sustainability

MDPI

Article

Identifying the Key Barriers to Promote Sustainable Construction in the United States: A Principal Component Analysis

Ali Karji [1], Mostafa Namian [2,*] and Mohammadsoroush Tafazzoli [3]

[1] Department of Architectural Engineering, Pennsylvania State University, University Park, PA 16802, USA; azk644@psu.edu

[2] Department of Construction Management, College of Engineering and Technology, East Carolina University, Greenville, NC 27858, USA

[3] School of Design and Construction, Voiland College of Engineering and Architecture, Washington State University, Pullman, WA 99164, USA; tommy.tafazzoli@wsu.edu

* Correspondence: namianm19@ecu.edu; Tel.: +1-252-328-1382

Received: 25 May 2020; Accepted: 15 June 2020; Published: 22 June 2020

check for updates

Abstract: The need to build more facilities has intensified the inherited adverse impacts of the construction industry on the triple bottom lines of sustainability (i.e., people, planet, and profit). The current practice of sustainability in the construction industry is far from reaching the targeted green goals. In order to foster these endeavors, this study aims to explore sustainable construction barriers in the United States. To achieve the objective, first, 12 sustainability barriers were identified based on an excessive and comprehensive literature review and solicitation of experts' opinions to validate the barriers. Next, a questionnaire survey was developed and distributed among 135 industry professionals to evaluate the relative importance of factors. To offer a practical solution, principal component analysis (PCA) was used to analyze the data and find the most effective barriers. The results show that four major barriers, including (1) pre-construction constraints, (2) managerial constraints, (3) legislative constraints, and (4) financial and planning constraints are the most influential challenges that the industry faces to foster sustainable construction. Practical solutions are suggested to tackle sustainable construction barriers. The findings of this study are beneficial to the architecture, engineering, and construction (AEC) industry members along with owners and policymakers.

Keywords: sustainable construction; sustainability barriers; principal component analysis; construction management; sustainable development

1. Introduction

Constant population growth around the globe has increased the demand for housing and expansion of infrastructure. Consequently, the construction industry has become one of the fastest-growing sectors on a global scale. This has made public and private entities around the world pay much attention to the construction industry, as one of the leading drivers of economic growth in any country [1].

The rush to meet the massive demand for more facilities has intensified the inherited adverse impacts of the construction industry on the triple bottom line of sustainability (i.e., people, planet, and profit). Parallel to construction growth, the world is moving towards a global climate change which, according to scientists, can dramatically affect our lives in multiple respects. Alarming climate concerns have encouraged environmental activists to advocate for preventive measures that can mitigate or decelerate the detrimental effects of human activities on the environment. These measures can range from reducing greenhouse gas emissions, such as carbon dioxide (CO_2) and chlorofluorocarbons (CFC), to increasing reliance on renewable energy and decreasing waste to reduce, reuse, and recycle materials.

In the construction industry, green building initiatives have been developed to fulfill the need to meet sustainability goals. The term "green construction" is used to address practices in creating the built environment by minimizing its footprint on the natural or existing setting. In a broader vision, green construction has evolved into "sustainable construction", which considers the social and economic outcomes of construction in addition to its environmental impacts. Construction activities significantly influence the social, environmental, and economic aspects of sustainability [2]. In the construction industry, green building initiatives have been developed to fulfill the need to meet sustainability goals. The sustainable development trend in the construction industry has resulted in sustainable design and construction practices, as well as the development of sustainable rating systems. A construction project must pass minimum green-oriented requirements, to be implemented during the design, construction, and operation of a project, to receive a recognition badge in a sustainability rating system such as Leadership in Energy and Environmental Design (LEED). Although implementing these sustainability requirements might require initial cost, they provide owners and builders with a set of guidelines to mitigate the environmental, social, and economic issues that are associated with construction and operation processes. Despite great previous effort, the current practice of sustainability in the construction industry is far from reaching the green goals of the triple bottom line of sustainability (i.e., people, planet, and profit) to fully achieve sustainable construction. Recent research has shown that the construction industry requires a significant transformation to fully implement sustainable practices to contribute to the achievement of SDGs [3]. Therefore, the goal of this study is to shed light on challenges and barriers to sustainable construction practices in the US construction industry and foster the integration of sustainable practices. The results of this paper are expected to pave the way for sustainability practice implementation in the construction industry.

2. Literature Review

Endeavor to lower the high pressure on the environment and its resources can only be successful through a comprehensive collaboration of all parties and individuals [4]. The construction section is not an exception in this effort, as it holds a substantial role in creating as well as potentially preventing a wide variety of environmental concerns [5–7]. According to a report published by the United Nations (UN), the built environment is one of the primary contributors to four major environmental concerns: (1) greenhouse gas emissions, (2) potable water consumption, (3) electricity consumption, and (4) energy consumption (see Figure 1). Therefore, it is essential to seek strategies and approaches that can restrict the adverse impacts of the construction process.

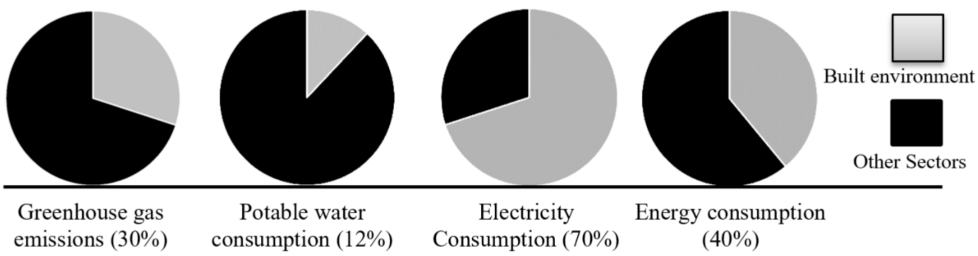

Figure 1. The share of the built environment in major environmental concerns (source: Tafazzoli 2017 [8]).

The term "sustainable development" emerged in the 1970s to describe a future in which the demand of future generations is not compromised by the existing generation [9,10]. A key objective of sustainable development is to identify the temporal and spatial patterns of use of the planet's resources as well as their availability, and design accordingly to balance the impacts of industries on natural resources [11]. Although the primary purpose of sustainable development is not to fight against climate change, it is inseparably bound to actions against it. Therefore, sustainable development practices can be a critical solution to contribute to sustainability on a global scale and mitigate climate change.

The UN has identified 17 sustainable development goals (SDGs), which can be categorized into three pillars: social, economic, and environmental sustainability goals [12]. Social sustainability promises a better and more equitable quality of life for people [13]. Zero hunger, no poverty, good health and well-being, and quality education are other examples of social sustainability. Economic sustainability is positive and smart economic growth without adversely affecting the environment or society. For example, the construction of soccer stadiums for the 2014 World Cup soccer tournament in Brazil was not economically sustainable, and it provoked the social opposition of protestors [14]. The taxpayers of Brazil demanded that $3.6 billion of stadium construction was invested in healthcare, education, and public transportation [15]. Finally, environmental sustainability includes vast sustainability practices to control and prevent undesirable environmental consequences such as air pollution by reducing the need for non-renewable energy sources. Examples of these practices include the use of sustainable materials, energy-saving systems, and sustainable waste management, to name a few [16–19].

Parallel to rapid population growth and the urbanization process, the construction industry must keep pace to supply the constantly growing housing and infrastructure demand [20–22]. There is abundant research that confirms the significant role of the construction industry in sustainable development [1,23–25], which indicates that, to contribute to sustainable development, investing in sustainable construction is instrumental [26,27]. The adverse impact of the construction industry on sustainable development could be explained in four categories of depleting natural resources, polluting the environment, generating solid and toxic wastes, and deforestation. The examples of each category are presented in Table 1 [28].

Table 1. The adverse impact of the construction industry on sustainable development (Source: Tafazzoli 2018 [28]).

Adverse Impact	Examples
Depleting natural resources	Energy resources, including natural gas, petroleum, coal; construction materials that are manufactured using non-renewable resources, e.g., cement, wood, soil, sand, gravel, clay, metals, limestone, granite, slate, bituminous, etc.
Polluting the environment	Air pollution (dust and particulate matter), water pollution (oil, paint, and chemicals), soil pollution (oil penetration, soil compaction, and removing vegetation), and noise pollution.
Generating solid and toxic wastes	Plastics, glass, wood, metals, chemicals, oil, etc.
Deforestation	Timber extraction, dam construction, and other infrastructure development in the proximity of forests.

The construction industry is a massive consumer of natural resources [29,30]. According to the Global Status Report, “buildings and construction together account for 36% of global final energy use and 39% of energy-related carbon dioxide” [6,31]. Figure 2 shows the share of global final energy consumption by sector, and the percentage of global energy-related CO_2 emissions by industry, in 2015. As can be seen, the construction industry alone accounts for 1/6 of the energy consumption of all sectors on a global scale and almost 27% of all energy-related CO_2 emissions generated by all sectors.

In addition, the construction industry, by its nature, drastically contributes to several types of pollution [32]. Dust pollution and distribution of particulate matter are a critical challenge for building projects in urban areas [33]. Construction activities also adversely impact surface water. Harbor (1999) [34] highlighted that sedimentation is the most significant pollutant on a construction project. According to Burton and Pitt (2001) [35], construction accounts for 10% of the sediment load to water bodies in the United States. In addition to sedimentation, construction activities release oils, paints, volatile organic compounds (VOCs), glues, diesel, cement, and other toxic chemicals to water and adversely impact the environment and social well-being [36].

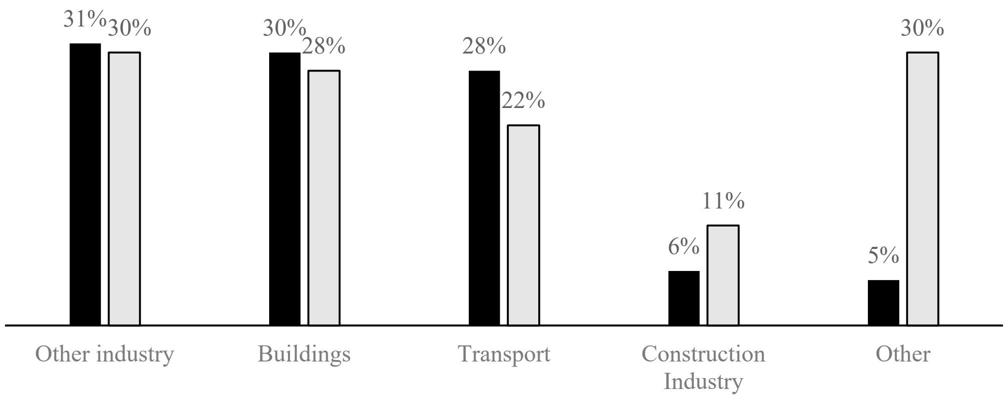

Figure 2. Share of global final energy consumption by sector (black) and percentage of global energy-related CO_2 emissions by sector (gray) in 2015.

Construction projects and, more particularly, construction equipment, intensify erosion and soil pollution and can create irreversible damage to the environment [37]. This type of pollution is commonly a result of oil leaks [38], soil compaction [39], and removal of vegetation [40]. Furthermore, noise pollution caused by construction equipment is considered one of the critical detriments of social sustainability [41]. The dramatic increase in the number of residential projects poses the threats of deforestation and losing undeveloped green space. In a study by Roger et al. (2017) [42], the authors investigated the impact of power line construction on deforestation in the Central African region. They mentioned that the falling of neighboring trees or their branches was a potential threat to the operation of power lines. However, the removal of trees is not an ideal solution because it can contributed to deforestation.

The literature highlights that sustainable construction requires a paradigm shift and transformation of processing methods in a holistic life-cycle approach that encompasses planning through to the destruction of buildings. This concept is shown in Figure 3 [26].

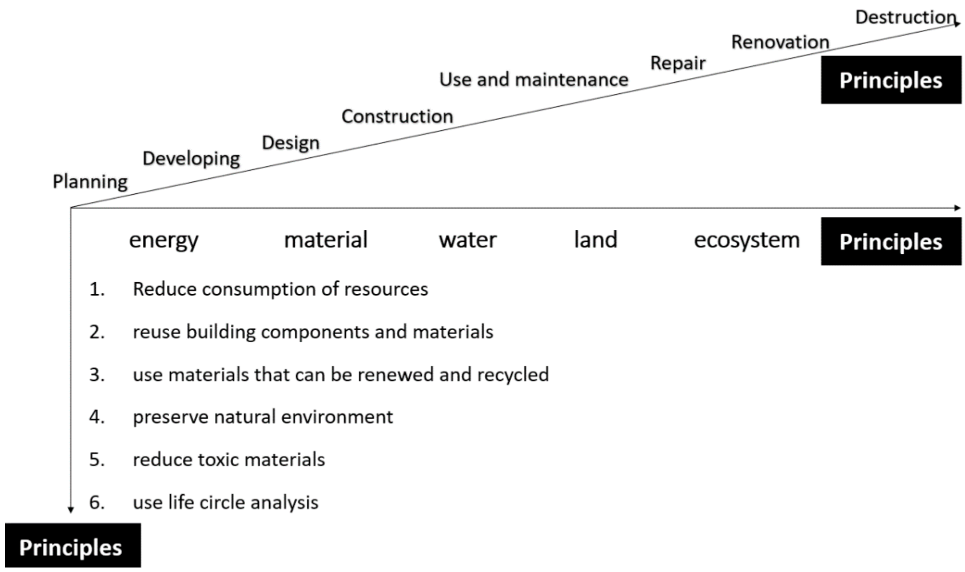

Figure 3. Sustainable construction model (Source: Kibert 2016 [26]).

Research studies on different aspects of sustainable construction can be divided into the following categories.

Group 1—Studies that investigate the negative impacts of the construction industry on the triple bottom lines of sustainability. In the previous section, some of these adverse impacts were discussed. Reviewing the literature indicates a gradual shift from studying the general adverse effects of construction, such as material consumption, to investigating more detailed and less noticeable effects, such as social sustainability.

Group 2—Studies that focus on creating more sustainable practices and methods for planning, design, construction, maintenance, renovation, and demolition of buildings. For instance, Panda et al. (2017) [43] introduced and studied the mechanical performance of 3D-printed fiber-reinforced concrete as a sustainable construction material.

Similarly, Achal and Mukherjee (2015) [44] studied biomineralization as a solution to reduce the demand for concrete as the most consumed artificial material on the planet. Chang et al. (2016) [45] studied the existing key policies of regulations and control in China to push the sustainable movement. It is worth mentioning that many studies in this category are region-specific and reflect the needs and potentials of shifting towards more sustainable practices in the construction industry. For example, in some countries, technology might be a major barrier for further implementation of construction sustainable practices, but that might not be the case in the US. In general, demography, culture, norms, background, and standards of a community can affect the process of identifying important barriers.

Group 3–A new trend that focuses on developing a strategic planning framework for sustainable development implementation. As an example of these studies, Cruz et al. (2019) [46], in a recent study, introduced the concept of "sustainable sustainability" in the construction industry. They provided a roadmap of actions and strategies for different stakeholders to plan for long-term sustainable development implementation.

Group 4–Studies that focus on developing specific sustainable assessment systems. Examples of this category include the research by Karji et al. (2019) [14], who developed a sustainable assessment system for mass housing construction, and Shuqin et al. (2019) [47], who developed a sustainability evaluation system for a university campus.

Group 5–Studies that investigate major barriers to sustainable construction. Acknowledging the conflicting interests of owners, contractors, and residents in what is called sustainable or "green" building has been highlighted in past research as a critical consideration in finding solutions to increase the sustainability of construction [8]. Table 2 summarizes the results of similar studies that focused on finding the impediments to applying sustainable practices in the construction sector [28].

Table 2. Primary barriers to the thriving of sustainability practices in the literature.

Author	Country/Region	Major Barriers
Van Bueren and Priemus (2002) [48]	Netherlands	Institutional factors
Studer et al. (2005) [49]	Hong Kong	Lack of a legal requirement to report sustainability, inadequate support from senior management, no demand from shareholders for sustainability reporting
Pitt et al. (2009) [50]	England	Low affordability
Pinkse and Dommisse (2009) [51]	Netherland	Costs for the contractors
Sourani and Sohail (2011) [52]	England	Lack of funding, restrictions on expenditure and reluctance to incur a higher capital cost when needed

Similar to in Group 2, the barriers to sustainable construction are mainly studied based on specific conditions in the studied region. For example, AlSanad (2015) [53] investigated the barriers to sustainable construction in Kuwait. Although the US is a leading country in the construction industry, limited research has been conducted to discover the barriers to promoting sustainable construction. In a limited study by Tafazzoli (2018) [28], a few barriers (e.g., unwillingness to pay the additional initial costs of the green buildings) were reported by interviewing a small sample of twelve construction professionals in the United States, primarily investigating the barriers only from the perspectives of owners and investors. Therefore, this study aims to be a comprehensive attempt to explore sustainable construction barriers in the United States and recognize the most influential obstacles. The methodology exercised to achieve the research objectives is explained in the following section.

3. Methodology

The methodology of the study consists of two phases. In Phase 1, a comprehensive literature review was conducted to identify sustainable construction barriers. Overall, this resulted in identifying 15 barriers. Then, based on experts' opinion, the authors validated and consequently narrowed down the 15 identified barriers to 12 items. In Phase 2, the barriers identified in Phase 1 were further investigated using a convenience sample of 135 industry experts, obtaining their perspectives on the importance of each barrier. The researchers asked the interviewed experts to determine how important each barrier is. The research study was reviewed and approved for exemption by the Institutional Review Board (IRB). Due to the diversity and the high number of identified barriers (i.e., 12 barriers), further analysis was conducted using principal component analysis (PCA) to reduce the number of variables and find the most important barriers to yield more practical results. Figure 4 shows the methodology's steps.

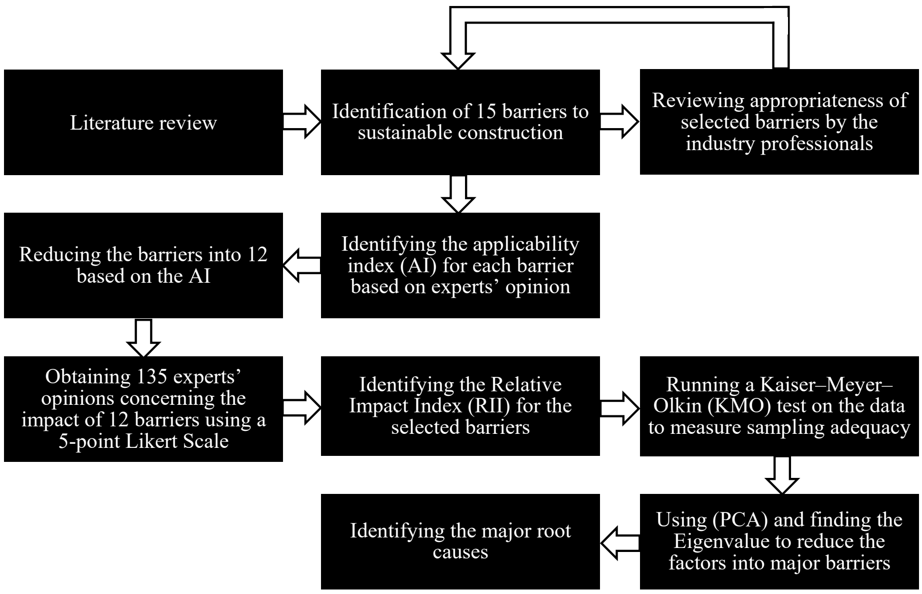

Figure 4. Research methodology scheme.

3.1. Phase 1—Identifying and Verifying Sustainable Construction Barriers

A comprehensive literature review was conducted to identify the most-cited sustainability development barriers in construction, reviewing relevant research studies in the construction industry and other related industries and fields. This extensive literature review resulted in the identification of 15 barriers, which are shown in Table 3.

To verify the authenticity and applicability of the sustainable construction barriers (SCBs) before a further investigation, 30 construction experts were asked to validate and evaluate the comprehensiveness and applicability of the barriers based on their experiences. They were also asked to suggest any other barriers that they thought the research team might have overlooked on the list. The experts were invited to participate in the study via email. One follow-up reminder was sent to the participant after initial invitation. The responses were collected over the course of six weeks in 2019. Out of 30 invited experts, 25 participated in the study, which corresponds to an 83.33% response rate. The participants identified themselves as experts and active in the field of construction. Three (12%) out of 23 participants had a valid LEED certificate. Although the experts made some comments about barriers, overall, due to the overlap of suggested and identified barriers, no more items were added to the list.

Table 3. Identified barriers to sustainable construction.

#	Sustainable Construction Barriers (SCBs)
1	Design constraints [54–58]
2	Financial constraints [55–62]
3	Improper contract method [54,57,58,63]
4	Inadequate proactive plans [57,58,64,65]
5	Inefficient legal framework [54,57,58]
6	Inefficient technology [55,58,59,61,63,66]
7	Insufficient commitment of upper-level management [56–58]
8	Insufficient environmental competencies [56–58,61]
9	Lack of awareness amongst stakeholders [54,56–59,63]
10	Lack of employee welfare package [60,65,67]
11	Lack of sustainable waste management [55–57,60,63,67]
12	Lack of worker's training in sustainable operations [55,57,59,61,63,64]
13	Management [54,55,57,61,64,65,68]
14	Political impacts [56–59,61,69–71]
15	Preferences of suppliers/institutional buyers [54–56,58,63,70]

The 25 experts expressed their opinions on the applicability of each barrier and rated them by choosing a number between "1: applicable barrier" or "0: not applicable barrier". Equation (1) was used to find the percentage of applicability for each barrier. The data were integrated and accordingly analyzed using XLSTAT 2019, and the results presented in Figure 5 were achieved.

$$AI_i = a_i/n, \quad (1)$$

where AI is the applicability index of barrier i; a is the number of respondents who rated SB_i as an applicable barrier; and n is the total number of participants (i.e., 25).

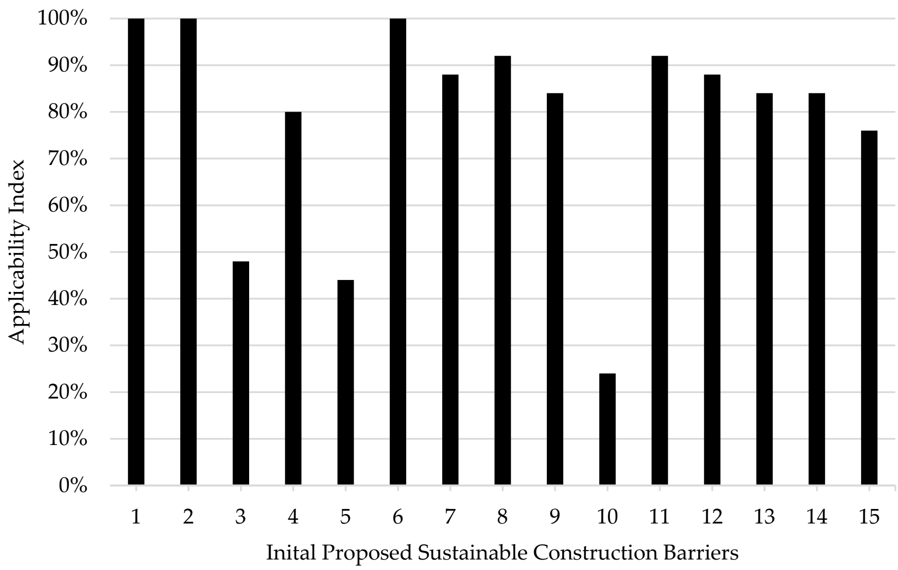

Figure 5. Applicability index of the initial proposed sustainable construction barriers.

Based on the primary results obtained from the experts, the research team decided to disregard the factors with a low applicability index (AI < 50%). Three factors fell below this limit, including "improper contract method," "inefficient legal framework," and "lack of employee welfare package."

Therefore, the number of barriers reduced to 12 from the initial 15 (see Table 4). The respondents noted that the "lack of employee welfare packages" could not be fulfilled "due to requirements by law." The respondents also mentioned their reasoning that an "improper contract method" could not be a barrier because "contracts can be written with the same framework as a typical building." Also, "an inefficient legal framework" cannot be a barrier because "sustainability rating requirement can be mentioned as part of the contract."

Table 4. Final sustainable construction barriers for investigation in Phase 2.

Sustainable Construction Barriers	Index
Design constraints	SCB01
Financial constraints	SCB02
Inadequate proactive plans	SCB03
Inefficient technology	SCB04
Insufficient commitment of upper-level management	SCB05
Insufficient environmental competencies	SCB06
Lack of awareness amongst stakeholders	SCB07
Lack of sustainable waste management	SCB08
Lack of worker's training in sustainable operations	SCB09
Management's unwillingness	SCB10
Political impacts	SCB11
Preferences of suppliers/institutional buyers	SCB12

3.2. Phase 2—Identifying the Most Important Barriers

In Phase 2 of the research, the 12 previously identified barriers were further studied. A questionnaire was designed and developed to gain experts' opinions on the importance of each barrier. The questionnaire had three parts. Part 1 of the survey had questions related to demographic information on the research participants. In part 2, each expert was asked to rate how they perceived the importance of the barriers. Finally, part 3 consisted of an open-ended question: "How do you see the future of sustainable construction in the US, and what makes sustainable construction move faster?"

First, to fulfill the research objectives, the researchers contacted active construction project job sites, mainly located in the southeast region of the country, and randomly interviewed construction professionals and experts. Over two months starting in March 2019, a total of 135 construction professionals participated in the research study. The interviewed participants had nationwide experiences working in 48 states (i.e., all the states of the USA except the states of Idaho and North Dakota). The demographic information on the interviewees is presented in Tables 5 and 6.

Table 5. Demographic information for the 135 survey respondents.

Experience (Years)				LEED Certification?	
0–10	11–20	21–30	+30	Yes	No
24.44%	27.41%	25.93%	22.22%	28.15%	71.85

Table 6. Demographic information for the 135 survey respondents, continued.

Current Job Title				
Project Manager	Superintendent	Project Engineer	Project Director	Other *
51.11%	14.07%	12.59%	5.18%	17.05%

* Including Owner, President, Vice President, Project Executive, Civil Engineer, MEP Coordinator, Safety Coordinator, and Production Manager.

Following part 1, the second part of the questionnaire was considered to capture the respondents' opinion on the importance of 12 sustainability barriers indicators on a five-point Likert scale from

1 (not important) to 5 (very important). Based on the collected answers, a number from 1 to 5 was assigned to each barrier. Numbers 1, 2, 3, 4, and 5 respectively represented “Not Important,” “Slightly Important,” “Moderately Important,” “Important,” and “Very Important.

After collecting the data, in order to identify the most critical barriers, the relative impact index (*RII*) of each obstacle was calculated using the following Equation (2). The method has been used in a wide variety of construction studies [72–76].

$$RII_i = \frac{\sum W_i}{(AN)}, \tag{2}$$

where:

RII = the relative impact index for barrier i;
$\sum W_i$ = the sum of all ratings from all experts for barrier i;
A = the highest possible rating permissible in the adopted scale (i.e., 5 in this study);
N = the total number of respondents (i.e., 135 in this study).

The *RII* equation provides an easily interpretable value. The value of *RII* ranges between 0 and 1, representing the lowest relative impact and highest relative impact, respectively. Table 7 shows the results, where the identified sustainable construction barriers are rank-ordered in accordance with their calculated *RII*. According to the table, “financial constraints” (*RII* = 0.912) and “political impacts” (*RII* = 0.653) were respectively rated as having the highest and lowest impact on the development of sustainable construction.

Table 7. Relative impact index for sustainable construction barriers.

Sustainable Construction Barriers	Index	*RII*	Rank
Financial constraints	SCB02	0.912	1
Insufficient commitment of upper-level management	SCB05	0.794	2
Management’s unwillingness	SCB10	0.788	3
Design constraints	SCB01	0.754	4 *
Inadequate proactive plans	SCB03	0.754	4 *
Lack of awareness amongst stakeholders	SCB07	0.733	6
Insufficient environmental competencies	SCB06	0.720	7
Lack of sustainable waste management	SCB08	0.710	8
Inefficient technology	SCB04	0.704	9
Lack of worker’s training in sustainable operations	SCB09	0.701	10
Preferences of suppliers/institutional buyers	SCB12	0.670	11
Political impacts	SCB11	0.653	12

* There was a tie between SCB01 and SCB03

3.3. Principal Component Analysis

Although identification of the sustainable construction barriers in the US revealed insightful results, the plurality of identified barriers is a major challenge to adopt feasible approaches to address the barriers. To offer a practical solution for construction professionals to cultivate the implementation of sustainable construction practices, principal component analysis (PCA) was used to reduce the size of the data and effective barriers. PCA is a popular method in scientific research to reduce the number of variables to a smaller amount and find the principal components that represent the essence of the original data. To do this, PCA identifies the variables that are similar and can be grouped to form a new variable. PCA is, particularly, an effective method to study variables that are difficult to measure with precision. One of the main advantages of applying the PCA is reducing the number of variables to just a few, which facilitates finding a parsimonious solution explaining the relationships between the variables. The identified principal components will be the main variables after the PCA method is implemented for a set of data. For every n variables, there will be n components. However, not all the components will be important or meaningful enough to keep. This means that, out of all the possible components, only those that can explain the variance in the data will be chosen as principal components. This is the mechanism of reducing the variables in PCA. This method has been extensively used in similar studies, where multiple variables are involved and reducing the variables would make it easier to study the important variables more effectively. Examples of the application of the PCA method can be found in numerous construction studies [32,77–79].

The data were analyzed using SPSS 2019 software. The Kaiser–Meyer–Olkin (KMO) test was performed on the data to measure sampling adequacy. The KMO test identifies whether the data is appropriate for PCA. Typically, a KMO sampling adequacy of more than 0.6 is acceptable [80,81]. The collected data received a 0.706 adequacy, indicating that the set of data is appropriate for PCA. For each component, the eigenvalue was calculated to determine how much variation in the data is explained by each component. The results of data analysis are provided in the next section.

4. Results and Discussion

To find the critical barriers to foster the development of sustainable construction, 135 construction experts were approached and interviewed in this study. The data pertaining to the respondents' opinions were then integrated and analyzed. Table 8 shows the descriptive information for the results.

Table 8. Descriptive statistics of the received data.

Sustainable Construction Barriers	N	Minimum	Maximum	Mean	Std. Deviation	*RII*	Rank
SCB01	135	1	5	3.77	1.085	0.754	4 *
SCB02	135	1	5	4.56	0.687	0.913	1
SCB03	135	1	5	3.77	0.992	0.754	4 *
SCB04	135	1	5	3.52	1.280	0.704	9
SCB05	135	1	5	3.97	1.051	0.794	2
SCB06	135	1	5	3.60	1.059	0.720	7
SCB07	135	1	5	3.67	1.153	0.733	6
SCB08	135	1	5	3.55	1.104	0.710	8
SCB09	135	1	5	3.50	1.196	0.701	10
SCB10	135	1	5	3.94	0.912	0.788	3
SCB11	135	1	5	3.27	1.367	0.653	12
SCB12	135	1	5	3.35	1.254	0.670	11

* There was a tie between SCB01 and SCB03.

Based on the experts' opinion, SCB2 or "financial constraint" has been identified as one of the most important sustainable construction barriers. On the other hand, SCB11 or "political impacts" received the lowest mean score among all the barriers.

4.1. Principal Component Analysis

In this study, the respondents were asked to rate the impact of each of 12 sustainable construction barriers on a scale of one to five. The SPSS 2019 software tool was used to apply the PCA method. As was mentioned before, PCA is a common method in scientific research to reduce the number of variables to a smaller amount, i.e., the principal components that represent the essence of the original data. To do this, PCA identifies variables that are similar and can be grouped to form a new variable. The goal is to extract the components that explain most of the variation in the data. For the dataset with 135 observations (i.e., the number of the participants) for 12 variables (i.e., identified construction barriers), PCA provides an approximation of the original dataset using a lower number of variables (less than 12 variables), formulated based on a linear combination of the original variables. Several sets of PCA directions or PCA modes can be calculated. In order to choose the principal components, three tests can be used, including the eigenvalue test, the scree plot test, and the proportion of the variances explained by the components test [82].

(1) Eigenvalue Test

In the eigenvalue test, for each PCA mode, an associated eigenvalue is calculated, which represents the variance in the original dataset explained by that specific mode. In order to determine the principal components, the eigenvalue of each component was calculated, as shown in Table 9. In the eigenvalue method, components that have an eigenvalue of greater than one will be selected, and those with an eigenvalue of less than one will be disregarded [83,84]. Using this rule will result in choosing components 1, 2, 3, and 4 and disregarding components 5, 6, 7, 8, 9, 10, 11, and 12.

Table 9. The eigenvalue of each component and the proportion of the corresponding variance in the data.

Component	Eigenvalue	Variance (%)	Cumulative Variance (%)
1	2.976	24.804	24.804
2	1.523	12.691	37.495
3	1.354	11.282	48.777
4	1.005	8.375	57.152
5	0.910	7.581	64.733
6	0.879	7.323	72.056
7	0.717	5.973	78.030
8	0.640	5.336	83.365
9	0.620	5.169	88.534
10	0.516	4.296	92.830
11	0.441	3.672	96.503
12	0.420	3.497	100.000

(2) Scree Plot Test

The components can also be chosen by using the scree plot (Figure 6). A scree plot is a common diagram that plots the eigenvalues from the greatest to the smallest.

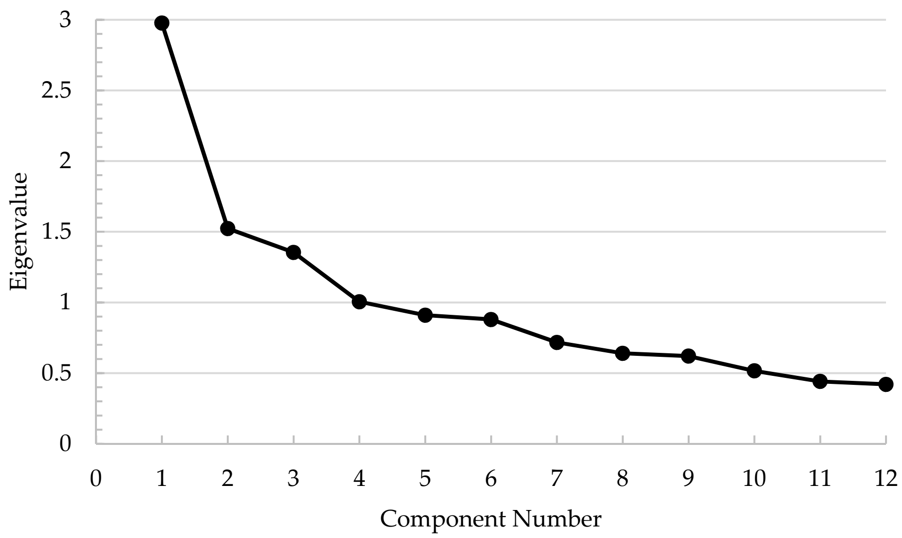

Figure 6. Scree plot of the principal components.

It is common to disregard components that appear after the elbow shape [85,86]. As seen in Figure 6, components 5 to 12 can be disregarded.

(3) Proportion of the Variance Explained by the Components Test

Using the variance method, those components that explain most of the variance in the data are selected. Usually, a proportion of the cumulative variance components greater than 70% is acceptable [87].

In this study, the cut-off value of 70% resulted in components 1 to 6 being chosen and components 7 to 12 being disregarded.

Therefore, the eigenvalue test resulted in proposing components 1 to 4, the scree plot test resulted in proposing components 1 to 4, and the proportion of the variances explained by the components' test resulted in proposing components 1 to 6 as the potential principal components. Therefore, the research team decided to choose components 1, 2, 3, and 4, as it was the result of two tests out of three, and to disregard components 5 to 12. The selected components 1 to 4 account for approximately 60% of the total variance in the data.

In the next step, to achieve a better understanding of the four components and how they are related to the 12 sustainable construction barriers, a rotated component matrix was used with the varimax rotation method (see Table 10). The rotated component matrix, as the result of principal components analysis, shows the correlations between each of the variables for the components in a more straightforward way than a regular factor matrix. The rotated component matrix also provides the factor loading of each variable (i.e., sustainable construction barrier) in the component. In other words, the rotated component matrix makes it easier to understand what each principal component represents. To obtain a better understanding of the correlations, a factor loading cut-off of 0.55 was employed (i.e., factor loadings ≥ |0.55|). The choice of cut-off varies depending on the ease of interpretation and determines how many variables are included in the PCA mode [88]. The cut-off criterion is also aligned with the factor loading cut-off used in several research studies [89,90].

Table 10. Rotated component matrix [a]

Barrier Index	Component			
	1	**2**	**3**	**4**
SCB01	0.704			
SCB12	0.670			
SCB09	0.576			
SCB05		0.747		
SCB08		0.720		
SCB11			0.849	
SCB02				0.742
SCB03				0.709

[a] Rotation converged in seven iterations. Extraction Method: principal component analysis. Rotation Method: varimax with Kaiser normalization.

The rotated component matrix shows the Pearson correlation of a variable with the components. The greater the loading factor of the variable, the more strongly it correlates with the component. By taking a closer look at component **1**, it can be observed that SCB1, SCB12, and SCB09 have a strong correlation with component **1**. Component **2** has a strong correlation with SCB5 and SCB08. Similarly, component **3** has a strong correlation with SCB11. Finally, component **4** has a strong correlation with SCB02 and SCB03. Although not required, researchers usually provide names for the components. In order to find a proper name for each component, it is recommended to study the variables that each component has a strong correlation with. Table 11 shows each component and the corresponding variables accompanied by the suggested name for each component. In the process of naming each component, the research team tried to incorporate the ideas in all the components' correlated variables.

In addition to rating the variables, the respondents provided insightful comments regarding major barriers to fostering implementation of sustainable construction. Using the content analysis, the outstanding comments and corresponding components are explored and presented in Table 12.

One of the most repeated comments was about the upfront cost of sustainable construction. One participant mentioned that "Owners are sometimes not willing to make the extra upfront investment for the sustainable alternative. The owner often prefers upfront savings (instant gratification) as opposed to long term savings. This can be attributed to the lack of education and awareness on the owner's part." Another respondent pointed out that "It is not cost-effective. By the time you start seeing the benefit of the building "green," the life of the building is about 75 percent passed."

Table 11. List of components, corresponding variables, and suggested names.

Component	Corresponding Variables with Strong Correlations	Suggested Names for Components
Component 1	• Design constraints • Preferences of suppliers/institutional buyers • Lack of workers' training in sustainable operations	Pre-construction constraints
Component 2	• Insufficient commitment of upper-level management • Lack of sustainable waste management	Managerial constraints
Component 3	• Political impacts	Legislative constraints
Component 4	• Financial constraints • Inadequate proactive plans	Financial and planning constraints

Table 12. Comments and the extracted barriers.

Comment(s)	Barrier
• "Paperwork involved. Lack of education of the entire industry, especially on items that are counted towards awarding of points to gain certification." • "The biggest barrier faced is people do not like to change their ways", "I believe that there are a lot of older people in construction that have resistance to change and I see it often costs too much to implement and teach everyone who works for you."	Pre-construction constraints
• "Management, Scheduling, and communication are some of the biggest barriers that are faced in sustainable building." • "We live in a world with so many older buildings that I do see a limitation on the adaptability of these buildings and how to incorporate sustainable systems without creating more waste. This would come down to cost and how much a company wants to spend to retrofit rather than demolish and rebuild. This is where I see some major sustainable constraints." • "The biggest barrier seems to be that the Client sees little to no reward for implementing sustainable building practices. If there were proven methods of sustainable building practices that showed quicker returns on investment, the clients would be more likely to use sustainable building practices." • "The technology is there. We just build what the owner wants us to build. If they don't design a green building, we don't build a green building."	Managerial constraints
• "Culture change resistance, lack of government commitment, fear of higher investment cost, lack of professional knowledge, and lack of legislation respectively." • "Lack of collaboration between different groups of professional and construction companies, lack of articulate demand, or inappropriate regulations." • "You also have a lot of struggles coordinating a LEED-certified building in particular because there is a lot of paperwork involved as well as extra work to check. For example, all unused materials have to be recycled properly to get LEED points."	Legislative constraints
• "Cost, maintenance of sustainable systems, limited trade knowledge of sustainable building practices." • "Certification fees are expensive. The cost of our industry has been rising. Therefore, budgets are tighter. Also, LEED doesn't have a good program for multi-family." • "Cost and Timeline." • "These projects typically take longer." • "Money is the barrier."	Financial and planning constraints

4.2. Complementary Inquiry

The questionnaire survey also included an open-ended question: "How do you see the future of sustainable construction in the US, and what makes sustainable construction move faster?" Most participants were optimistic, providing positive answers indicating that sustainable construction has a promising future and will continue to expand in the future. Among the responses, some experts provided valuable feedback, which can be perceived as suggested solutions to tackle the identified sustainability barriers in this study. Table 13 shows the suggested solutions and the corresponding barrier.

Table 13. Extracted proposed solutions to foster sustainable construction.

Barrier	Comment(s)	Proposed Solution
Pre-construction constraints	• "Finding a way to get qualified worker into the construction industry [will improve the sustainable construction practices]" • "I think that more sustainable projects will be considered in the future due to increased knowledge in the field of sustainability", "In the future sustainable construction could be a more common practice in the US. In order for this to be the case, though, people need to become more educated on the process, and there need to be options that do not cost much more than traditional methods."	Training workers and qualified employee acquisition
Managerial constraints	• "Climate change and reduces resources may also encourage sustainable building."	Climate change prevention advocacy
	• "Sustainable construction has a good future if only people are more aware of the topic. The younger generations are keener to get involved in sustainability if it is made more approachable." • "I see the future as a lot greener, at least that is my hopes. Currently, branding and social media presence have driven companies to be a lot more obvious about their sustainable practices."	Social awareness
	• "I hope there will be tax reduction to developers of sustainable construction projects to encourage and take it to the next level.", "Has worked our various LEED projects. Thinks that LEED is more geared towards the public contracts where governments offer incentives for owners but don't feel the local supply chains support the efforts."	Incentives such as tax reduction
	• "If CM's, Owners, and Architects could somehow come around to not only the benefits but the NEED, to build things sustainably, I think it has a bright future. Right now, it feels more like bragging rights." • "Like Safety, it needs to be a culture change."	Change of culture and attitude
Legislative constraints	• "New laws and codes are requiring more project to incorporate sustainable practices.", "In my opinion, the only way that we will see total green construction in the United States would be if the expenses were brought down, and if government regulation mandates it." • "Sustainability can only advance as far as politics will allow. The undermining of environmental agencies and the impacts of lobbying groups keep the US in a "see-saw" movement of attempting to advance and achieve sustainability."	Supportive and stable administration, rules and regulations
Financial and planning constraints	• "I believe it will continue to grow, but until the prices become comparable, there will always be people building the old way."	Competitive price
	• "Sustainable construction will become more prevalent and attractive as time moves forward, particularly as costs continue to drop due to advances in technology and methodology."	Advanced technology

Despite the positive comments, some respondents were not optimistic about the future of sustainable construction. One expert asserted that "speaking as someone who has been in the construction industry for many years [27 years of experience], the movement needs to be driven harder. In my career, I have not seen a big enough push to impact future development [with respect to sustainability]". Another site manager with 32 years of experience working in eight states mentioned that "It won't be in industrial but will be more prevalent in hotels, motels, convention centers, and other places with a public appeal where people are working and/or residing." A construction professional who had a LEED certification and 22 years of accumulated experience commented that "On the infrastructure side, I have not seen many calls for sustainable construction." A few respondents were not sure about the future of sustainable construction. A project manager working in North Carolina explained that the future is tied to unknown variables and mentioned that "I see the future of sustainability in the US as an unknown. Sustainable practices have always been a reaction to high fuel costs. Until it is cost-effective for us sustainable product and energy, it will not be the norm."

However, as mentioned earlier, overall, the respondents promised a bright future for sustainable construction in the US and also in the world. In fact, some participants predicted that sustainable construction would keep improving, and that, eventually, people will no longer show interest in pursuing a sustainable rating system badge because it will become part of standard construction practice. A 49-year-old expert with 24 years of design experience declared that "I believe that what we now view as the sustainable design will become part of good design. [. . .] These people will continue to do the basic green design and construction steps as best practice but will no longer pay or go through the process for certification because the cost and time are too burdensome. Then there will be a minority who believe in and promote pushing this as far as they can and will continue with green certification."

5. Study Limitations

Although the research was satisfactorily conducted, certain limitations need to be considered. These limitations are discussed in the following and are expected to be addressed in future research. First, the research team tried to incorporate the most major barriers. However, the identified sustainable construction barriers provided in Table 3 might lack some barriers. In addition, the identified barriers are time- and region-specific and apply to the current needs of the industry in the US. In other words, as the construction industry evolves with respect to sustainability, some of the identified barriers might not be applicable to the future needs of the evolved industry. Second, the four selected components satisfy the eigenvalue greater than one and the scree plot test but not the proportion of the variances explained by the components test. In other words, the presented model of principal components includes eight barriers and does not include four obstacles (i.e., 'Inefficient technology,' 'Insufficient environmental competencies,' 'Lack of awareness amongst stakeholders,' and 'Management's unwillingness').

6. Conclusions

The rush to meet the massive need to build more facilities has intensified the inherited adverse impacts of the construction industry. Therefore, green building initiatives have developed to fulfill sustainability needs. Despite great previous efforts, the current practice of sustainability in the construction industry is far from reaching the targeted green goals to achieve sustainable construction fully. In order to foster these endeavors, this study aimed to explore sustainable construction barriers in the United States. The research study was conducted in two phases. In phase one, starting with a literature review, 15 barriers were initially identified, as shown in Table 3. The subjectivity of "sustainability" was a challenge in the process of extracting the barriers from the literature review. What might be considered an important sustainability barrier based on one study might not be the same in other research that is taking place in different regions or circumstances. After conducting an extensive literature review, 25 construction experts were approached to express their opinions on the applicability of each barrier and rate them by choosing a number between "1: applicable barrier" and "0: not applicable barrier". This inquiry resulted in the reduction of the barriers to 12 for further study, as shown in Table 4.

In phase 2, a questionnaire survey was designed, approved by IRB, and accordingly distributed among 135 industry experts across the US. Construction experts' opinions were solicited on the importance of each 12 sustainable construction barriers on a scale of one to five. In order to identify the most critical barriers, the relative impact index (*RII*) of each obstacle was calculated. "Financial constraints" was ranked as the most important barrier. Despite the benefit of ranking identified barriers, the plurality of them is a major challenge to adopt feasible approaches to tackle the barriers. To offer a practical solution for construction professionals to cultivate the implementation of sustainable construction practices, principal component analysis (PCA) with varimax rotation was used to analyze the data and reduce the number of barriers to a few key components that represent the essence of the data. Initially, four principal components were identified that represent approximately 60% of the variance in the data. The four selected components, namely, "pre-construction constraints," "managerial constraints," "legislative constraints," and "financial and planning constraints," satisfy the eigenvalue greater than one and scree plot tests.

In addition to the identification of the sustainability barriers, the respondents provided some suggestions as solutions to further improvement of sustainable construction practices, as shown in Table 13. "Training workers and qualified employee acquisition" was offered to tackle pre-construction constraints. To mitigate managerial constraints, "change of culture and attitude," "incentives such as tax reduction," "climate change prevention advocacy," and "social awareness" were suggested by the interviewed construction experts. A "supportive and stable administration" can considerably help to address legislative constraints and barriers, according to the research participants. Last but not least, "competitive price" and "advanced technology" can facilitate fostering sustainable construction and overcoming financial and planning constraints.

In spite of the research limitations, the findings of this study are expected to help not only the construction industry but also architecture, engineering and construction (AEC) industry members along with owners and policymakers in the US to focus on the most important barriers to sustainable construction, applying the proposed solutions to foster the development of sustainability in construction. In addition, the results of this study can be used in other countries with the needed culturally and regionally related modifications.

Author Contributions: Conceptualization, M.N. and A.K.; methodology, M.N. and A.K.; software, A.K.; validation, M.N.; formal analysis, M.N. and A.K.; investigation, M.N.; resources, M.N., A.K., and M.T.; data curation, M.N.; writing—original draft preparation, A.K. and M.T.; writing—review and editing, M.N., A.K., and M.T.; supervision, M.N.; project administration, M.N. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Acknowledgments: The authors would like to appreciate those industry experts who participated in this study and helped with their valuable opinions.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Alwan, Z.; Jones, P.; Holgate, P. Strategic sustainable development in the UK construction industry, through the framework for strategic sustainable development, using Building Information Modelling. *J. Clean. Prod.* **2017**, *140*, 349–358. [CrossRef]
2. Ebrahimi, P.R.; Alizadehsalehi, S.; Mosaberpanah, M.A. Interactions of Sustainability and BIM in Support of Existing Buildings. *J. Comput. Civ. Eng.* **2019**. [CrossRef]
3. Tafazzoli, M.; Nochian, A.; Karji, A. Investigating Barriers to Sustainable Urbanization. In Proceedings of the International Conference on Sustainable Infrastructure 2019, Los Angeles, CA, USA, 6–9 November 2019; pp. 607–617.
4. Holliday, C.O.; Schmidheiny, S.; Watts, P. *Walking the Talk: The Business Case for Sustainable Development*; Berrett-Koehler Publishers: San Francisco, CA, USA, 2002; ISBN 978-1-57675-234-0.
5. Asman, G.E.; Kissi, E.; Agyekum, K.; Baiden, B.K.; Badu, E. Critical components of Environmentally Sustainable Buildings Design Practices of office buildings in Ghana. *J. Build. Eng.* **2019**, *26*, 100925. [CrossRef]
6. Azari, K.T.; Asadian, E.; Ardebili, A.V. Evaluation of Multi-criteria Selection Factors of Intelligent Buildings. In Proceedings of the 2nd International Congress of Technology, Management and Social Sciences-16 (ICTMS-16), Toronto, ON, Canada, 25–26 June 2016.
7. Rafsanjani, H.N.; Ghahramani, A. Extracting occupants' energy-use patterns from Wi-Fi networks in office buildings. *J. Build. Eng.* **2019**, *26*, 100864. [CrossRef]

8. Tafazzoli, M. Becoming Greener in Construction: Overcoming Challenges and Developing Strategies. *Int. Conf. Sustain. Infrastruct.* **2017**, *2017*, 1–13. [CrossRef]
9. Hardi, P.; Zdan, T. *Assessing Sustainable Development: Principles in Practice*; The International Institute for Sustainable Development: Winnipeg, MB, Canada, 1997.
10. WCED, S.W.S. World commission on environment and development. *Our Common Future* **1987**, *17*, 1–91.
11. Mirhosseini, H.; Carmody, K.; Iulo, L.D. A framework for the co-benefits and trade-offs of resilience & sustainability certification programs. In Proceedings of the ARCC Conference Repository, Toronto, ON, Canada, 29 May–1 June 2019.
12. Bergman, Z.; Bergman, M.M.; Fernandes, K.; Grossrieder, D.; Schneider, L. The Contribution of UNESCO Chairs toward Achieving the UN Sustainable Development Goals. *Sustainability* **2018**, *10*, 4471. [CrossRef]
13. Karji, A.; Woldesenbet, A.; Khanzadi, M. Social Sustainability Indicators in Mass Housing Construction. In Proceedings of the 53rd ASC Annual International Conference Proceedings, Seattle, WA, USA, 5–8 April 2017.
14. Karji, A.; Woldesenbet, A.; Khanzadi, M.; Tafazzoli, M. Assessment of Social Sustainability Indicators in Mass Housing Construction: A Case Study of Mehr Housing Project. *Sustain. Cities Soc.* **2019**, *50*, 101697. [CrossRef]
15. Mitra, A. An ethical analysis of the 2014 FIFA World Cup in Brazil. *Law Bus. Rev. Am.* **2015**, *21*, 3.
16. Marques, B.; Tadeu, A.; Almeida, J.; António, J.; de Brito, J. Characterisation of sustainable building walls made from rice straw bales. *J. Build. Eng.* **2020**, *28*, 101041. [CrossRef]
17. Rafsanjani, H.N.; Ghahramani, A.; Nabizadeh, A.H. iSEA: IoT-based smartphone energy assistant for prompting energy-aware behaviors in commercial buildings. *Appl. Energy* **2020**, *266*, 114892. [CrossRef]
18. Akbari, S.; Khanzadi, M.; Gholamian, M.R. Building a rough sets-based prediction model for classifying large-scale construction projects based on sustainable success index. *Eng. Constr. Archit. Manag.* **2018**, *25*, 534–558. [CrossRef]
19. Nazari-Heris, M.; Sadat-Mohammadi, M.; Mirzaei, M.A.; Asadi, S.; Mohammadi-Ivatlo, B.; Jebelli, H. Robust Energy Management of Integrated Power Infrastructure and Gas Networks with High Penetration of Renewable Energy Sources. In Proceedings of the Construction Research Conference (CRC) 2020, Tempe, AZ, USA, 8–10 March 2020.
20. Hong, J.; Shen, G.Q.; Guo, S.; Xue, F.; Zheng, W. Energy use embodied in China's construction industry: A multi-regional input–output analysis. *Renew. Sustain. Energy Rev.* **2016**, *53*, 1303–1312. [CrossRef]
21. Liu, Y.; Yang, Y.; Li, Y.; Li, J. Conversion from rural settlements and arable land under rapid urbanization in Beijing during 1985–2010. *J. Rural Stud.* **2017**, *51*, 141–150. [CrossRef]
22. Pribadi, D.O.; Pauleit, S. The dynamics of peri-urban agriculture during rapid urbanization of Jabodetabek Metropolitan Area. *Land Use Policy* **2015**, *48*, 13–24. [CrossRef]
23. Lukichev, S.; Romanovich, M. The quality management system as a key factor for sustainable development of the construction companies. *Procedia Eng.* **2016**, *165*, 1717–1721. [CrossRef]
24. Rafsanjani, H.N.; Moayedi, S.; Ahn, C.R.; Alahmad, M. A Load-Disaggregation Framework to Sense Personalized Energy-Use Information in Commercial Buildings. *Energy Build.* **2019**, 109633. [CrossRef]
25. Yigitcanlar, T.; Teriman, S. Rethinking sustainable urban development: Towards an integrated planning and development process. *Int. J. Environ. Sci. Technol.* **2015**, *12*, 341–352. [CrossRef]
26. Kibert, C.J. *Sustainable Construction: Green Building Design and Delivery*; John Wiley & Sons: Hoboken, NJ, USA, 2016.
27. Ruparathna, R.; Hewage, K. Sustainable procurement in the Canadian construction industry: Current practices, drivers and opportunities. *J. Clean. Prod.* **2015**, *109*, 305–314. [CrossRef]
28. Tafazzoli, M. Accelerating the Green Movement: Major Barriers to Sustainable Construction. In Proceedings of the 54rd ASC Annual International Conference Proceedings, Minneapolis, MN, USA, 18–21 April 2018.
29. Namian, M.; Al-Bayati, A.; Karji, A.; Tafazzoli, M. Investigating Barriers to Implement and Develop Sustainable Construction. Proceedings 1st Joint International Conference on Design and Construction of Smart City Components, Cairo, Egypt, 17–19 December 2019.
30. Mehta, P.K. Greening of the concrete industry for sustainable development. *Concr. Int.* **2002**, *24*, 23–28.
31. Abergel, T.; Dean, B.; Dulac, J.; Hamilton, I. *2018 Global Status Report: Towards a Zero-Emission, Efficient, and Resilient Buildings and Construction Sector*; Global Alliance for Buildings and Construction: Katowice, Poland, 2018.

32. Rahman, I.A.; Al-Emad, N.; Nagapan, S. Categorization of Saudi Arabia's construction delay factors using factor analysis technique. In *Engineering Challenges for Sustainable Future*; Taylor & Francis Group: London, UK, 2016; Volume 177, pp. 177–181.
33. Azarov, V.; Petrenko, L.; Manzhilevskaya, S. The Study of Local Dust Pollution of Atmospheric Air on Construction Sites in Urban Areas. In Proceedings of the Energy Management of Municipal Transportation Facilities and Transport; Springer: Cham, Switzerland, 2018; pp. 430–439.
34. Harbor, J. Engineering geomorphology at the cutting edge of land disturbance: Erosion and sediment control on construction sites. *Geomorphology* **1999**, *31*, 247–263. [CrossRef]
35. Burton, G.A., Jr.; Pitt, R. *Stormwater Effects Handbook: A Toolbox for Watershed Managers, Scientists, and Engineers*; CRC Press: Boca Raton, FL, USA, 2001.
36. Belayutham, S.; Gonzalez, V.A.; Yiu, T.W. A cleaner production-pollution prevention based framework for construction site induced water pollution. *J. Clean. Prod.* **2016**, *135*, 1363–1378. [CrossRef]
37. Wallace, M.; Mickovski, S.B.; Griffin, I. An innovative framework for selecting sustainable options to reduce the risk of soil erosion and environmental pollution incidents on road construction sites. In *Proceedings of the XVII ECSMGE-2019: Geotechnical Engineering Foundation of the Future*; The Icelandic Geotechnical Society: Reykjavik, Iceland, 2019.
38. Ranieri, E.; Bombardelli, F.; Gikas, P.; Chiaia, B. Soil pollution prevention and remediation. *Appl. Environ. Soil Sci.* **2016**, *2016*, 9415175. [CrossRef]
39. Sweigard, R.; Burger, J.; Zipper, C.; Skousen, J.; Barton, C.; Angel, P. Low compaction grading to enhance reforestation success on coal surface mines. In *The Forestry Reclamation Approach: Guide to Successful Reforestation of Mined Lands*; Adams, M.B., Ed.; Gen. Tech. Rep. NRS-169; US Department of Agriculture, Forest Service, Northern Research Station: Newtown Square, PA, USA, 2017; pp. 4-1–4-8.
40. Arnold, E.; Toran, L. Effects of Bank Vegetation and Incision on Erosion Rates in an Urban Stream. *Water* **2018**, *10*, 482. [CrossRef]
41. Hammad, A.W.A.; Akbarnezhad, A.; Rey, D. A multi-objective mixed integer nonlinear programming model for construction site layout planning to minimise noise pollution and transport costs. *Autom. Constr.* **2016**, *61*, 73–85. [CrossRef]
42. Roger, T.; Frederic, B.M.; Raymond, T.; Bernard, N.; Nyuysever, M.E.; Ndem, T.M. Deforestation in power line construction in the Central African Region. *Afr. J. Environ. Sci. Technol.* **2017**, *11*, 266–271.
43. Panda, B.; Paul, S.C.; Tan, M.J. Anisotropic mechanical performance of 3D printed fiber reinforced sustainable construction material. *Mater. Lett.* **2017**, *209*, 146–149. [CrossRef]
44. Achal, V.; Mukherjee, A. A review of microbial precipitation for sustainable construction. *Constr. Build. Mater.* **2015**, *93*, 1224–1235. [CrossRef]
45. Chang, R.; Soebarto, V.; Zhao, Z.; Zillante, G. Facilitating the transition to sustainable construction: China's policies. *J. Clean. Prod.* **2016**, *131*, 534–544. [CrossRef]
46. Cruz, C.O.; Gaspar, P.; de Brito, J. On the concept of sustainable sustainability: An application to the Portuguese construction sector. *J. Build. Eng.* **2019**, *25*, 100836. [CrossRef]
47. Shuqin, C.; Minyan, L.; Hongwei, T.; Xiaoyu, L.; Jian, G. Assessing sustainability on Chinese university campuses: Development of a campus sustainability evaluation system and its application with a case study. *J. Build. Eng.* **2019**, *24*, 100747. [CrossRef]
48. Van Bueren, E.M.; Priemus, H. Institutional barriers to sustainable construction. *Environ. Plan. B Plan. Des.* **2002**, *29*, 75–86. [CrossRef]
49. Studer, S.; Welford, R.; Hills, P. *Drivers and Barriers to Engaging Small and Medium-Sized Companies in Voluntary Environmental Initiatives*; The Centre of Urban Planning and Environmental Management, The University of Hong Kong: Hong Kong, China, 2005.
50. Pitt, M.; Tucker, M.; Riley, M.; Longden, J. Towards sustainable construction: Promotion and best practices. *Constr. Innov.* **2009**, *9*, 201–224. [CrossRef]
51. Pinkse, J.; Dommisse, M. Overcoming barriers to sustainability: An explanation of residential builders' reluctance to adopt clean technologies. *Bus. Strategy Environ.* **2009**, *18*, 515–527. [CrossRef]
52. Sourani, A.; Sohail, M. Barriers to addressing sustainable construction in public procurement strategies. In Proceedings of the Institution of Civil Engineers-Engineering Sustainability; ICE Publishing: London, UK, 2011; Volume 164, pp. 229–237.

53. AlSanad, S. Awareness, drivers, actions, and barriers of sustainable construction in Kuwait. *Procedia Eng.* **2015**, *118*, 969–983. [CrossRef]
54. Taheriattar, R.; Farzanehrafat, M. Construction managers' perception of the factors affecting sustainability in construction projects. *Int. J. Sustain. Constr. Eng. Technol.* **2014**, *5*, 22–32.
55. Shen, L.-Y.; Li Hao, J.; Tam, V.W.-Y.; Yao, H. A checklist for assessing sustainability performance of construction projects. *J. Civ. Eng. Manag.* **2007**, *13*, 273–281. [CrossRef]
56. Oyekanmi, O.O.; Abisuga, A.O. Organizational factors affecting the usage of sustainable building materials in the Nigerian construction industry. *J. Emerg. Trends Econ. Manag. Sci.* **2014**, *5*, 113–119.
57. Enshassi, A.; Mohamed, S.; Abushaban, S. Factors affecting the performance of construction projects in the Gaza strip. *J. Civ. Eng. Manag.* **2009**, *15*, 269–280. [CrossRef]
58. Banihashemi, S.; Hosseini, M.R.; Golizadeh, H.; Sankaran, S. Critical success factors (CSFs) for integration of sustainability into construction project management practices in developing countries. *Int. J. Proj. Manag.* **2017**, *35*, 1103–1119. [CrossRef]
59. Patrick, E.W.; Kagiri, A. An Evaluation of Factors Affecting Sustainability of Fish farming projects in public secondary schools in Kiambu County. *Int. J. Sci. Res. Publ.* **2016**, *6*, 488–507.
60. Shen, L.Y.; Wu, Y.Z.; Chan, E.H.W.; Hao, J.L. Application of system dynamics for assessment of sustainable performance of construction projects. *J. Zhejiang Univ. Sci. A* **2005**, *6*, 339–349. [CrossRef]
61. Jajac, N.; Kilić, J.; Rogulj, K. An Integral Approach to Sustainable Decision-Making within Maritime Spatial Planning—A DSC for the Planning of Anchorages on the Island of Šolta, Croatia. *Sustainability* **2019**, *11*, 104. [CrossRef]
62. Mangialardo, A.; Micelli, E.; Saccani, F. Does Sustainability Affect Real Estate Market Values? Empirical Evidence from the Office Buildings Market in Milan (Italy). *Sustainability* **2019**, *11*, 12. [CrossRef]
63. Lam, P.T.; Chan, E.H.; Poon, C.S.; Chau, C.K.; Chun, K.P. Factors affecting the implementation of green specifications in construction. *J. Environ. Manag.* **2010**, *91*, 654–661. [CrossRef]
64. Beyene, H.A. Factors Affecting the Sustainability of Rural Water Supply Systems: The Case of Mecha Woreda, Amhara Region, Ethiopia. Master's Thesis, Cornell University, Ithaca, NY, USA, 2012.
65. Di Fabio, A.; Tsuda, A. The psychology of harmony and harmonization: Advancing the perspectives for the psychology of sustainability and sustainable development. *Sustainability* **2018**, *10*, 4726. [CrossRef]
66. Kazimieras Zavadskas, E.; Baušys, R.; Lazauskas, M. Sustainable assessment of alternative sites for the construction of a waste incineration plant by applying WASPAS method with single-valued neutrosophic set. *Sustainability* **2015**, *7*, 15923–15936. [CrossRef]
67. Leao-Aguiar, L.; Ferreira, E.A.M.; Marinho, M.M.O. What do we mean by corporate social responsibility in the construction sector. In Proceedings of the Conference on Sustainable Building South East Asia; Institute Sultan Iskandar of Urban Habitat and Highrise: Skudai, Malaysia, 2005; Volume 11, p. 13.
68. Mardani, A.; Jusoh, A.; Zavadskas, E.K.; Cavallaro, F.; Khalifah, Z. Sustainable and renewable energy: An overview of the application of multiple criteria decision making techniques and approaches. *Sustainability* **2015**, *7*, 13947–13984. [CrossRef]
69. Abdel-Raheem, M.; Ramsbottom, C. Factors affecting social sustainability in highway projects in Missouri. *Procedia Eng.* **2016**, *145*, 548–555. [CrossRef]
70. Khasreen, M.M.; Banfill, P.F.; Menzies, G.F. Life-cycle assessment and the environmental impact of buildings: A review. *Sustainability* **2009**, *1*, 674–701. [CrossRef]
71. Xu, Y.-S.; Shen, S.-L.; Ren, D.-J.; Wu, H.-N. Analysis of factors in land subsidence in Shanghai: A view based on a strategic environmental assessment. *Sustainability* **2016**, *8*, 573. [CrossRef]
72. Namian, M.; Albert, A.; Zuluaga, C.M.; Jaselskis, E.J. Improving hazard-recognition performance and safety training outcomes: Integrating strategies for training transfer. *J. Constr. Eng. Manag.* **2016**, *142*, 04016048. [CrossRef]
73. Choudhry, R.M.; Aslam, M.A.; Hinze, J.W.; Arain, F.M. Cost and schedule risk analysis of bridge construction in Pakistan: Establishing risk guidelines. *J. Constr. Eng. Manag.* **2014**, *140*, 04014020. [CrossRef]
74. Gündüz, M.; Nielsen, Y.; Özdemir, M. Quantification of delay factors using the relative importance index method for construction projects in Turkey. *J. Manag. Eng.* **2013**, *29*, 133–139. [CrossRef]
75. Jarkas, A.M.; Bitar, C.G. Factors affecting construction labor productivity in Kuwait. *J. Constr. Eng. Manag.* **2012**, *138*, 811–820. [CrossRef]

76. Aibinu, A.A.; Odeyinka, H.A. Construction delays and their causative factors in Nigeria. *J. Constr. Eng. Manag.* **2006**, *132*, 667–677. [CrossRef]
77. Bakshan, A.; Srour, I.; Chehab, G.; El-Fadel, M.; Karaziwan, J. Behavioral determinants towards enhancing construction waste management: A Bayesian Network analysis. *Resour. Conserv. Recycl.* **2017**, *117*, 274–284. [CrossRef]
78. Bandalos, D.L.; Finney, S.J. Factor analysis: Exploratory and confirmatory. In *The Reviewer's Guide to Quantitative Methods in the Social Sciences*; Routledge: New York, NY, USA, 2018; pp. 98–122.
79. Głuszak, M.; Leśniak, A. Construction Delays in Clients Opinion—Multivariate Statistical Analysis. *Procedia Eng.* **2015**, *123*, 182–189. [CrossRef]
80. Pallant, J.F. Development and validation of a scale to measure perceived control of internal states. *J. Personal. Assess.* **2000**, *75*, 308–337. [CrossRef]
81. Tabachnick, B.G.; Fidell, L.S.; Ullman, J.B. *Using Multivariate Statistics*; Pearson: Boston, MA, USA, 2007; Volume 5.
82. Abdi, H.; Williams, L.J. Principal component analysis. *Wiley Interdiscip. Rev. Comput. Stat.* **2010**, *2*, 433–459. [CrossRef]
83. Cliff, N. The eigenvalues-greater-than-one rule and the reliability of components. *Psychol. Bull.* **1988**, *103*, 276. [CrossRef]
84. Kaiser, H.F. The varimax criterion for analytic rotation in factor analysis. *Psychometrika* **1958**, *23*, 187–200. [CrossRef]
85. Osazuwa, E.M.; Oke, A.E. Relevance of Competencies of Construction Project Risk Managers to Quantity Surveying Practice. In Proceedings of the Construction Industry Development Board Postgraduate Research Conference, Johannesburg, South Africa, 28–30 July 2019; pp. 100–111.
86. Ruano, L.; Branco, M.; Severo, M.; Sousa, A.; Castelo, J.; Araújo, I.; Pais, J.; Cerqueira, J.; Amato, M.P.; Lunet, N. Tracking cognitive impairment in multiple sclerosis using the Brain on Track test: A validation study. *Neurol. Sci.* **2020**, *41*, 183–191. [CrossRef] [PubMed]
87. O'Rourke, N.; Hatcher, L.; Stepanski, E.J. *A Step-by-Step Approach to Using SAS for Univariate and Multivariate Statistics*, 2nd ed.; SAS Publishing: Cary, NC, USA, 2005; ISBN 978-1-59047-417-4.
88. Yong, A.G.; Pearce, S. A beginner's guide to factor analysis: Focusing on exploratory factor analysis. *Tutor. Quant. Methods Psychol.* **2013**, *9*, 79–94. [CrossRef]
89. Davies, C.R.; Rosenberg, M.; Knuiman, M.; Ferguson, R.; Pikora, T.; Slatter, N. Defining arts engagement for population-based health research: Art forms, activities and level of engagement. *Arts Health* **2012**, *4*, 203–216. [CrossRef]
90. Swanepoel, J.M. The Relationship between Perceived Social Support, on-Line Social Network Usage and Reflective Practice in Forensic Social Work. Ph.D. Thesis, North-West University, Potchefstroom, South Africa, 2019.