1} \\ M & M & M & M & M \\ W^{1j} & M & W^{ij} & L & W^{nj} \\ M & M & M & M & M \\ W^{1n} & L & W^{in} & L & W^{nn} \end{bmatrix}$$

$$W^{\alpha} = T_D^{\alpha} W = \begin{bmatrix} t_D^{\alpha 11} \times W^{11} & t_D^{1i1} \times W^{i1} & t_D^{\alpha n1} \times W^{n1} \\ t_D^{\alpha 1j} \times W^{1j} & t_D^{\alpha ij} \times W^{ij} & t_D^{\alpha nj} \times W^{nj} \\ t_D^{\alpha 1n} \times W^{1n} & t_D^{\alpha in} \times W^{in} & t_D^{\alpha nn} \times W^{nn} \end{bmatrix} \quad \text{(A12)}$$

$$\lim_{Z \to \infty} (W^{\propto})^Z \quad \text{(A13)}$$

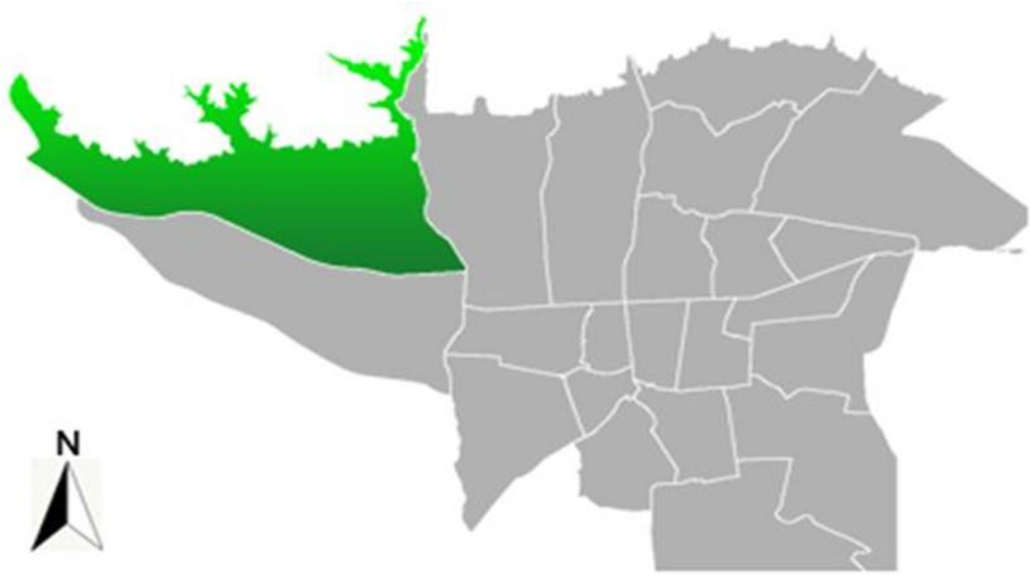

Figure A1. Our case, which is a map of Tehran, Iran.

Table A1. Questionnaire sample in the present research (there is no relation between bold items).

	C11	**C12**	**C13**	**C14**	**C21**	**C22**	**C23**	**C31**	**C32**	**C33**	**C41**	**C42**	**C43**	**C51**	**C52**
C11	**0**														
C12		**0**													
C13			**0**												
C14				**0**											
C21					**0**										
C22						**0**									
C23							**0**								
C31								**0**							
C32									**0**						
C33										**0**					
C41											**0**				

Table A1. *Cont.*

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C42												**0**			
C43													**0**		
C51														**0**	
C52															**0**

Table A2. Determined influential and influenced barriers.

Feature Description	Symbol Criteria	D	R	D + R	D − R	Sort
Lack of design and construction knowledge	C11	0.467	0.232	0.699	0.235	Cause
Insufficient experience of contractors in the construction and implementation of green constructions	C12	0.241	0.347	0.588	−0.106	Effect
Lack of technology and market for green materials	C13	0.297	0.264	0.560	0.033	Cause
Lack of trained manpower in the field of green construction	C14	0.164	0.326	0.490	−0.162	Effect
Lack of long-term and strategic goals in relation to local urban development	C21	0.405	0.479	0.884	−0.075	Effect
Conflicts of interest and lack of cooperation between related organizations	C22	0.540	0.346	0.886	0.195	Cause
Uncertainty of the performance of green construction according to the climate and regional-local context	C23	0.415	0.535	0.950	−0.120	Effect
Risk of investment	C31	0.444	0.368	0.812	0.076	Cause
Lack of an executive plan for green construction with economic justification	C32	0.377	0.304	0.681	0.074	Cause
Lack of facilities and tax incentives to public and private building developers	C33	0.164	0.314	0.478	−0.150	Effect
Lack of awareness by people about the serious consequences of climate change	C41	0.464	0.247	0.712	0.217	Cause
Looking at green construction as luxurious	C42	0.363	0.483	0.802	−0.075	Effect
Lack of proper awareness and knowledge for proper or optimal use of green buildings	C43	0.211	0.353	0.563	−0.142	Effect
Lack of local standards and framework for continuous evaluation of green construction	C51	0.139	0.258	0.397	−0.120	Effect
Lack of mandatory regulations for creating green buildings	C52	0.245	0.125	0.370	0.120	Cause

Table A3. Determining influential and influenced dimensions during DANP computations.

Criterion Name	Code	D	R	D + R	D − R	Criterion Type
Design, construction, and execution	C1	0.487	0.422	0.909	0.066	Cause
Managerial	C2	0.749	0.573	1.321	0.176	Cause
Economical	C3	0.409	0.722	1.131	−0.313	Effect
cultural and social	C4	0.453	0.621	1.074	0.167	Effect
Legal	C5	0.674	0.435	1.110	0.239	Cause

Table A4. Direct relation matrix.

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0	3.778	2.889	2.889	1.333	0.333	3.444	3.111	3.556	1.667	0.333	3	1.111	0.667	0.667
C12	0.889	0	0.778	1.556	0	0	2.222	3.111	2	2	1	1	2	2	1
C13	2	1	0	1	1.222	0	2	2	2	2	2	3	3	3.222	0
C14	0	1	0.778	0	0.444	0.222	1	3	2	1.222	1	2	2	1	0
C21	1.222	1	0	1.111	0	2	3	4	3	3	3	3	2	3.222	1
C22	2	2	3.111	2	3.889	0	4	3	3	2	3	2	2	3.222	2
C23	1.222	1	0	0	3	3	0	4	2	3	1	3	2	2	2
C31	1.222	1.222	1.556	1.111	3	2	2	0	3	4	0	3	0	1	0
C32	1	2	0	0	1.444	0	1.222	4	0	1.222	1	4	1	2	2

Table A4. *Cont.*

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C33	1	1	1	2	0	1.222	0	1	1.111	0	0	1	0	0	0
C41	1	2	2	1.222	1	2	2	2	3	1.222	0	3.889	3.889	1	1
C42	0	0	1	1	2	1.222	3	1	2	1	3	0	2.889	1	1
C43	0.333	1	0	1	1.111	0	0	1.222	0	1.222	1	2.778	0	1	1
C51	2	1	1	1.889	2.111	2.111	3	3	1	0	1.222	1.778	1.222	0	1
C52	2.111	3.333	2.444	3.222	3.333	1.444	3.778	2.778	2	2.222	1.222	3.222	1.222	3.222	0

Table A5. Normalized direct relations matrix.

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0	0.101	0.078	0.078	0.036	0.009	0.093	0.084	0.096	0.045	0.009	0.081	0.030	0.018	0.018
C12	0.024	0	0.021	0.042	0	0	0.060	0.084	0.054	0.054	0.027	0.027	0.054	0.054	0.027
C13	0.054	0.027	0	0.027	0.033	0	0.054	0.054	0.054	0.054	0.054	0.081	0.081	0.087	0
C14	0	0.027	0.021	0	0.012	0.006	0.027	0.081	0.054	0.033	0.027	0.054	0.054	0.027	0
C21	0.033	0.027	0	0.030	0	0.054	0.081	0.107	0.081	0.081	0.081	0.081	0.054	0.087	0.027
C22	0.054	0.054	0.084	0.054	0.104	0	0.107	0.081	0.081	0.054	0.081	0.054	0.054	0.087	0.054
C23	0.033	0.027	0	0	0.081	0.081	0	0.107	0.054	0.081	0.027	0.081	0.054	0.054	0.054
C31	0.033	0.033	0.042	0.030	0.081	0.054	0.054	0	0.081	0.107	0	0.081	0	0.027	0
C32	0.027	0.054	0	0	0.039	0	0.033	0.107	0	0.033	0.027	0.107	0.027	0.054	0.054
C33	0.027	0.027	0.027	0.054	0	0.033	0	0.027	0.030	0	0	0.027	0	0	0
C41	0.027	0.054	0.054	0.033	0.027	0.054	0.054	0.054	0.081	0.033	0	0.104	0.104	0.027	0.027
C42	0	0	0.027	0.027	0.054	0.033	0.081	0.027	0.054	0.027	0.081	0	0.078	0.027	0.027
C43	0.009	0.027	0	0.027	0.030	0	0	0.033	0	0.033	0.027	0.075	0	0.027	0.027
C51	0.054	0.027	0.027	0.051	0.057	0.057	0.081	0.081	0.027	0	0.033	0.048	0.033	0	0.027
C52	0.057	0.090	0.066	0.087	0.090	0.039	0.101	0.075	0.054	0.060	0.033	0.087	0.033	0.087	0

Table A6. Total relation matrix (Tc).

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0.051	0.161	0.122	0.133	0.116	0.066	0.185	0.206	0.191	0.138	0.073	0.201	0.110	0.099	0.063
C12	0.059	0.045	0.054	0.083	0.058	0.042	0.121	0.162	0.117	0.114	0.065	0.111	0.102	0.102	0.056
C13	0.095	0.081	0.042	0.079	0.101	0.051	0.134	0.154	0.134	0.125	0.105	0.182	0.146	0.145	0.039
C14	0.027	0.059	0.046	0.031	0.057	0.038	0.076	0.140	0.103	0.082	0.060	0.119	0.093	0.066	0.024
C21	0.090	0.100	0.059	0.098	0.097	0.121	0.187	0.237	0.187	0.177	0.147	0.214	0.139	0.167	0.078
C22	0.127	0.145	0.149	0.137	0.215	0.084	0.241	0.251	0.215	0.179	0.167	0.226	0.165	0.195	0.115
C23	0.087	0.095	0.057	0.068	0.168	0.140	0.107	0.226	0.155	0.173	0.094	0.202	0.129	0.134	0.099
C31	0.076	0.086	0.082	0.081	0.145	0.101	0.135	0.105	0.161	0.178	0.058	0.177	0.067	0.094	0.039
C32	0.066	0.102	0.041	0.051	0.105	0.050	0.113	0.194	0.078	0.105	0.076	0.196	0.087	0.111	0.086
C33	0.043	0.049	0.045	0.073	0.028	0.048	0.035	0.069	0.064	0.031	0.022	0.067	0.028	0.027	0.015
C41	0.075	0.114	0.100	0.091	0.108	0.105	0.147	0.169	0.170	0.119	0.066	0.219	0.179	0.104	0.072
C42	0.040	0.051	0.063	0.071	0.116	0.079	0.149	0.120	0.125	0.095	0.127	0.098	0.138	0.088	0.063
C43	0.029	0.052	0.022	0.054	0.063	0.026	0.044	0.080	0.043	0.069	0.055	0.121	0.035	0.058	0.044
C51	0.098	0.086	0.073	0.103	0.132	0.108	0.168	0.187	0.117	0.085	0.090	0.156	0.103	0.072	0.067
C52	0.123	0.170	0.128	0.163	0.192	0.115	0.227	0.234	0.182	0.176	0.116	0.240	0.137	0.186	0.058

Table A7. Total relation matrix of dimensions.

	C1	C2	C3	C4	C5
C1	0.073	0.087	0.139	0.114	0.074
C2	0.101	0.151	0.200	0.165	0.131
C3	0.066	0.084	0.109	0.086	0.062
C4	0.064	0.093	0.110	.0115	0.071
C5	0.118	0.157	0.163	0.140	0.096

Table A8. Normalized Td matrix for dimensions.

	C1	C2	C3	C4	C5
C1	0.15	0.135	0.162	0.140	0.175
C2	0.179	0.202	0.206	0.205	0.233
C3	0.285	0.267	0.268	0.243	0.242
C4	0.234	0.22	0.212	0.254	0.208
C5	0.153	0.176	0.152	0.158	0.142

Table A9. The normalized total relation matrix (Tc).

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0.110	0.345	0.260	0.285	0.317	0.179	0.505	0.385	0.357	0.258	0.190	0.522	0.287	0.611	0.389
C12	0.244	0.188	0.225	0.342	0.264	0.188	0.548	0.412	0.298	0.290	0.234	0.399	0.367	0.646	0.354
C13	0.319	0.274	0.141	0.266	0.353	0.179	0.468	0.373	0.323	0.303	0.243	0.421	0.336	0.787	0.213
C14	0.166	0.362	0.280	0.191	0.333	0.220	0.447	0.431	0.318	0.251	0.219	0.437	0.344	0.731	0.269
C21	0.260	0.288	0.170	0.282	0.238	0.300	0.462	0.394	0.311	0.295	0.293	0.429	0.278	0.681	0.319
C22	0.227	0.259	0.268	0.246	0.398	0.156	0.446	0.389	0.334	0.277	0.299	0.405	0.296	0.630	0.370
C23	0.284	0.310	0.184	0.222	0.404	0.338	0.257	0.408	0.280	0.312	0.222	0.475	0.304	0.575	0.425
C31	0.234	0.265	0.252	0.249	0.381	0.265	0.354	0.237	0.362	0.401	0.191	0.588	0.221	0.703	0.297
C32	0.254	0.391	0.159	0.195	0.393	0.185	0.422	0.515	0.208	0.277	0.212	0.547	0.241	0.564	0.436
C33	0.204	0.233	0.214	0.348	0.250	0.435	0.315	0.418	0.393	0.188	0.191	0.570	0.239	0.652	0.348
C41	0.198	0.301	0.262	0.239	0.300	0.292	0.408	0.369	0.372	0.260	0.141	0.472	0.386	0.591	0.409
C42	0.180	0.226	0.279	0.315	0.338	0.229	0.433	0.353	0.368	0.279	0.350	0.270	0.380	0.581	0.419
C43	0.185	0.331	0.142	0.342	0.474	0.196	0.330	0.419	0.222	0.359	0.260	0.574	0.167	0.568	0.432
C51	0.272	0.238	0.203	0.287	0.324	0.265	0.411	0.481	0.302	0.218	0.257	0.447	0.296	0.517	0.483
C52	0.210	0.291	0.219	0.280	0.360	0.215	0.425	0.396	0.307	0.297	0.236	0.486	0.278	0.762	0.238

Table A10. Unweighted matrix in the present investigation.

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0.110	0.244	0.319	0.166	0.260	0.227	0.284	0.234	0.254	0.204	0.198	0.180	0.185	0.272	0.210
C12	0.345	0.188	0.274	0.362	0.288	0.259	0.310	0.265	0.391	0.233	0.301	0.226	0.331	0.238	0.291
C13	0.260	0.225	0.141	0.280	0.170	0.268	0.184	0.252	0.159	0.214	0.262	0.279	0.142	0.203	0.219
C14	0.285	0.342	0.266	0.191	0.282	0.246	0.222	0.249	0.195	0.348	0.239	0.315	0.342	0.287	0.280
C21	0.317	0.264	0.353	0.333	0.238	0.398	0.404	0.381	0.393	0.250	0.300	0.338	0.474	0.324	0.360
C22	0.179	0.188	0.179	0.220	0.300	0.156	0.338	0.265	0.185	0.435	0.292	0.229	0.196	0.265	0.215
C23	0.505	0.548	0.468	0.447	0.462	0.446	0.257	0.354	0.422	0.315	0.408	0.433	0.330	0.411	0.425
C31	0.385	0.412	0.373	0.431	0.394	0.389	0.408	0.237	0.515	0.418	0.369	0.353	0.419	0.481	0.396
C32	0.357	0.298	0.323	0.318	0.311	0.334	0.280	0.362	0.208	0.393	0.372	0.368	0.222	0.302	0.307
C33	0.258	0.290	0.303	0.251	0.295	0.277	0.312	0.401	0.277	0.188	0.260	0.279	0.359	0.218	0.297
C41	0.190	0.234	0.243	0.219	0.293	0.299	0.222	0.191	0.212	0.191	0.141	0.350	0.260	0.257	0.236
C42	0.522	0.399	0.421	0.437	0.429	0.405	0.475	0.588	0.547	0.570	0.472	0.270	0.574	0.447	0.486
C43	0.287	0.367	0.336	0.344	0.278	0.296	0.304	0.221	0.241	0.239	0.386	0.380	0.167	0.296	0.278
C51	0.611	0.646	0.787	0.731	0.681	0.630	0.575	0.703	0.564	0.652	0.591	0.581	0.568	0.517	0.762
C52	0.389	0.354	0.213	0.269	0.319	0.370	0.425	0.297	0.436	0.348	0.409	0.419	0.432	0.483	0.238

Table A11. Weighted matrix in the present study.

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0.016	0.037	0.048	0.025	0.035	0.031	0.038	0.038	0.041	0.033	0.028	0.025	0.026	0.048	0.037
C12	0.052	0.028	0.041	0.054	0.039	0.035	0.042	0.043	0.063	0.038	0.042	0.032	0.046	0.042	0.051
C13	0.039	0.034	0.021	0.042	0.023	0.036	0.025	0.041	0.026	0.035	0.037	0.039	0.020	0.035	0.038
C14	0.043	0.051	0.040	0.029	0.038	0.033	0.030	0.040	0.032	0.056	0.033	0.044	0.048	0.050	0.049
C21	0.057	0.047	0.063	0.059	0.048	0.080	0.082	0.079	0.081	0.052	0.062	0.069	0.097	0.075	0.084
C22	0.032	0.034	0.032	0.039	0.061	0.031	0.068	0.055	0.038	0.090	0.060	0.047	0.040	0.062	0.050
C23	0.090	0.098	0.084	0.080	0.093	0.090	0.052	0.073	0.087	0.065	0.084	0.089	0.068	0.096	0.099

Table A11. *Cont.*

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C31	0.110	0.118	0.106	0.123	0.105	0.104	0.109	0.063	0.138	0.112	0.089	0.086	0.102	0.117	0.096
C32	0.102	0.085	0.092	0.091	0.083	0.089	0.075	0.097	0.056	0.105	0.090	0.089	0.054	0.073	0.074
C33	0.074	0.083	0.086	0.072	0.079	0.074	0.083	0.107	0.074	0.050	0.063	0.068	0.087	0.053	0.072
C41	0.044	0.055	0.057	0.051	0.065	0.066	0.049	0.040	0.045	0.040	0.036	0.089	0.066	0.054	0.049
C42	0.122	0.093	0.098	0.102	0.094	0.089	0.104	0.124	0.116	0.121	0.120	0.069	0.146	0.093	0.101
C43	0.067	0.086	0.079	0.080	0.061	0.065	0.067	0.047	0.051	0.051	0.098	0.097	0.042	0.061	0.058
C51	0.093	0.099	0.120	0.112	0.119	0.111	0.101	0.107	0.086	0.099	0.093	0.092	0.090	0.074	0.108
C52	0.059	0.054	0.033	0.041	0.056	0.065	0.075	0.045	0.066	0.053	0.064	0.066	0.068	0.069	0.034

Table A12. Limited matrix during the computations of the present research.

	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43	C51	C52
C11	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345	0.0345
C12	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429	0.0429
C13	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329	0.0329
C14	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415	0.0415
C21	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709	0.0709
C22	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522	0.0522
C23	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821	0.0821
C31	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033	0.1033
C32	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825	0.0825
C33	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749	0.0749
C41	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546	0.0546
C42	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054	0.1054
C43	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657	0.0657
C51	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983	0.0983
C52	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584	0.0584

References

1. He, L.; Sopjani, L.; Laurenti, R. User participation dilemmas in the circular economy: An empirical study of Scandinavia's largest peer-to-peer product sharing platform. *Sustain. Prod. Consum.* **2021**, *27*, 975–985. [CrossRef]
2. Ramos, C.d.M.; Laurenti, R. Synergies and Trade-offs among Sustainable Development Goals: The Case of Spain. *Sustainability* **2020**, *12*, 10506. [CrossRef]
3. Akbarpour, N.; Salehi-Amiri, A.; Hajiaghaei-Keshteli, M.; Oliva, D. An innovative waste management system in a smart city under stochastic optimization using vehicle routing problem. *Soft Comput.* **2021**, *25*, 6707–6727. [CrossRef]
4. Nasrollahi, M.; Ghadikolaei, A.S.; Ghasemi, R.; Sheykhizadeh, M.; Abdi, M. Identification and prioritization of connected vehicle technologies for sustainable development in Iran. *Technol. Soc.* **2022**, *68*, 101829. [CrossRef]
5. Ahzahar, N.B.; Hashim, S.Z.B.; Zakaria, I.B.B.; Noor, N.N.M.; Rahman, N.A.B.A. Identification of Barriers and Challenges Faced by Construction Key Players in Implementing the Green Building Incentives in Malaysia. In *Sustainability Management Strategies and Impact in Developing Countries*; Din, M.F.M., Alias, N.E., Hussein, N., Zaidi, N.S., Eds.; Emerald Publishing Limited: Bingley, UK, 2022; Volume 26, pp. 209–218.
6. Luthra, S.; Pandey, H.; Garg, D. Identification and ranking of enablers of green lean Six Sigma implementation using AHP. Int. *J. Product. Qual. Manag.* **2018**, *23*, 187. [CrossRef]
7. Fazli, M.; Afshari, A.; Hajiaghaei-Keshteli, M. Identification and ranking of risks in Green Building projects using the hybrid SWARA-COPRAS method. In Proceedings of the 11th International conference of Iranian Operations Research Society, Kermanshah, Iran, 2–4 May 2018.
8. Mathiyazhagan, K.; Datta, U.; Bhadauria, R.; Singla, A.; Krishnamoorthi, S. Identification and prioritization of motivational factors for the green supply chain management adoption: Case from Indian construction industries. *OPSEARCH* **2018**, *55*, 202–219. [CrossRef]
9. Luthra, S.; Garg, D.; Haleem, A. Identifying and ranking of strategies to implement green supply chain management in Indian manufacturing industry using analytical hierarchy process. *J. Ind. Eng. Manag.* **2013**, *6*, 930–962. [CrossRef]
10. Karji, A.; Namian, M. Identifying the Key Barriers to Promote Sustainable Construction in the United States: A Principal Component Analysis. *Sustainability* **2020**, *12*, 5088. [CrossRef]

11. Yadegaridehkordi, E.; Hourmand, M.; Nilashic, M.; Alsolami, E.; Samad, S.; Mahmoud, M.; Alarood, A.A.; Zainol, A.; Majeed, H.D.; Shuib, L. Assessment of sustainability indicators for green building manufacturing using fuzzy multi-criteria decision making approach. *J. Clean. Prod.* **2020**, *277*, 122905. [CrossRef]
12. Wu, Z.; Jiang, M.; Cai, Y.; Wang, H.; Li, S. What hinders the development of green building? An investigation of China. *Int. J. Environ. Res. Public Health* **2019**, *16*, 3140. [CrossRef] [PubMed]
13. Firdaus, A.; Setiawan, T.H.; Reynaldy, J.I. Barriers to the implementation of green construction: A case study in Bandung, Indonesia. *Int. J. Integr. Eng.* **2018**, *10*, 1–7. [CrossRef]
14. Ping, A.; Chan, C.; Darko, A.; Olubunmi, A.; Effah, E. Critical barriers to green building technologies adoption in developing countries: The case of Ghana. *J. Clean. Prod.* **2018**, *172*, 1067–1079. [CrossRef]
15. Abraham, P.S. Cities and the Environment (CATE) 'Greening' the Buildings—An Analysis of Barriers to Adoption in India 'Greening' the Buildings—An Analysis of Barriers to Adoption in India. *Cities Environ.* **2018**, *10*, 10.
16. Nguyen, H.T.; Skitmore, M.; Gray, M.; Zhang, X.; Olanipekun, A.O. Will green building development take off? An exploratory study of barriers to green building in Vietnam. *Resour. Conserv. Recycl.* **2017**, *127*, 8–20. [CrossRef]
17. Yang, J.; Yang, Z. Critical factors affecting the implementation of sustainable housing in Australia. *J. Hous. Built Environ.* **2015**, *30*, 275–292. [CrossRef]
18. Shen, W.; Tang, W.; Siripanan, A.; Lei, Z.; Duffield, C.F. Understanding the Green Technical Capabilities and Barriers to Green Buildings in Developing Countries: A Case Study of Thailand. *Sustainability* **2018**, *10*, 3585. [CrossRef]
19. Wilson, J.L.; Tagaza, E. Green Buildings in Australia: Drivers and Barriers. *Aust. J. Struct. Eng.* **2006**, *7*, 57–63. [CrossRef]
20. Deng, W.; Yang, T.; Tang, L.; Tang, Y.-T. Barriers and policy recommendations for developing green buildings from local government perspective: A case study of Ningbo China. *Intell. Build. Int.* **2018**, *10*, 61–77. [CrossRef]
21. Nasereddin, M.; Price, A. Developments in the Built Environment Addressing the capital cost barrier to sustainable construction. *Dev. Built Environ.* **2021**, *7*, 100049. [CrossRef]
22. Darko, A.; Zhang, C.; Chan, A.P.C. Drivers for green building: A review of empirical studies. *Habitat Int.* **2017**, *60*, 34–49. [CrossRef]
23. Ayarkwa, J.; Opoku, D.G.J.; Antwi-Afari, P.; Li, R.Y.M. Sustainable building processes' challenges and strategies: The relative important index approach. *Clean. Eng. Technol.* **2022**, *7*, 100455. [CrossRef]
24. Yang, J.L.; Tzeng, G.-H. An integrated MCDM technique combined with DEMATEL for a novel cluster-weighted with ANP method. *Expert Syst. Appl.* **2011**, *38*, 1417–1424. [CrossRef]
25. Chou, Y.C.; Yang, C.H.; Lu, C.H.; Dang, V.T.; Yang, P.A. Building criteria for evaluating green project management: An integrated approach of DEMATEL and ANP. *Sustainability* **2017**, *9*, 740. [CrossRef]
26. Tsui, C.-W.; Tzeng, G.-H.; Wen, U.-P. A hybrid MCDM approach for improving the performance of green suppliers in the TFT-LCD industry. *Int. J. Prod. Res.* **2015**, *53*, 6436–6454. [CrossRef]
27. Chiu, W.; Tzeng, G.; Li, H. Knowledge-Based Systems A new hybrid MCDM model combining DANP with VIKOR to improve e-store business. *Knowl.-Based Syst.* **2013**, *37*, 48–61. [CrossRef]
28. Hsu, C.; Wang, F.; Tzeng, G. Resources, Conservation and Recycling The best vendor selection for conducting the recycled material based on a hybrid MCDM model combining DANP with VIKOR. *Resour. Conserv. Recycl.* **2015**, *66*, 95–111. [CrossRef]
29. Darko, A.; Chan, A.P.C. Critical analysis of green building research trend in construction journals. *Habitat Int.* **2016**, *57*, 53–63. [CrossRef]
30. Masrom, M.A.N.; Rahim, M.H.I.A.; Ann, S.C.; Mohamed, S.; Goh, K.C. A Preliminary Exploration of the Barriers of Sustainable Refurbishment for Commercial Building Projects in Malaysia. *Procedia Eng.* **2017**, *180*, 1363–1371. [CrossRef]
31. Zhang, X.; Platten, A.; Shen, L. Green property development practice in China: Costs and barriers. *Build. Environ.* **2011**, *46*, 2153–2160. [CrossRef]
32. Azeem, S.; Naeem, M.A.; Waheed, A.; Thaheem, M.J. Smart and Sustainable Built Environment Examining barriers and measures to promote the adoption of green building practices in Pakistan. *Smart Sustain. Built Environ.* **2017**, *6*, 86–100. [CrossRef]
33. Hoffman, A.J.; Henn, R. Overcoming the Social and Psychological Barriers to Green Building. *SSRN Electron. J.* **2008**, *21*, 390–419. [CrossRef]
34. Chakravarthy, P.R.K.; Suganya, R.; Nivedhitha, M.; Parthiban, A.; Sivaganesan, S. Barriers and project management practices in green buildings. *Mater. Today Proc.* **2022**, *52*, 1131–1134. [CrossRef]
35. Wimala, M.; Akmalah, E.; Sururi, M.R. Breaking through the Barriers to Green Building Movement in Indonesia: Insights from Building Occupants. *Energy Procedia* **2016**, *100*, 469–474. [CrossRef]
36. Darabpour, M.; Sardroud, J.M.; Smallwood, J.; Darabpour, M.; Tabarsa, G. A legal management model towards sustainable development: An approach in Iranian green construction. *Environ. Dev. Sustain.* **2022**, *24*, 7874–7895. [CrossRef]
37. Keshavarz-Ghorabaee, M.; Amiri, M.; Hashemi-Tabatabaei, M.; Zavadskas, E.K.; Kaklauskas, A. A New Decision-Making Approach Based on Fermatean Fuzzy Sets and WASPAS for Green Construction Supplier Evaluation. *Mathematics* **2020**, *8*, 2202. [CrossRef]
38. Wang, Y.; Chong, D.; Liu, X. Evaluating the Critical Barriers to Green Construction Technologies Adoption in China. *Sustainability* **2021**, *13*, 6510. [CrossRef]
39. Kaswan, M.S.; Rathi, R. Investigating the enablers associated with implementation of Green Lean Six Sigma in manufacturing sector using Best Worst Method. *Clean Technol. Environ. Policy* **2020**, *22*, 865–876. [CrossRef]

40. Wu, Z.; Li, H.; Feng, Y.; Luo, X.; Chen, Q. Developing a green building evaluation standard for interior decoration: A case study of China. *Build. Environ.* **2019**, *152*, 50–58. [CrossRef]
41. Abdel-Raheem, M.; Lima, J. A Framework for Assessing the Economic Feasibility of LEED for Homes Guidelines for Water Efficiency. In Proceedings of the Construction Research Congress 2018, New Orleans, LA, USA, 2–4 April 2018.
42. Shojaei, P.; Bolvardizadeh, A. Rough MCDM model for green supplier selection in Iran: A case of university construction project. Built Environ. *Proj. Asset Manag.* **2020**, *10*, 437–452. [CrossRef]
43. Chan, A.; Darko, A.; Effah, E.; Owusu-Manu, D.-G. Barriers Affecting the Adoption of Green Building Technologies. *J. Manag. Eng.* **2016**, *33*, 04016057. [CrossRef]
44. Aghlmand, R.; Gheibi, M.; Takhtravan, A.; Kian, Z. Implementation of green marketing frameworks based on conceptual system designing by integration of PESTLE, classical Delphi and MCDM modeling. *SN Bus. Econ.* **2022**, *2*, 1–33. [CrossRef]
45. Joshi, A.; Kale, S.; Chandel, S.; Pal, D.K. Likert scale: Explored and explained. *Br. J. Appl. Sci. Technol.* **2015**, *7*, 396. [CrossRef]
46. Abadi, M.; Moore, D.R. Selection of Circular Proposals in Building Projects: An MCDM Model for Lifecycle Circularity Assessments Using AHP. *Buildings* **2022**, *12*, 1110. [CrossRef]
47. Kurinjimalar Ramu, M.R.; Nathiya, M.; Manjula, M. Green Supply Chain Management; with Dematel MCDM Analysis. *Recent Trends Manag. Commer.* **2022**, *2*, 8–15.
48. Erol, I.; Ar, I.M.; Peker, I.; Searcy, C. Alleviating the impact of the Barriers to circular economy adoption through blockchain: An investigation using an integrated MCDM-based QFD with hesitant fuzzy linguistic term sets. *Comput. Ind. Eng.* **2022**, *165*, 107962. [CrossRef]
49. Luo, W.; Sandanayake, M.; Hou, L.; Tan, Y.; Zhang, G. A systematic review of green construction research using scientometrics methods. *J. Clean. Prod.* **2022**, *366*, 132710. [CrossRef]
50. Mojumder, A.; Singh, A.; Kumar, A.; Liu, Y. Mitigating the barriers to green procurement adoption: An exploratory study of the Indian construction industry. *J. Clean. Prod.* **2022**, *372*, 133505.
51. Nelms, C. Russell, A.D.; Lence, B.J. Assessing the performance of sustainable technologies for building projects. *Can. J. Civ. Eng.* **2005**, *32*, 114–128. [CrossRef]
52. Dawood, S.; Crosbie, T.; Dawood, N.; Lord, R. Designing low carbon buildings: A framework to reduce energy consumption and embed the use of renewables. *Sustain. Cities Soc.* **2013**, *8*, 63–71.
53. Ahn, Y.H.; Pearce, A.R. Green construction: Contractor experiences, expectations, and perceptions. *J. Green Build.* **2007**, *2*, 106–122. [CrossRef]
54. Breakwell, G.M. Models of risk construction: Some applications to climate change. *Wiley Interdiscip. Rev. Clim. Change* **2010**, *1*, 857–870. [CrossRef]
55. Si, J.; Marjanovic-Halburd, L.; Nasiri, F.; Bell, S. Assessment of building-integrated green technologies: A review and case study on applications of Multi-Criteria Decision Making (MCDM) method. *Sustain. Cities Soc.* **2016**, *27*, 106–115. [CrossRef]
56. Avotra, A.A.R.N.; Chenyun, Y.; Yongmin, W.; Lijuan, Z.; Nawaz, A. Conceptualizing the state of the art of corporate social responsibility (CSR) in green construction and its nexus to sustainable development. *Front. Environ. Sci.* **2021**, *541*, 774822. [CrossRef]
57. Diyana, N.; Abidin, Z. Motivation and expectation of developers on green construction: A conceptual view. *Int. J. Humanit. Soc. Sci.* **2013**, *7*, 914–918.
58. Moosavi, J.; Fathollahi-Fard, A.M.; Dulebenets, M.A. Supply chain disruption during the COVID-19 pandemic: Recognizing potential disruption management strategies. *Int. J. Disaster Risk Reduct.* **2022**, *75*, 102983. [CrossRef]
59. Soleimani, H.; Chhetri, P.; Fathollahi-Fard, A.M.; Mirzapour Al-e-Hashem, S.M.J.; Shahparvari, S. Sustainable closed-loop supply chain with energy efficiency: Lagrangian relaxation, reformulations and heuristics. *Ann. Oper. Res.* **2022**, 1–26. [CrossRef]
60. Seydanlou, P.; Jolai, F.; Tavakkoli-Moghaddam, R.; Fathollahi-Fard, A.M. A multi-objective optimization framework for a sustainable closed-loop supply chain network in the olive industry: Hybrid meta-heuristic algorithms. *Expert Syst. Appl.* **2022**, *203*, 117566. [CrossRef]
61. Pasha, J.; Nwodu, A.L.; Fathollahi-Fard, A.M.; Tian, G.; Li, Z.; Wang, H.; Dulebenets, M.A. Exact and metaheuristic algorithms for the vehicle routing problem with a factory-in-a-box in multi-objective settings. *Adv. Eng. Inform.* **2022**, *52*, 101623. [CrossRef]
62. Tian, G.; Yuan, G.; Aleksandrov, A.; Zhang, T.; Li, Z.; Fathollahi-Fard, A.M.; Ivanov, M. Recycling of spent Lithium-ion Batteries: A comprehensive review for identification of main challenges and future research trends. *Sustain. Energy Technol. Assess.* **2022**, *53*, 102447. [CrossRef]
63. Ni, S.; Liu, H.; Li, Q.; Quan, H.; Gheibi, M.; Fathollahi-Fard, A.M.; Tian, G. Assessment of the engineering properties, carbon dioxide emission and economic of biomass recycled aggregate concrete: A novel approach for building green concretes. *J. Clean. Prod.* **2022**, *365*, 132780. [CrossRef]
64. Gheibi, M.; Eftekhari, M.; Akrami, M.; Emrani, N.; Hajiaghaei-Keshteli, M.; Fathollahi-Fard, A.M.; Yazdani, M. A Sustainable Decision Support System for Drinking Water Systems: Resiliency Improvement against Cyanide Contamination. *Infrastructures* **2022**, *7*, 88. [CrossRef]
65. Tian, G.; Fathollahi-Fard, A.M.; Ren, Y.; Li, Z.; Jiang, X. Multi-objective scheduling of priority-based rescue vehicles to extinguish forest fires using a multi-objective discrete gravitational search algorithm. *Inf. Sci.* **2022**, *608*, 578–596. [CrossRef]