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Exploring the Barriers to Managing Green Building Construction Projects and Proposed Solutions

Ruveyda Komurlu [1,*], Dilara Kalkan Ceceloglu [2] and David Arditi [3]

[1] Department of Architecture, Kocaeli University, Kocaeli 41300, Turkey
[2] Independent Researcher, Ankara 06010, Turkey; dilarakalkann@gmail.com
[3] Department of Civil, Architectural and Environmental Engineering, Illinois Institute of Technology, Chicago, IL 60616, USA; arditi@iit.edu
* Correspondence: ruveydakomurlu@gmail.com or ruveyda.komurlu@kocaeli.edu.tr

Abstract: Sustainability has gained importance in the building design/construction industry due to the increase in the need for energy, the extensive use of non-renewable resources, and therefore the damage caused to the environment by traditional building design and construction. The concept of green building was developed for this reason. Green buildings can be defined as structures that consume less water, energy, and other resources while emphasizing human health and protecting the environment. While green buildings have these advantages over traditional buildings, the rate of green building production is less than expected because many barriers are encountered during the design and production of green buildings, despite the recent attention paid to sustainable practices. This research focuses on exploring the barriers encountered during green building production in Turkiye and the possible solutions for overcoming these barriers. According to the data obtained through a questionnaire survey, the most important difficulties encountered in Turkiye include the lack of government subsidies, the lack of green building regulations, the public's indifference to green building technologies, and education and technology deficiencies. According to the respondents, the possible solutions involve government incentives, adoption of national standards and best practices, educating the public and the design/construction professionals about green buildings, and the development of novel green building technologies. The major contribution of the findings is that it highlights the fact that the stakeholders of green building projects (i.e., owners, designers, constructors, and facility managers) face important barriers and lets stakeholders recognize that solutions to overcome these barriers are available. The major implication is that the stakeholders in green building projects will likely be better prepared to deal with any barrier before undertaking green building projects in Turkiye and countries with similar socio-economic conditions.

Keywords: sustainability; green buildings; construction industry; project management; architecture

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1. Introduction

The construction industry plays a major role in meeting social needs and improving the quality of life. In addition, buildings consume a significant amount of energy during construction and through their life cycle, creating a negative impact on the environment. Due to the heightened environmental consciousness and an increased emphasis on environmental preservation, the principle of "sustainable development" began to gain widespread prominence approximately three decades ago [1]. Sustainable development on building scale directed construction companies to cultivate strategies that promote sustainable practices. The strategies developed led to the concept of green building. Although the definition of green building keeps evolving and is not easy to state because of different interpretations by different researchers [2], green buildings involve designs that focus on using existing resources more efficiently in the construction, operation, maintenance, and demolition of buildings. Additionally, improved indoor environmental quality improves human health [3]. This concept led to using environmentally friendly materials and resources, improving the quality of the indoor environment, protecting resources, and encouraging practices that reduce waste and consumption [4]. Supporting ecosystems, preserving natural resources, improving air and water quality, and decreasing waste production are among the environmental benefits of green buildings [5]. Green buildings have become a competitive alternative to conventional buildings as green buildings consume 35–40% less energy, have lower operating costs, and offer a healthier and more efficient living environment [6]. Overall, 30% of the operation costs are energy expenses [7]. According to Zuo and Zhao [8,9], green buildings introduce 30% savings in operational costs and 55% in energy costs. The economic benefits of green buildings include lower operation costs, supporting markets for green materials and services, higher occupant productivity, and improved life cycle performance [5]. A significant number of research studies report green buildings' positive impact on the financial performance of properties and enhanced cash flows and property values [10]. Additionally, social benefits such as improving occupant comfort and health, minimizing strain on infrastructure, and promoting quality of life are provided by green buildings [9]. The building construction processes have also become more environment-friendly.

Although green building technologies contribute considerably to sustainable development, numerous problems arise in green building production in various parts of the world. Even though Turkiye, as a developing country, has an increasing interest in green building production, the number of studies focusing on the barriers to green building production in Turkiye is quite limited. Although the benefits of green buildings are numerous, it is also necessary to recognize the challenges before one can promote green building production. Challenges may differ significantly from country to country depending on local conditions [11].

Turkiye is a developing country situated partly in Europe and partly in Asia. According to the IMF [12], as of 2023, Turkiye has the 17th biggest economy in the world measure by GDP. Turkiye is placed 2nd in ENR 250 with 42 construction companies, and 7th regarding the income [13]. The construction industry plays a pivotal role in the nation's economy, supplying approximately 5% of the GDP and accounting for 10% of the workforce [14]. The implementation of sustainable practices significantly influences both the economy and the environment. There are 1613 LEED-certified buildings, 54 BREEAM-certified buildings, 3 EDGE-certified buildings, 1 DGBN-certified building, and 23 BEST-certified buildings, for a total of 1694 green buildings, in Turkiye [15]. Considering that LEED is the most preferred certification system in Turkiye, it should be noted that the number of LEED-registered projects increased exponentially over the years, i.e. 37 in 2019, 39 in 2020, 64 in 2021, 116 in 2022 and 380 in 2023 [15]. However, the country is still behind the government's sustainability objectives [16]. Despite their advantages, there are barriers to implementing green building projects, which need to be addressed for wider acceptance. A number of studies focusing on barriers to green building production have been conducted in different countries with different social, political, and economic conditions. Several of these studies have been reviewed during this study. This study aims not only to identify the benefits of green buildings but also to explore the critical barriers to the management of green building construction projects in Turkiye and to propose solutions to eliminate these barriers. The remaining part of this paper is organized as follows. After discussing project management and architecture in Section 2.1, sustainability issues are described in Section 2.2 relative to architecture and building construction including an overview of the benefits and challenges of green buildings and the role of project management in sustainable design and construction. A detailed literature review is presented in Section 2.3, which identifies a total of 30 barriers encountered in 16 countries and explains why these 30 barriers are used in this study. Section 3 includes the methodology of the study, which involved the development of a survey tool that was administered to professionals employed by companies involved in green building production in Turkiye. After the presentation and discussion of the findings in Section 4, the conclusions of the study are reported in Section 5.

The primary aim of this research study is to investigate the barriers that impede the adoption and implementation of sustainable practices in the design and construction of buildings in Turkiye and other developing nations with similar socio-economic conditions. Governmental and commercial entities may develop strategies targeting these barriers based on the findings of this study.

2. Literature Review

Section 2.1 involves background information about the role of project management in building design and information. Section 2.2 is devoted to a discussion about sustainability in building design and construction. Finally, Section 2.3 reports on a review of the literature on barriers to green building design and construction.

2.1. Project Management and Building Design and Construction

A building construction project involves a set of activities performed in a set period of time with a predetermined start and end. The inputs and outcomes of a building construction project have significant economic, social, and environmental impacts on society in the long term. Therefore, it is important that projects are carried out using well-established and effective project management principles. Each building construction project is unique and involves numerous stakeholders with differing priorities concerning costs, risks, and environmental sensitivities. While architects are in charge of architectural design, engineers are involved in the geotechnical, structural, mechanical, and electrical design; contractors build the building; subcontractors deal with specialty works; and financial institutions provide the funds necessary for design and construction. Once construction is complete, facility managers operate and maintain the constructed facility. The Project Management Institute (PMI) has divided the project management processes into scope, communication, budget, time, human resources, supply, risk, quality, stakeholder, and integration management [17]. In the competitive environment of the building construction industry, projects can be completed in minimum time with minimum cost, maximum safety, and maximum quality by using resources efficiently, coordinating the works of subcontractors effectively, and taking minimum risk. Having a solid project management strategy and effective time and cost planning and control are among the key factors for the success of a building construction project. Project management in construction projects not only considers parameters such as cost, time, quality, safety, productivity, and environmental impact but also requires a comprehensive relationship between the stakeholders. With the increasing competition in the industry and the increasing complexity of the projects, design, construction, and facility management companies are bound to organize their activities by using scientific management methods [18].

2.2. Sustainability in Building Design and Construction

Buildings constitute the main cause of environmental pollution. According to the United Nations Environmental Program [19], buildings and the construction industry consume 36% of the global energy produced and 39% of the carbon emission related to energy use. Climate change, disproportionate population growth, global warming, environmental pollution, and a rapid increase in natural resource consumption greatly affect the design, construction, and operation of buildings. The increasing demand for energy raises concerns about environmental problems. According to Gilman [20], sustainability is maintaining a healthy balance between natural resources and the ecosystem. Goksal [21] states that sustainability involves protecting the environment while transferring natural resources to future generations. A clearer definition of sustainability involves using resources without depleting them. In the context of this study, sustainability focuses on the economic and environmental impacts of an endeavor in all phases of a project, including planning, design, construction, operation, and demolition. Sustainable construction has emerged since the incorporation of the concept of sustainability into the construction industry [22]. Due to mounting concerns about the environment, sustainable construction has gained importance in most countries. Building certification systems and green practices are being developed in growing numbers all around the world [23]. Sustainability principles are applied throughout the entire life cycle of a building from pre-design to demolition. Thus, project plans are created and managed such that the negative effects on the environment are minimized [24]. In sustainable design, construction, and operation of a building, the use of materials, water, and energy is carefully monitored for the interest of future generations [25]. Given their traditional role of providing creative, functional, and aesthetically pleasing designs, architects occupy a special position in the sustainability movement because the architect acts as the leader of the team that contributes to the design, construction, and operation of a building. As such, the architect is the initiator of sustainable practices and the one who encourages engineers and constructors to use sustainable materials and methods.

2.2.1. Advantages and Disadvantages of Green Buildings

According to Yudelson [26] green buildings are structures that have the least negative impact on human health and the environment throughout the life cycle of the building and consume the least water and energy. Green buildings reduce buildings' negative impacts on the environment, such as CO_2 emissions, depletion of natural resources, and high energy consumption. Green buildings consume approximately 40% less energy than existing traditionally designed buildings [6]. Today, many companies around the world design and construct green buildings. Indeed, green buildings account for a growing share of the existing building stock worldwide and are considered promising investments for the future.

The concept of green building involves sustainability and high performance. The design, construction, operation, and demolition of a green building has not only reduced the negative impacts of buildings on the environment but also has economic and social importance for society [27]. Indeed, green buildings are more efficient than conventional buildings, more economical to operate, and healthier and more comfortable for users [28].

The management of green building projects should consider the different and sometimes conflicting objectives of the stakeholders, possibly via integrated project management, hence maximizing the benefits of stakeholders including owners, designers, contractors, subcontractors, suppliers, users, and society at large [29].

Sustainable buildings can become a source of material for new buildings after they are demolished. Some materials recovered after a green building is demolished may return to nature to help with sustainability efforts or may be used in new buildings, thus preventing the rapid depletion of these materials [25].

Despite the expected positive impacts of green buildings, some barriers may be encountered in the adoption of green principles in building production. Many advanced and industrialized countries such as the U.S., the U.K., Canada, Germany, France, Denmark, Italy, Japan, Australia, and China, as well as some developing countries such as Egypt [2], India, United Arab Emirates, Turkiye [11], Brazil [30], and Indonesia [31], have fully adopted green building principles. Some countries, such as Finland [2], Myanmar [32], and Ghana [33], are in the process of adopting them. While investigating the advantages of green buildings, it is also necessary to identify the challenges faced in green building projects. Some of the barriers that limit the adoption of green building production are listed below:

- The contracts and specifications needed for green building projects are different from those prepared for traditional buildings [34,35];
- The materials used in green building projects are more costly than those used in traditional building projects [6,16,34–37];
- The design processes take longer than those in traditional building projects [38–41];
- The availability of experts on green buildings is limited [42];
- There are only a few training programs about green building design, construction, operation, and demolition [1,4,16,35–38,42–53];
- Government support is limited [1,4,37,43,44,48–50,54].

2.2.2. Integration of Sustainability with Building Project Management

Regular project management does not specifically address sustainability issues [55]. The design and construction of sustainable buildings may necessitate the use of special project management services that ensure the use of sustainable resources, attention to energy consumption, and sensitivity to environmental impacts.

The inclusion of the concept of sustainability in project management processes brings a new perspective to the construction industry, enabling project managers to make business plans and perform stakeholder management by considering the most appropriate resources and practices for use in a sustainable project with the objective being the minimization of the negative social, economic, and environmental impacts of construction projects. The demands of the customers who will use the relevant sustainable structure can be met with effective project management that involves effective planning, judicious choice of materials and methods, and energy conservation alternatives.

Some processes in construction project management differ from those in other industries. These differences have an impact on the activities included in the project timeline and the roles assigned to stakeholders [56]. Similarly, to meet the expectations for a project while maintaining a sustainable construction life cycle, some changes have to be introduced to the traditional project management processes and practices. Kibert [57] proposes seven principles for the integration of the concept of sustainability into project management practices:

- Minimizing resource usage;
- Ensuring the reuse of natural resources;
- Using resources suitable for recycling;
- Preventing damage to nature;
- Removal of harmful substances;
- Minimizing life cycle cost;
- Emphasizing quality.

The construction industry’s share of material, water, and energy use is relatively high. In addition, a considerable amount of waste is produced, which causes pollution. On the other hand, ignorance on the part of society at large of the positive impact of implementing sustainability principles in building projects may result in a lack of demand for green buildings [58].

There are a number of ways to minimize the negative impact of construction activities [59]. For example, the use of green building certification systems such as LEED and BREEAM is encouraged to determine the sustainability levels of buildings. However, project stakeholders must collaborate closely to fulfill the certification requirements [60]. The professionals who manage green building projects should be well trained in green practices throughout the entire project [61]. Banihashemi et al. [62] state that the implementation of sustainable alternatives in project management practices should be conveyed from clients and stakeholders to a skilled, trained, and certified workforce. Indeed, Yilmaz et al. [60] assert that in green building projects, integrated project delivery (IPD) is a better alternative than the traditional design–bid–build project delivery method because IPD involves early collaboration between the stakeholders that begins at the very beginning of the design phase of a project. According to Kibert [63], in IPD, green building stakeholders should have a good understanding of sustainability, the efficient use of resources, and the certification processes while being open to using advanced building technologies, energy conservation techniques, state-of-the-art software, and effective communication between the stakeholders [64]. IPD also enables all stakeholders to express their opinions any time during the project and ensures that the project is carried out in a cost- and time-effective way. The differences between using IPD and the traditional design–bid–build in green building projects are summarized in Table 1.

Table 1. Comparison of traditional design–bid–build vs. integrated project delivery (adapted from [56,65,66]).

Traditional Project Delivery (Design–Bid–Build) System	Integrated Project Delivery (IPD) System
Short term	Long term
Aims at maximizing stakeholders' benefits	Aims at maximizing present and future generations' benefits
Focuses on delivery	Focuses on life cycle
Focuses on scope, time, budget	Focuses on humans, earth, benefits
Is simple	Is complex
Provides gradual design information shared rarely	Provides pre-loaded design information shared often
Emphasizes first cost	Emphasizes life cycle cost
Offers limited options for synergy	Enhances synergy
Team members are involved at particular times	All team members are always involved
Shows linear progression, with design first and construction later	Design is continuously improved, even during construction
Provides limited optimization	Provides optimized performance
Each team member carries individual risk	Team members share risk

2.3. Review of the Literature on Barriers to Green Building Design and Construction

The adoption of green building principles by stakeholders in the construction industry has not been very extensive probably because of a number of barriers such as higher first cost; radically different materials, methods, and technologies; lack of interest from the general public; lack of adequate research and development; and lack of government support. A literature review was conducted to identify the barriers encountered in green building projects in as many countries as possible. The results are summarized in Table 2.

Table 2. Barriers to green building projects in different countries.

Country	Reference	Categories of Barriers to Green Building Projects						
		Project Conditions	Contract Environment	Cost of Construction/Operation	Training and Education	Cost and Availability of Materials	Green Technologies	Government Support
Australia	Wilson and Tagaza, 2006 [34]	✓		✓		✓		
Brazil	Kasai and Jabbour, 2014 [1]				✓		✓	✓
China	Hasan and Zhang, 2016 [36]; Zhang et al., 2011 [35]	✓	✓	✓	✓	✓		
Ghana	Kineber et al., 2022 [43]; Chan et al., 2017 [44]				✓		✓	✓
Hong Kong	Qian et al., 2015 [54]							✓

Table 2. *Cont.*

Country	Reference	Categories of Barriers to Green Building Projects						
		Project Conditions	Contract Environment	Cost of Construction/Operation	Training and Education	Cost and Availability of Materials	Green Technologies	Government Support
India	Luthra et al., 2013 [45]; Yang, 2006 [46], Potbhare et al., 2009 [47]				✓		✓	
Iran	Kamranfar et al., 2022 [67]	✓	✓	✓				
Italy/Spain	Orsi et al., 2020 [38]	✓			✓			
Kuwait	Alsanad, 2015 [4]				✓			✓
Malaysia	Samari et al., 2013 [48]; Abdul Hamid et al., 2023 [49]; Wong and Voon, 2020 [50]		✓	✓	✓			✓
Singapore	Hwang and Ng, 2013 [68]; Hwang and Tan, 2012 [69]		✓	✓				
Sweden	Persson and Grönkvist, 2015 [51]			✓	✓		✓	
Saudi Arabia/South Africa	Hamed, 2019 [52]; Mosly, 2015 [42]; Jacobs, 2015 [53]		✓		✓		✓	
Thailand	Chaisaard and Taemthong, 2018 [6]	✓	✓	✓		✓		
Turkiye	Akcay, 2023 [16]; Komurlu and Gonel, 2020 [37]			✓	✓	✓		✓

In a study conducted about the problems encountered in green building projects in Singapore, the need for longer time in the design and construction processes, the high costs of environmentally friendly materials, the limited choice of subcontractors providing green building services, and the longer time from design to construction are stated as difficulties [68,69].

In another study conducted about the problems encountered in green building projects in Thailand, the barriers are listed as project costs being higher than expected, the emergence of hidden costs throughout the project life cycle, the high frequency of meetings and difficulties in coordination, adversities in supplying materials, and the lack of information about the materials [6].

In an investigation performed on the problems encountered in green building projects in Malaysia, the indexed barriers are current customers' lack of interest in green building projects, lack of experience, lack of technical procedures, lack of resources in information technologies, lack of government support, and the delays in delivery to the operation [48], whereas another study adds the issues of additional construction costs and increased maintenance costs [49].

A review of the problems encountered in green building projects in China identifies the barriers as the interpretation of the specifications prepared for green building projects, lack of coordination between stakeholders, problems in material supply, increases in initial investment costs, and lack of public awareness [35,36].

In a study conducted about the problems encountered in green building projects in Ghana, high project costs, insufficient information on green building materials, and insufficient R&D studies are listed as difficulties [44]. Additionally, lack of standards limits the adoption of green buildings in the construction industry [43].

In an investigation performed about the problems encountered in green building projects in Saudi Arabia and South Africa, the barriers are listed as the lack of training for the stakeholders, the lack of conducted studies in the literature regarding the country, and the lack of technical procedures [42,52,53].

According to a study conducted about the problems encountered in green building projects in Hong Kong, the main barrier is the construction permit process carried out by the government, which points to the lack of design guidelines [54].

In another study conducted about the problems encountered in green building projects in Kuwait, the indexed difficulties are the lack of interest of the stakeholders, the insufficient scope of state policies, and the inadequate level of awareness and attitudes towards energy efficiency [4].

In an investigation performed about the problems encountered in green building projects in Italy and Spain, the main barriers are stated as the lack of involvement of key stakeholders in the early stages of design and failure to perform scope management properly [38].

In a study conducted on the problems encountered in green building projects in Brazil, the lack of education of project stakeholders, the lack of literature on green building production, the inadequate coverage of government policies, and the limited selection of subcontractors providing green construction services were induced as barriers [1].

A review of the problems encountered in green building projects in Sweden identified the difficulties as the emergence of hidden costs, the lack of resources for green building technologies, and low willingness to take risks due to uncertainty [51].

In an investigation performed about the problems encountered in green building projects in India, the indexed barriers are the lack of training of stakeholders, problems in the technology infrastructure, and the insufficient level of R&D studies [45–47].

In a study conducted on the problems encountered in green building projects in Australia, the difficulties are listed as the lack of training for stakeholders, the high cost of environmentally friendly materials and equipment, and the inadequate scope of government policies [50].

A review made about the problems encountered in green building projects in Iran groups the barriers according to their weights. Economic barriers lead the list, followed by cultural and social barriers and then managerial barriers [67].

Finally, in an investigation performed about the problems encountered in green building projects in Turkey, higher construction costs, lack of knowledge about green buildings, lack of a green building rating system, unavailability of sustainable materials, and inadequate demand are listed as the main barriers [16]. Another study, by Komurlu and Gonel, 2020 [37], points to higher costs and lack of regulations.

3. Research Method

A flowchart of the methodology is presented in Figure 1. As seen in Table 2, a total of seven barrier categories were identified in the 17 countries surveyed by different researchers over the years. The barriers and the relevant references are listed in Table 3. When the literature was examined, it became apparent that each category was populated by a number of barriers. We categorized the 30 barriers as follows according to their relevance: 8 barriers in the category of Project Conditions, 4 in Contract Environment, 2 in Cost of Construction and Operation, 4 in Training and Education of the Stakeholders and the General Public, 3 in Green Technologies, 4 in Cost and Availability of Green Materials, and 5 in Government Support. The 30 barriers can be seen in Table 3. The calculation method for the mean impacts of the barriers is stated in Table 4. The 30 statements in Table 5 were presented to the respondents with a request to rate their impact relative to green building design and construction on a Likert scale of 1 to 5.

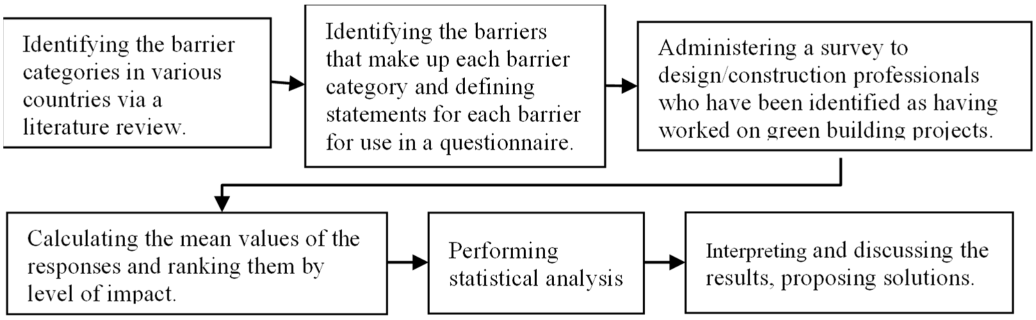

Figure 1. Flowchart of the methodology.

Table 3. Barriers to green building and the relevant references.

Barrier	Reference
Stakeholders' lack of interest in green building technologies	[4,36,43,44,47]
Weak communication between the stakeholders	[1,6,34,35,38,42,43,47,50,51,67,68]
Lack of experience in green building production	[6,16,34,35,38,44,45,48–50,52,54,67,68]
Difficulties in documentation processes	[6,43]
Commitment to traditional building technologies	[4,37,42,44,50,51]
Lack of trust in R&D about green building technologies	[38,44,50]
Distinct differences between green building and traditional building specifications	[6,34–36,38,42,44,51]
Higher risks in green building production than in traditional building production	[4,34,45,51,68]
Limited number of subcontractors that can provide green building production	[6,16,34,44,50]
Inability of the experts in a company to convey their green building experiences	[36,37,43]
Longer design time of green buildings	[6,16,34–36,50,68]
Different contractual arrangements in green building projects	[6,68]
Higher initial investment cost in green building production	[1,4,16,34,42–45,47–51,54,68,69]
Hidden costs discovered during the construction and operation of green buildings	[4,16,34–36,38,42,43,45,50,51,69]
Lack of public awareness about the long-term benefits of green buildings	[4,16,37,38,42–45,47–51,67]
Lack of literature on green building production	[1,44,48,49,52]
Lack of green building programs in universities	[37,44,47,48,53,67]
Insufficient training activities about green building production	[1,4,16,43,44,47–50,53]
Difficulties in adopting green building technologies	[16,34,52]
Scarcity of R&D in green building technologies	[16,43–45,47,50,51]
Lack of documentation about green building technologies	[6,36,45,47,48,50]
High price of green materials	[6,16,34,35,68]
Shortage of green materials	[16,34,43,44]

Table 3. *Cont.*

Barrier	Reference
Resistance to use green building materials	[34,36,50]
Lack of information about green building materials and technologies	[16,45,47,48,50,68]
Insufficient government subsidies for green building production	[4,42,44–50,67]
The lack of regulations about green building production	[1,4,35,37,43,45,47–50,54,67]
Insufficient government incentives offered to the public	[4,37,42,44–47,49,54,67]
Few public buildings with green building certification	[44,50]
Lack of recognition of the government's green building certification program	[36,42,44,46,47]

Table 4. Matrix of respondents (R_i) vs. barriers to green building production (B_j).

B_j / R_i	Barrier 1	Barrier 2	Barrier 3	...	...	...	Barrier 30
Respondent 1	R_1B_1	R_1B_2	R_1B_3	...	...	...	R_1B_{30}
Respondent 2	R_2B_1	R_2B_2	R_2B_3	...	...	...	R_2B_{30}
Respondent 3	R_3B_1	R_3B_2	R_3B_3	...	...	...	R_3B_{30}
⋮	⋮	⋮	⋮	...	...	...	⋮
⋮	⋮	⋮	⋮	...	...	...	⋮
⋮	⋮	⋮	⋮	...	...	...	⋮
Respondent 20	$R_{20}B_1$	$R_{20}B_2$	$R_{20}B_3$	...	...	...	$R_{20}B_{30}$
Mean Impact of Barrier B_j	$\frac{\sum_{i=1}^{20} R_iB_1}{20}$	$\frac{\sum_{i=1}^{20} R_iB_2}{20}$	$\frac{\sum_{i=1}^{20} R_iB_3}{20}$	...	...	...	$\frac{\sum_{i=1}^{20} R_iB_{30}}{20}$

Table 5. Impacts of the barriers to green building design and construction.

Barrier Category	Barrier	Mean Impact of Barrier	Category Order	Global Order
Project conditions AVE = 3.65 (α = 0.81)	Stakeholders' lack of interest in green building technologies	4.45	1	3
	Weak communication between the stakeholders	4.00	2	7
	Lack of experience in green building production	3.90	3	10
	Difficulties in documentation processes	3.80	4	15
	Commitment to traditional building technologies	3.70	5	18
	Lack of trust in R&D about green building technologies	3.35	6	27
	Distinct differences between green building and traditional building specifications	3.20	7	28
	Higher risks in green building production than in traditional building production	2.80	8	30

Table 5. *Cont.*

Barrier Category	Barrier	Mean Impact of Barrier	Category Order	Global Order
Contract environment AVE = 3.59 (α = 0.70)	Limited number of subcontractors that can provide green building production	3.85	1	14
	Inability of the experts in a company to convey their green building experiences	3.75	2	17
	Longer design time of green buildings	3.60	3	23
	Different contractual arrangements in green building projects	3.15	4	29
Cost of construction and operation AVE = 3.90 (α = 0.97)	Higher initial investment cost in green building production	3.90	1	10
	Hidden costs discovered during the construction and operation of green buildings	3.90	1	10
Training and education of the project stakeholders and the general public AVE = 3.80 (α = 0.88)	Lack of public awareness about the long-term benefits of green buildings	4.20	1	5
	Lack of literature on green building production	3.70	2	18
	Lack of green building programs in universities	3.70	2	18
	Insufficient training activities about green building production	3.60	4	23
Green technologies AVE = 3.82 (α = 0.89)	Difficulties in adopting green building technologies	4.20	1	5
	Scarcity of R&D in green building technologies	3.80	2	15
	Lack of documentation about green building technologies	3.45	3	26
Cost and availability of green materials AVE = 3.81 (α = 0.92)	High price of green materials	3.95	1	8
	Shortage of green materials	3.90	2	10
	Resistance to use green building materials	3.70	3	18
	Lack of information about green building materials and technologies	3.70	3	18
Government support AVE = 4.22 (α = 0.80)	Insufficient government subsidies for green building production	4.65	1	1
	The lack of regulations about green building production	4.50	2	2
	Insufficient government incentives offered to the public	4.40	3	4
	Few public buildings with green building certification	3.95	4	8
	Lack of recognition of the government's green building certification program	3.60	5	23

Note: α represents Cronbach's alpha coefficient.

This study used snowballing method of sampling (also known as chain-referral sampling), which allows referrals through social networks. In addition to the limited direct contacts, a number of professionals were approached via a business network platform, and these professionals were asked to share the survey with other equally qualified professionals. Snowball sampling is a non-probability sampling method whereby the sample is chosen by the researchers rather than being randomly selected [70]. It is often used in qualitative and exploratory research when the population is hard to reach or difficult to locate. In addition to being able to undertake studies when finding participants is challenging, a distinct advantage of snowball sampling is investing less money and time in planning and sampling. On the other hand, snowball sampling has limitations, including the possibility of bias because current participants select other participants and not knowing whether the sample is representative of the target population. For these reasons snowball sampling should be used only in exploratory research that is qualitative in nature [70].

The questions were answered by 20 professionals employed in the green building industry, including architects, civil engineers, mechanical engineers, and electrical engineers. The respondents had 11 to 25 years of experience in the management of green building projects.

The barriers mentioned in the literature review were examined under seven categories, and their solutions were explored. The categories were as follows:

- Project conditions;
- Contract environment;
- Cost of construction and operation;
- Training and education of the project stakeholders and the general public;
- Cost and availability of green materials;
- Green building technologies;
- Government support.

The 20 respondents rated the 30 barriers to green building production on a 1-to-5 Likert scale, where 1 represents no impact, 2 little impact, 3 moderate impact, 4 great impact, and 5 maximum impact on building design and construction. The data collected were stored in an ($i \times j$) matrix, where i represents the 20 respondents and j represents the 30 barriers (Table 4).

The mean impacts of the barriers B_j at the bottom row of Table 4 were calculated by dividing the sum of all respondents' ratings of that barrier by the number of respondents, as in Equation (1). The mean impacts of the 30 barriers on green building production are listed in the third column of Table 5.

$$Mean\ Impact\ of\ Barrier\ B_j = \frac{\sum_{i=1}^{20} R_i B_j}{N} \qquad for\ j = 1, 2, 3, \ldots, n \tag{1}$$

where R_i represents the respondents, N is the number of respondents (in this case 20 participants), and B_j represents the barriers (where j represents the barrier ID in the same order listed in Table 5, with j = 1, 2, . . . , n, and n = 30 barriers).

According to the demographic information obtained in the survey, the majority of the participants (12 out of 20 participants—60%) stated that they gained their green building experience by working with consulting companies, 11 out of 20 (55%) by following scientific and professional publications, 10 out of 20 (50%) by attending conferences and seminars, and 8 out of 20 (40%) through their teammates and co-workers. Only 1 out of 20 participants (5%) reported acquiring experience and knowledge via formal educational programs on green building production at universities. This information indicates that courses about green buildings offered at universities and available to practitioners are limited. Slightly over half of the participants (11 out of 20 participants—55%) stated that they closely follow technological trends for performing green building production, that their companies were able to easily adapt to green building technologies, and their companies had successfully transitioned to green building project management. According to 60% (12 out of 20 participants), there are no standard contracts specially designed for green building project management.

4. Findings, Discussion, and Recommendations

The average impacts of the 30 barriers organized in 7 categories, their order in the categories, and their global orders are presented in Table 5. The average impact of each barrier is calculated by dividing the sum of the ratings for a question by the number of responses to that question. The average impact of a barrier category is calculated by dividing the sum of the ratings for the category in question by the number of barriers in that category and is presented in the first column in Table 5.

There are various methods for checking the consistency of the data. Cronbach's alpha (α) coefficient is used to check the reliability of the results obtained. As seen in Table 5, the reliability values of all seven constructs meet Nunally's [71] recommendation, as the Cronbach's α values exceed 0.7 for all categories.

4.1. Global Order of the Barriers

The findings of this study are discussed in each category separately in the following Sections 4.2–4.8, and recommendations are introduced. However, at this early stage of the discussion, it is worth looking at the global ranking presented in the last column of Table 5. It is noteworthy that three of the five most cited barriers are in the Government Support category, indicating that government leadership is essential if green building production is to take root in the construction industry. The barriers comprise "insufficient subsidies provided by the government", "lack of regulations issued by the government", and "not enough incentives (e.g., tax incentives, lower interest rates, etc.) provided by the government to the public, i.e., potential building owners". All three of these barriers can be removed by government action, but such action has not been taken so far, indicating that currently the government is not persuaded that green building construction is advantageous in the long run.

In addition, "lack of stakeholder interest in green buildings" in the Project Conditions category, "lack of public awareness about the benefits of green buildings" in the Training and Education category, and "difficulties in adopting green building technologies" in the Green Technologies category are also in the top five most cited barriers and point to the fact that there is a disconnect between the potential building owners and sustainability issues in addition to the passive posture of the government relative to the lack of incentives to encourage sustainability practices in building design and construction. These and other barriers are discussed in detail in their respective categories 4.2, 4.5, and 4.6.

On the other hand, three of the five least cited barriers are in the Project Conditions category. These barriers comprise "higher risks in sustainable projects" in the Contract Environment category, "distinct differences between green building and traditional building specifications" in the Project Conditions category, and "lack of trust in R&D about green building technologies" in the Project Conditions category, pointing out to a lack of accumulated knowledge about the risks involved, the specifications currently in effect, and the novelties developed in research studies. This lack of maturity can only be addressed by education, training, and many years of experience with sustainable practices. These and other barriers categorized are discussed in detail in their respective categories in Sections 4.2 and 4.3.

In addition, the fact that "contractual arrangements in green building projects may be quite different than the contractual arrangements in conventional building projects" in the Contract Environment category and "the lack of adequate documentation about green building technologies" in the Green Technologies category are also part of the five least cited barriers. These barriers can easily be overcome by offering courses relevant to sustainable practices for the benefit of current university students, and by offering continuing education courses for the benefit of current practitioners in their professional life. The younger generation of university graduates as well as better trained practitioners should improve the quantity and quality of accumulated knowledge and experience in design firms and construction companies over the years. These and other barriers are discussed in detail in their respective categories in Sections 4.3–4.6.

4.2. Project Conditions

The most important barrier in this category is "the stakeholders' lack of interest in green building technologies". The barriers "lack of experience in green building production", "commitment to traditional building technologies", and "lack of trust in R&D about green building technology" are closely related to it.

According to Kamranfar et al. [67], these barriers are cultural and social in nature. A considerable number of professionals refrain green applications regarding the approval processes [72]. As a result, the owner's unfamiliarity with green technologies directly affects the owner's specifications [73]. Green building project owners must be sensitive to environmental problems and take the necessary precautions for the project. The lack of trust in green building technology and stakeholders' lack of interest in this technology must be addressed. Additionally, green building performance data should be recorded to guide new green building projects. Azeem et al. [74] suggest that creating public awareness of green projects is the most important action to follow to overcome these barriers.

Zhang et al. [35] and Wilson and Tagaza [34] suggest that technical difficulties encountered during green construction may be caused by the difference and complexity of green technologies and may partly explain the barriers "distinct differences between green building and traditional building specifications" and "commitment to traditional building technologies" Indeed, according to Hwang and Tan [69], alternative systems and materials are the factors that make the green construction processes more complicated than the conventional. Additionally, Orsi et al. [38], Marcelino-Sádaba et al. [39], Darko et al. [40], and Knotten et al. [41] claim that special equipment and materials, and green requirements in the specifications are major barriers to green construction.

The barrier "lack of experience in green building production" may be a direct result of the lack of experienced and knowledgeable staff in sustainable building construction. Designers and construction professionals can overcome this barrier by filling the positions in a green project team by professionals who have acquired a strong background specifically about green building principles in their college years and/or who have extensive field experience in green building production. Ayarkwa et al. [75] suggest that providing formal in-house training to the existing staff and exposing them to information about the benefits of green practices may also be a practical way to overcome this barrier.

According to Hasan and Zhang [36], the members of a green project team may gain experience in green building practices through strong communication. The barrier "weak communication between the stakeholders" should be addressed throughout the project, starting at the beginning of the project. Good communication is of critical importance for conveying experience between parties and may be a critical solution to the staff's lack of experience [68]. This situation is particularly a problem in the design–bid–build project delivery system, where the design is completed by the designer and the contractor is hired later. Communication is weak in this type of project delivery and may result in the designer designing without the input of the contractor, and the contractor facing numerous and sometimes quite severe constructability issues. It goes without saying that this fragmentation causes a severe deficiency in the transfer of knowledge and experience about green practices from the designer to the contractor and vice versa. A practical solution to this problem involves the use of an alternative project delivery system, namely Integrated Project Delivery (IPD) where the owner, the designer, the contractor, and the subcontractors are involved in the project from the very beginning and exchange ideas and experiences back and forth, hence improving communication between all stakeholders throughout the entire project, from planning to completion [56,65,66].

"Difficulties in documentation processes", which is another important barrier in the project conditions category, is among the major barriers in green building construction [6,76]. An effective project management involves proper project documentation.

The last barrier, in the project conditions category is "higher risks in green building production than in traditional building production". Since traditional building production is most common in the construction industry, all the parties involved in a project are familiar with and experienced in the processes and risks. The design phase has special importance because any changes performed in the succeeding phases produce cost overruns and delays [38,41,77]. Green building production introduces new risks because of the new requirements, methods, and technologies. The two solutions to overcome this barrier are education/training programs and experience sharing between professionals. Additionally, the green building concept should be integrated into the project at the feasibility stage resulting in minimizing the initial as well as the life cycle costs of a project.

4.3. The Contract Environment

"Limited number of subcontractors that can provide green building production" is the most important barrier in this category. According to the results of the survey conducted by Hwang and Ng [68], the limited number of competitive subcontractors specialized in building green is among the major barriers to green building construction. Actions to increase the number of subcontractors providing green building services should be taken, such as advertising the advantages of the green products and services provided by the subcontractors and certifying the subcontractors.

The second most important barrier in the contract environment category is "inability of the experts in a company to convey their green building experiences". Hasan and Zhang [36] argue that increases in the number of green buildings inevitably generate a larger number of green building experts. Expert project managers should share their knowledge and experience with stakeholders and ensure the dissemination of information.

"Longer design time of green buildings", which is another barrier in the contract environment category, is one of the major challenges faced by designers of green buildings [38–41]. The complexity of green building design introduces not only longer design time but also higher design costs [35]. The design of a green building takes a relatively longer time than the design of a traditional building because the design of a green building requires a special effort to avoid future changes, which in turn increases cost [38,41,77]. However, the higher design cost is instrumental in reducing project life-cycle cost by as much as 17% [78]. For example, it has been reported that operational costs for green buildings are 14% lower than traditional buildings [77,79].

"Different contractual arrangements in green building projects", which is the final barrier in the contract environment category, points to two important issues, namely, construction insurance and post-construction liability [36,80]. Thus, there is an increase in the green building warranty procedures [36]. Additionally, green building processes should be included in the general and technical specifications.

4.4. Cost of Construction and Operation

"Higher initial investment cost in green building production" is the most important of the two barriers in this category. Ayarkwa et al. [75] state that higher initial costs of green building practices constitute one of the key challenges for green building projects. Initial costs are incurred during the planning, design, and construction phases of a project. Chaisaard and Taemthong [6] state that setting goals for the project, integrating project teams, and launching a whole team design approach are the factors causing increased costs during the planning and design phases. To limit the impact of these, administrative institutions should support professionals working in green building production. The design of green buildings takes a longer time than the design of traditional buildings, which in turn results in higher design cost [38,41,77]. The construction phase, on the other hand, includes direct costs that consist of green production processes, green materials, and green technologies. Based on data collected from 1300 cases in 11 countries, Hu and Skibniewski [81] found that green buildings cost an additional 7% while other researchers claim that green buildings cost only 1.84% more than traditional buildings [82,83]. According to a report published in 2014, only 13.8% of office buildings in the U.S. and only 5.4% of the office buildings in the world are green buildings [84], which points out that the adoption of green buildings is limited worldwide. As a result, the availability of green production processes, green materials, and green technologies is limited, which results in higher costs. Actually, the fact that there are only a few green building projects undertaken because of the perception that the construction and operation of green buildings is costlier than traditional buildings is debatable. It is possible that the construction and operation of green buildings is costlier because of the fact that only a few green building projects are undertaken and consequently only a few and expensive alternatives of green processes, materials, and technologies are available. Regardless, as more green building projects are completed and as the availability (and therefore the cost) of green processes, materials, and technologies goes down it is expected that this barrier will be sidelined.

"Hidden costs discovered during the construction and operation of green buildings" is the other barrier in this category. In the process of adopting new technologies such as sustainable practices, a number of activities such as information gathering, learning how to use the new technology, and establishing connections with the suppliers need to be undertaken but are generally overlooked or ignored when project costs are estimated at the beginning of a project. These costs are known as hidden costs [51,85].

Hwang and Ng [68] state that green buildings cost higher than traditional buildings. According to Kats et al. [82], the cost of green buildings is 1–25% higher than the cost of traditional buildings. In addition to the highly complex design [35,68] and the use of water- and energy-saving equipment and high-performance insulation [36], one of the reasons for this higher cost is hidden costs. Stakeholders who are used to traditional building practices are often surprised by the higher cost of sustainable practices.

A consistent construction cost definition framework for cost comparisons and information share, a reliable cost database for the construction industry, and better education and training of cost professionals could be conducive to reducing high construction costs [81]. It must be noted however that it may be hard to define and address the hidden costs, since they are indirect and personnel-based.

Weerasinghe et al. [86] analyzed 38 green buildings in Sri Lanka and reported that green buildings' life cycle cost is 24–28% less than the life cycle cost of traditional buildings. Weerasinghe and Ramachandra [87] reported that the life cycle cost is 21% less than the life cycle cost of traditional buildings after reviewing 38 green industrial manufacturing buildings in Sri Lanka. Kats et al. [82], on the other hand, analyzing 33 green buildings in California, found that the overall savings for green buildings would be 20% of the construction cost.

4.5. Training and Education of the Project Stakeholders and the General Public

"Lack of public awareness about the long-term benefits of green buildings" was selected as the most important barrier in this category by the survey respondents. Buildings are assumed to have a life-span of 30 to 50 years [88]. As reported in Section 4.4, one of the biggest benefits of green buildings is that the life-cycle cost of design, construction, and operation of a green building is expected to be 20–30% less than the cost of traditional building [82,86,87] even though the initial cost of construction of green buildings is typically higher [36,82]. Additionally, green buildings have a positive impact on the environment. According to Abdul Hamid et al. [49], lack of awareness about a sustainable environment and its benefits is among the important challenges of green building production. Lack of awareness about the long-term benefits of green buildings results in limited support to green building production. To overcome this, construction owners, project sponsors, contractors, subcontractors, consultants, architects, and engineers should consider attending technical training activities about the benefits of green buildings if they have not done so already, while the general public takes advantage of the publicity in the media. Mosly [42] suggests raising awareness about sustainability and green buildings in schools, universities, and business events, as well as sharing success stories about green buildings on social media.

The next barrier in this category, namely "lack of literature on green building production" limits awareness and practice about green building production. Ashworth and Perera [89] argue that some research papers do not refer to practice, which limits their contribution to the industry. Mosly [42] suggests encouraging green building research studies. Academia and the green building industry should cooperate in transferring the results of research studies to green building practice.

"Lack of green building programs in universities" limits the introduction of professionals to the construction industry. According to a comprehensive analysis of the International

Renewable Energy Agency (IRENA) Renewable Energy Learning Partnership (IRELP) database, the following proportions of total courses in higher education are related to renewable energy: Europe, 40.9%; North America, 33.3%; Asia, 12.2%; Latin America, 6.7%; Africa, 6.3%; and Oceania, 3.2% [90,91]. Another research study reviews sustainability-related courses at five major public universities in Turkiye, and the ratios are 6.25% to 20.8%. Moreover, according to Cavas et al. [92], universities in Turkiye are not strong in sustainability education. Cortese [93] argue that higher education institutions have the liability of addressing the demand for sustainability issues. Therefore, courses about sustainable design and construction should be added to the curricula of architecture and engineering programs. Additionally, sustainability seminars and training programs targeting newly hired architects and engineers as well as continuing education courses targeting existing professional staff must be made available.

The final barrier in this category is "Insufficient training activities about green building production". Kineber et al. [43] point out that lack of research and training in green buildings is among the major barriers for implementing green buildings. Kasai and Jabbour [1] also report that lack of training available about new sustainable techniques is an important barrier. This barrier limits the success of green building practices, thus limit the public interest in sustainability. Kineber et al. [43] argue that there is need for training professionals working for design firms, contractors, and construction owners and that such programs can help overcome this barrier. Indeed, according to Milne [94], professional education including workshops, seminars, and online and in-person courses should contribute to the industry's awareness and knowledge about sustainability and green buildings by addressing the lack of skills.

4.6. Green Technologies

The most important barrier in this category is "difficulties in adopting green building technologies". Kasai and Jabbour [1] and Ayarkwa et al. [75] report that the most important barrier to adopting green building technologies is lack of training about these technologies. Supporting this, Kineber et al. [43] claim that training professionals and relating the benefits to potential clients are among the most important barriers. Indeed, Jacobs [53] confirms that the status quo in education poses an important barrier, and that it may take several years to revamp the educational offerings relative to sustainable technologies. Kasai and Jabbour [1] point out that this is the most difficult barrier to overcome, since it involves multiple stakeholders in sustainable design and construction. Mosly [42], on the other hand, reports that (1) the lack of competent professionals, which limits the design, construction, operation, and maintenance of green buildings; (2) the lack of information caused by limited technical data and manuals for operations and maintenance; and (3) the lack of reliability, which limits diffusion in the industry, are the main barriers to the adoption of green technologies. Shen and Zhang [95] propose that building a database of green building technologies and making enough information about the contribution of these technologies widely available to the project stakeholders may eliminate reliability-related concerns.

Hwang and Tan [69] argue that since project management teams are the key professionals of the design and construction activities, they play the primary role in enhancing and promoting the adoption of green building technologies. Focusing primarily on the training of project management professionals is expected to facilitate the adoption of green technologies. Kibert [63] claims that building up a well-trained project team in green technologies that includes the many stakeholders in green building design and construction such as the owner, the designer, the general contractor, the subcontractors, and the building operator at the preliminary stages of a project ensures a better understanding of project targets among the stakeholders and easier agreement between the stakeholders about anything related to green technologies.

"Scarcity of R&D in green building technologies" is the second most important barrier in this category and is supported by Wong and Voon's [50] work that argues that the lack of tested and reliable green building technologies is an important barrier to the adoption of green building technologies. Increased R&D activity focusing on green materials, equipment, methods, and practices is expected to improve the existing green building technologies and ease the adoption of these technologies.

The final barrier in this category is the "lack of documentation about green building technologies" confirming Wong and Voon's [50] argument that the project stakeholders' lack of knowledge about green building technologies and their benefits is an important barrier to the adoption of green building technologies. In addition, Hwang and Tan [69] found that the lack of information about green products and building systems is among the key challenges in green building project management. The training of designers and project managers should be increased, and project stakeholders should be encouraged to record and share their experiences about green practices.

4.7. Cost and Availability of Green Materials

"High price of green materials" was selected by the survey respondents as the most important barrier in this category. Hasan and Zhang [36] state that green buildings cost more than traditional building projects because of the higher cost of green materials. Wilson and Tagaza [34], argue that green building construction costs are up to 25% higher compared to the cost of traditional building projects. Green building materials generally cost 3–4% more than conventional materials [35]. A project manager has to complete the project within a pre-set budget [73], but this budget should be set after searching for new local materials and techniques that could be cheaper even though they satisfy the sustainability requirements.

"Shortage of green materials" is the next important barrier in this category. According to Hwang and Ng [68], availability of green materials and equipment is an important barrier, since green materials and equipment may not be as available as conventional materials and equipment. To minimize the impact of this barrier, a supply chain for imported green materials should be set up to minimize the time and cost of the procurement operation. However, legal regulations regarding imports and testing of imported materials should be accounted for [68].

Although "lack of information about green building materials and technologies" was ranked as the least important barrier in this category, this issue not only restricts the success of green practices but also contributes to another barrier, namely, "resistance to use green building materials". Hwang and Ng [68] argue that uncertainty about the reliability of green materials and equipment is the second most important barrier regarding the materials. Hasan and Zhang [35,36] report that the cost of green materials is among the major barriers to designing and constructing green buildings. According to Akcay [16], stakeholders should be informed not only about the long-term benefits of green buildings but also about the higher cost of green materials and equipment. Zhang et al. [35] suggest that green materials will be more attractive as the cost of green materials goes down over time. Spiegel and Meadows [96] claim that currently, the process to select green materials is identical to the process to select standard materials. In both instances, material categories are identified, performance criteria are examined, options are investigated, technical information is collected, the collected information is validated, the resulting materials are evaluated, and the final choice is documented in detail. However, Franzoni [97] points out that the real value of green materials becomes apparent only after a life cycle analysis.

Introducing databases that consist of not only cost but also technical properties of materials used in green building technologies can put an end to the chronic lack of information about green building materials and technologies and can encourage stakeholders to prefer green materials and technologies. These databases may be developed by design firms, construction companies, professional associations, academic researchers, or private for-profit entities.

4.8. Government Support

The barrier "insufficient government subsidies for green building production" was selected as the most important barrier among all barriers in this category. Wong and Voon [50], Alsanad [4], and Kasai and Jabbour [1] mention that the lack of government support for green building technologies in their respective countries affects the adoption of green building technologies. The upfront cost, the risk of investment, the lack of demand, and the higher final price of green buildings are listed as the main risks faced by investors and/or the contractor, some of which may be mitigated by public/credit resources [1]. A major move for overcoming this barrier would be tax deductions for green building production.

The "lack of regulations about green building production" is the second most important barrier both in this category, and in the whole study. According to Komurlu and Gonel [37], traditional building codes and regulations that do not deal with green building practices limit the applicability of green building projects. The compatibility between international and national standards, on the other hand, poses an important barrier which may be overcome by universally applicable measurement methods [98]. In the traditional centralized government system in Turkiye, most regulations are initiated and administered by governmental entities such as the Ministry of the Environment, Urbanization and Climate Change; the Ministry of Energy and Natural Resources; the Turkish Standards Institute. In addition to these agencies, non-governmental entities such as the Turkish Green Building Council (CEDBIK) and the Center for Building Applications and Research of Mimar Sinan Fine Arts University are promoting sustainable practices in building design and construction.

"Insufficient government incentives offered to the public" was ranked among the most important barriers by the respondents in this study. This barrier limits society's acceptance and adoption of green practices [47]. Liu et al. [99], Potbhare et al. [47], and Komurlu and Gonel [37] argue that a major motivation for adopting green practices in China, India, and Turkiye, respectively, is government incentives. Lack of interest in the public [37,47] may be overcome by government incentives. Thus, introduction of government incentives such as subsidies, tax incentives, lower interest rates are expected to increase green building production.

"Few public buildings with green building certification" is a barrier that emphasizes the reluctance of the public to build green. Government policies directly impact society's tendencies and behavior relative to green buildings. Governments are expected to lead industries and maximize pubic well-being. Kamranfar et al. [67] list the lack of governmental green buildings among the barriers to green practices. Mosly [42] argues that government should lead the industry towards green practices by converting major government projects into green buildings. The number of public buildings with green building certification should be increased.

"Lack of recognition of the government's green building certification program" is the final barrier in the "government support" category. Samari et al. [48] state that government has the obligation to address environmental concerns by encouraging green building production among other measures. However, governments generally argue that sustainability is local authorities' and companies' responsibility [36]. Nevertheless, government's lack of promoting sustainability and green practices via printed matter or online information slows down society's adoption of green buildings [47]. Thus, increasing the number of non-governmental organizations such as the Turkish Green Building Council (CEDBIK) should improve green building production.

This study points out that the five most important barriers affecting the green building construction industry in Turkiye include government policies that do not offer sufficient subsidies and tax incentives for green building production, the lack of regulations about green building design and construction, and stakeholders' and customers' lack of knowledge and interest in green building technologies.

5. Conclusions

Because of environmental concerns, sustainability has become a popular topic, first in industrialized and then in developing countries. However, various barriers hinder the adoption of green building production. This study aimed to explore the most common barriers cited in the literature, to survey Turkish construction professionals' opinions about these barriers, to rank the barriers by importance, and to propose solutions to overcome these barriers. The implications of the major findings and the proposed solutions are summarized in the following bullet points.

- ***The "government support" category*** (average importance rating = 4.22 out of 5.00) is the most important barrier to adopting green building practices. First of all, since the construction industry and economic growth are strongly related [100], investment in the construction industry has an important place in the government's budget, which means the government has a strong effect on the construction industry. Second, in some countries the government directs the construction industry through rules and regulations, such as building codes, fire protection codes, parking regulations, waste management policies, energy performance directives, general conditions of construction contracts, and national standards. According to the information in Table 2, the barriers related to government support were mentioned in papers related to only 5 of the 17 countries reviewed in this study [1,4,43,44,48–50,54], perhaps because certifications are generally issued by organizations other than government agencies. The findings of this study show that government-related barriers can be overcome by providing government subsidies to potential building owners, setting up government-initiated incentives such as tax breaks, and extensively using green practices in government-funded building construction, hence creating visible examples and promoting green practices in the industry. Converting major projects to green buildings and advertising them for publicity, as well as introducing appropriate regulations and incentives to promote green building practices, can also be used to overcome government-related barriers.
- ***The "cost of construction and operation" category*** is, not surprisingly, the second most important barrier category (average importance rating = 3.90 out of 5.00) as it is well known that the initial cost of designing and constructing a green building is higher than the cost of the same building designed and constructed by using traditional practices, which can be reduced by introducing productive and lean construction methods [101,102]. The literature [6,16,34–37,48–51,67,69] also suggests that the barriers in this category are extremely common in most of the 16 countries represented in Table 2. However, life cycle costs for green buildings are reported to be up to 28% less than the conventional buildings [86].
- ***The "green technologies" category*** (average importance rating of 3.82 out of 5.00) consists of barriers related to difficulties in adopting green practices, scarcity of R&D and lack of information, lack of training, and lack of proficient professionals. These barriers may be handled by (1) providing effective information transfer, (2) introducing training programs for designers, project managers, contractors, and owners, and (3) producing green building technology databases.
- ***The "cost and availability of green materials" category*** of barriers has an average importance rating of 3.81 out of 5.00. Although this category is the fourth most important according to the respondents, the literature, specifically [6,34–36], indicates that the barriers in this category impact green building design and construction undertaken only in Australia, China, and Thailand out of the 16 countries represented in Table 2. The higher price of green materials, the shortage of green materials, and the lack of widely available information about green materials cause resistance to the purchase and use of green materials on the part of designers and constructors. The four barriers in this category can be overcome by (1) considering the use of locally available materials, (2) providing a reliable supply chain for imported materials, (3) revising the legal requirements, (4) sharing information about available materials and the long-term benefits of green buildings, (5) performing life cycle cost analysis, and (6) developing databases for the cost and technical properties of green materials.
- ***The "training and education of the project stakeholders and the general public" category*** (average importance rating = 3.80 out of 5.00) consists of barriers such as lack of

public awareness about sustainability and green buildings as well as lack of training and information at all levels, from universities to the public in general. Although this category is only the fifth important according to the respondents, the large majority of the papers presented in Table 2 [1,35,38,42–53,67–69] points out that the barriers in this category are the most common around the world. This category consists of barriers such as lack of public awareness about sustainability and green buildings as well as lack of training and information at all levels, from universities to the public in general. Thus, (1) offering sustainability-related courses and programs at universities; (2) encouraging research studies at the graduate and undergraduate levels; (3) promoting green buildings to the community at large, including potential construction owners; and (4) organizing training programs for newly hired professionals, continuing education courses for current professionals in the workforce, and seminars and podcasts for the public looking to acquire property, are the proposed solutions.

- ***The "project conditions" category*** has an average importance rating of 3.65 out of 5.00. The barriers in this category stem from the industry's consistent adherence to traditional building practices over decades, and the marked difference between traditional and green building production. The proposed solutions are (1) keeping a comprehensive record of green building performance data; (2) enhancing public awareness of green buildings using the press, TV, and social media; (3) promoting coordination and cooperation among stakeholders as well as communication about the varied experiences of the different stakeholders; and (4) using effective documentation and proactive design approaches.
- ***The "contract environment" category*** (average importance rating = 3.59 out of 5.00) consists of barriers related to the nature of the construction industry where most participants are used to traditional building practices but are uninformed about sustainable practices. The ways to overcome these barriers may include (1) increasing the current number of subcontractors proficient in green building construction; (2) making sure that suppliers, designers, construction professionals, and owners are knowledgeable in and comfortable with green building practices, having acquired enough confidence after persistent and effective information exchange and training; (3) letting owners know that the design of green buildings takes a longer time but that the life cycle cost of green buildings is higher than the life cycle cost of traditional buildings; and, finally, (4) modifying contracts and specifications to include green building processes.

There are three minor limitations associated with the study presented in this paper.

- All participants in the survey undertaken in this study were professionals who had many years of experience in the construction industry, providing reliable information about the barriers to the adoption of green practices in building design and construction, but the first limitation is the limited number of survey participants (20 participants) and the sampling method used to select the participants (snowball sampling). For less bias and more generalizability, similar investigations can be performed in future studies with the participation of a larger number of professionals selected by random sampling out of a well-defined target population so that the results reflect the unbiased views of a larger portion of the target population relevant to the issue investigated.
- The second limitation of this study is that it is of local interest only, as the data come strictly from the Turkish construction industry. The barriers identified and the remedies for these barriers are valid only for the socio-economic conditions present in the Turkish construction industry and should not be used in any other country. However, the very same methodology can be used to duplicate this study in other countries in future research studies.
- The third limitation is that the impact of the barrier categories was calculated by taking the simple mean of the impacts of the barriers in each category (i.e., assuming equal weights for the barriers in each category). This assumption may be of minor impor-

tance, since the Cronbach's α coefficients turned out to be quite high. Nevertheless, different weight-generating methods can be explored in future research.

In conclusion, this study sheds light on the relative importance of common barriers to green building production as perceived by practitioners. The findings are expected to help researchers of green building-related issues target the most important barriers first and develop detailed solutions to overcome these barriers. The findings are also expected to help practitioners be better informed about green practices and to improve their operations in the field. Most important of all, the findings of this study are expected to help both governmental and commercial entities to set strategies for developing green building projects. Finally, the findings are expected to guide government policies relative to green building design and construction.

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