buildings

Article

Identifying and Prioritizing the Challenges and Obstacles of the Green Supply Chain Management in the Construction Industry Using the Fuzzy BWM Method

Sayyid Ali Banihashemi [1], Mohammad Khalilzadeh [2,*], Jurgita Antucheviciene [3,*] and Seyyed Ahmad Edalatpanah [4]

1 Department of Industrial Engineering, Payame Noor University, Tehran 19395-4697, Iran
2 Department of Industrial Engineering, Science and Research Branch, Islamic Azad University, Tehran 14778-93855, Iran
3 Department of Construction Management and Real Estate, Vilnius Gediminas Technical University, Sauletekio al. 11, 10223 Vilnius, Lithuania
4 Department of Applied Mathematics, Ayandegan Institute of Higher Education, Tonekabon 46818-53617, Iran
* Correspondence: khalilzadeh@srbiau.ac.ir (M.K.); jurgita.antucheviciene@vilniustech.lt (J.A.)

Abstract: The construction supply chain network has been facing challenges in relation to reducing cost and delivery time, increasing the quality of the built assets, and reducing environmental pollution. These issues have caused contractors and project managers in this industry to note the concept of green construction supply chain management (GCSCM). This study examined the most important challenges and barriers to the implementation of GSCM in the construction industry. In this paper, the components and sub-components of GCSCM were identified using the literature review and opinions of the experts according to the supply chain management. The opinions of construction experts and project managers were collected through focus group meetings. The components were categorized into five main and supporting groups, with "Green Design", "Green Procurement", and "Green Production" as the main components and "Green Management" and "Green Information" as the supporting components. Subsequently, the sub-components, in regard to each component, were distinguished. Finally, the fuzzy best–worst method (BWM) was utilized to determine the importance weights of the identified components and sub-components through the opinions of five experts with practical relevant experience. The findings of the fuzzy BWM method show that "Green Design" is the most important component, followed by "Green Management" and "Green Implementation". Additionally, "Lack of designers, contractors and planners" was ranked the first among the identified sub-components. This paper can assist construction managers, contractors, and policymakers with finding and overcoming the barriers and obstacles of implementing GCSCM.

Keywords: green supply chain management; barrier; multi-criteria decision-making; fuzzy BWM; construction industry

check for updates

Citation: Banihashemi, S.A.; Khalilzadeh, M.; Antucheviciene, J.; Edalatpanah, S.A. Identifying and Prioritizing the Challenges and Obstacles of the Green Supply Chain Management in the Construction Industry Using the Fuzzy BWM Method. *Buildings* **2023**, *13*, 38. https://doi.org/10.3390/buildings13010038

Academic Editor: Ahmed Senouci

Received: 16 November 2022
Revised: 19 December 2022
Accepted: 20 December 2022
Published: 24 December 2022

1. Introduction

The construction sector is a main consumer of natural resources in the globe [1]. Additionally, it is accountable for a considerable amount of the entire pollution of the world [2]. The world-wide detrimental effects of the construction sector have been distinguished, and consequently, several countries have introduced guidelines and legalized environmental laws and regulations to diminish and prevent pollution, which enforce the construction industry to take environmental concerns into account [3,4]. On the other hand, the construction sector is facing challenges related to cost reduction, timely delivery, and the quality of the construction project [5]. As a result, increasing these challenges, as well as the growing pressure of the governing bodies and the stakeholders of the construction industry for taking the environmental standards and regulations into consideration, has imposed the contractors to pay more attention to green supply chain management (SCM) in this industry.

The SCM approach deals with improving tools and techniques, practices, and processes to enhance the efficiency and effectiveness of the entire supply chain [6]. This concept has incrementally been addressed by various construction companies [7]. A construction supply chain comprises the firms ranging from suppliers, contractors, and subcontractors that are engaged in rendering the built property to the client (end user) [8]. The increasing attention to the SCM, together with the negative environmental consequences of the construction operations, created the concept of green supply chain management (GSCM) in the construction industry. GSCM is basically related to integrating environmental concerns with the supply chain [9].

Further to the authors' knowledge, limited studies have been conducted on the challenges and obstacles of GSCM implementation in the construction industry. This matter caused the importance of implementation challenges and obstacles to be unknown. Therefore, it is not possible to develop a strategy plan and response to challenges and obstacles in the construction industry. The lack of research on the implementation obstacles of GCSCM made us investigate, identify, and prioritize these barriers and obstacles through reviewing the literature and seeking the experts' opinions.

Hence, the current study attempts to respond to the following critical questions: (1) What are the most important challenges and obstacles in implementing GSCM in the construction industry? (2) What are the substantial aspects in the implementation of GSCM in the construction industry? (3) What are challenges and obstacles in GSCM and their important weights and rankings?

The present paper attempts to contribute to the existing knowledge on GCSCM through examining and analyzing the most important challenges and barriers to the implementation of green construction management. For this purpose, fuzzy BWM, as one of the novel multi-criteria decision-making (MCDM) methods, is utilized to weigh and rank the identified challenges and obstacles of GSCM in the construction sector.

In MCDM problems, the existing alternatives should be scored according to the predefined criteria. However, the importance weights of the criteria are not identical. Hence, the weights of the criteria are determinant in the decision-making process performed by experts. On the other hand, there exist different criteria leading to several problems and difficulties in directly calculating the criteria's weights. The decision-making process becomes even more intricate when the vagueness and subjectivity of experts' opinions are taken into consideration. Numerous MCDM methods have been presented so far to specify the weights of criteria, some of which are on the basis of pairwise comparisons. However, the consistency rate of these pairwise comparisons remains a crucial issue. Rezaei [10] stated that the primary reason for this inconsistency is the unstructured comparisons. He introduced a new MCDM method based on pairwise comparisons, called the best–worst method (BWM), utilizing less comparison data and providing greater consistency rate. Therefore, the fuzzy BWM, as an extension of BWM, is employed in this study to cope with the vagueness and uncertainty associated with the opinions of experts.

This paper is structured as follows: In the next section, the previous studies on GSCM in the construction industry are reviewed to identify the obstacles and barriers to implementing GCSCM. The research methodology is briefly described in Section 3. In Section 4, based on the components of SCM, the main components and their related sub-components are identified using the opinions of experts. Additionally, the importance weights of components and sub-components are calculated using the fuzzy BWM. Finally, the discussion and conclusion are rendered in Section 5.

2. Literature Review

This section is classified into three subsections: In the first subsection, the related studies on construction supply chain management (CSCM) are discussed. The second part scrutinizes the relevant research on GCSCM. The last subsection presents the application of fuzzy BWM to GCSCM.

2.1. Construction Supply Chain Management (CSCM)

Segerstedt and Olofsson [11] reviewed numerous extant opportunities and threats in the supply chain of the construction sector. Subsequently, Behera et al. [12] described the concept of CSCM for better understanding and implementation. Hao et al. [13] applied game theory approach to examine the progressive knowledge sharing pattern of participants and the influencing factors in the construction supply chain. Battula et al. [14] investigated the factors that affect the implementation of CSCM. Koc and Gurgun [15] examined the risks of stakeholders in the construction supply chain. Liu et al. [16] reviewed the relevant studies and proposed a conceptual framework for the development of supply chain management in the prefabricated construction industry. In addition, Studer and De Berito Mello [17] studied the literature on CSCM and categorized the important components into five groups. Also, Hussein et al. [18] examined the existing problems in off-site CSCM and the solutions presented in the literature. Moreover, Masood et al. [19] conducted a systematic review on the prefabricated house-building supply chain management. Cigolini et al. [20] briefly mentioned the challenges associated with supply chain management in the construction sector. Salari et al. [21] addressed the problems and challenges relevant to supply chain management in off-site construction and developed a stochastic three-echelon model for supply chain management. Furthermore, Gurgun et al. [22] found out the obstacles associated with using cryptocurrencies in construction supply chain.

2.2. Green Construction Supply Chain Management (GCSCM)

Balasubramanian and Shukla [3] proposed an assessment framework containing nine constructs for GSCM in the construction industry. Dallasega and Rauch [23] developed a conceptual model for synchronizing demand and supply according to the concept of sustainable CSCM. Zeng et al. [24] examined the relationship between sustainable consumption of construction materials and supply chain. Mee-ngoen et al. [25] investigated the effect of green construction, green project, and green staff training on the customer satisfaction. Ali et al. [26] specified and prioritized the GCSCM practices related to the Chinese and Pakistani joint projects for implementation. Hussain and Malik [27] distinguished the interrelationship between the environmental performance of construction supply chain and the organizational enablers of circular economy using a structural equation modelling. Liao et al. [28] introduced a MCDM method considering hesitant verbal information for sustainable supplier selection problem in the construction sector, and Farnam and Darehmiraki [29] solved supply chain management problems in hesitant fuzzy environment. Lin et al. [30] developed a non-deterministic bi-level nonlinear robust optimization model considering coordination and incentives among the participants of construction supply chain. Marandi Ahmed et al. [31] identified the obstacles and opportunities in implementing GCSCM. According to the findings, the four highest ranked barriers are placed in the "involvement and support" classification, on the other hand, the four highest ranked opportunities are placed in the "environmental" categorization. Mojumder and Singh [32] conducted an exploratory study for the implementation of GCSCM in Indian companies. Kosanoglu and Kus [33] developed a sustainable CSCM model for Turkish construction industry. RezaHoseini et al. [34] suggested a bi-objective linear programming model for the sustainable construction supply chain problem taking project scheduling and supplier selection into account. They also considered the environmental consequences of transportation. Moreover, the issues of selecting suppliers, choosing fleet types, and scheduling project were examined such that the logistics costs, project delays, and the propagation of greenhouse gases are simultaneously minimized. Cataldo et al. [35] reviewed the literature of sustainable CSCM and suggested some directions for further studies. Mohammadnazari and Ghannadpour [36] developed a sustainable mathematical programming model for the ordering problem of construction materials. Alavi et al. [37] identified and prioritized GC project management activities. Xie et al. [38] investigated the governmental intervention in the GCSCM for supporting public–private partnerships. Sun et al. [39] developed a grey possibility DEMATEL-NK-based path analysis framework to identify the obstacles and barriers in performing GCSCM.

2.3. The Application of Fuzzy BWM to GCSCM

Amoozad Mahdiraji et al. [40] identified and prioritized the main sustainability factors in Iranian contemporary architecture through an integrated fuzzy BWM-COPRAS approach. Mathiyazhagan et al. [41] proposed a sustainable evaluation model using a combination of BWM and fuzzy TOPSIS methods for selecting materials in the construction sector. Liu et al. [16] utilized a combined model of DEMATEL and BWM to distinguish the causal relationship of several factors, as well as their importance for a green building assessment system. Naghizadeh Vardin et al. [5] suggested a hybrid model of BWM and fuzzy VIKOR for sustainable contractor selection problem. Alkan et al. [42] applied a hybrid Bayesian BWM-SAW method for selecting sustainable construction materials. Singh et al. [43] employed BWM for selecting green suppliers in construction companies in India.

2.4. Obstacles and Barriers to the Implementation of GCSCM

The obstacles and barriers to the implementation of GCSCM were collected using the literature survey shown in Table 1.

Table 1. The Obstacles and barriers to the implementation of GCSCM, based on the literature review.

Author(s) Year	Implementation Challenges and Obstacles
Balasubramanian and Shukla [3]	Shortfall of necessary technical skills in the construction industry, lack of complete understanding of project goals and requirements, inappropriate working conditions
Ayarkwa et al. [44]	Lack of related laws and regulations and government support
Aigbavboa et al. [45]	Cost increase, unwillingness to use new methods in construction, lack of necessary technical skills in the construction industry
Baron and Donath [46]	Cost increase, lack of access to green materials, and improper maintenance
Shrestha [47]	Cost increase
AlSanad [48]	Unwillingness to use new methods in the construction industry
Babalola et al. [49]	Poor performance during construction, unrealistic project duration
Wei et al. [50]	Lack of complete understanding of project goals and requirements
Govindan et al. [51]	Cost increase, unwillingness to use new methods in the construction industry, lack of necessary technical skills in the construction industry, lack of access to green materials, low efficiency during construction, unrealistic project duration, lack of complete understanding of project goals and requirements, inappropriate working conditions, lack of designers, contractors and planners in the green construction industry, lack of related laws and regulations and government support
Djokoto et al. [52]	Poor performance during construction, unrealistic project duration
Opoku and Fortune [53]	Lack of related laws and regulations and government support
Ojo et al. [54]	Lack of access to green materials, lack of market for recyclable materials, lack of awareness of environmental effects, lack of information sharing between construction organizations and suppliers, weak commitment of senior management, lack of related laws and regulations and government support, demand shortage
Liu et al. [55]	Lack of designers, contractors and planners in the green construction industry, lack of training, knowledge, and experience of the green supply chain

Table 1. *Cont.*

Author(s) Year	Implementation Challenges and Obstacles
Holt and Ghobadian [56]	Low efficiency during construction, lack of proper training, awareness, and experiences of green supply chain
Sharfman et al. [57]	Lack of proper training, awareness, and experience of green supply chain
Dashore and Sohani [58]	Lack of designers, contractors, and planners in the green construction industry

3. Materials and Methods

The research methodology contains three steps. Figure 1 depicts the flowchart of the research methodology.

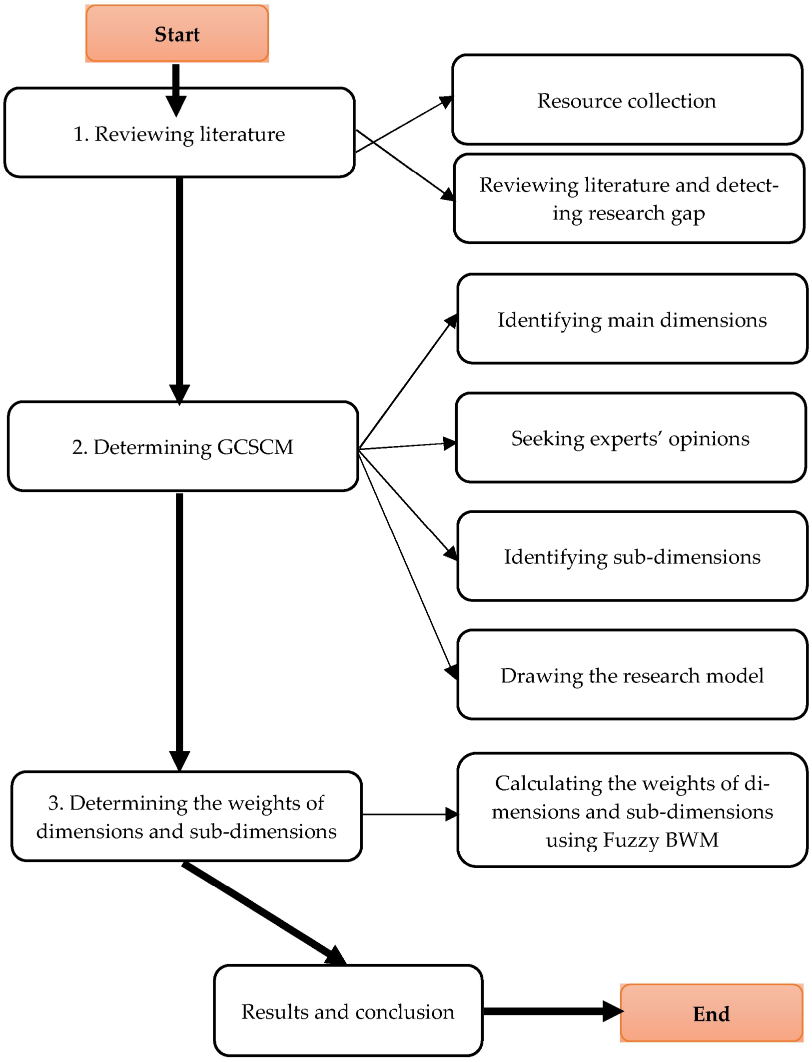

Figure 1. The flowchart of the research methodology.

In the first step, the research literature was examined, and the most important challenges and obstacles related to implementing GSCM in the construction industry were distinguished. In the second step, the components of GCSCM were determined using the opinions of the experts. The opinions of 20 experts and construction project managers were collected through a two-hour focus group meeting. The specialists and experts used in this research included scholars and scientific experts (university professors), together with executive experts (project managers). Table 2 shows the demographic information of the experts.

Table 2. Sample Demographic Information.

Category	Frequency	Percentage
Gender		
Male	17	85%
Female	3	15%
Age		
<30	1	5%
30–35	4	20%
35–40	5	25%
40–45	8	40%
45–50	1	5%
>50	1	5%
Job Position		
University	15	75%
Executive	5	25%
Expert		
Civil Engineering	7	35%
Project Management	8	40%
Construction Management	4	20%
Else	1	5%

These components were categorized into five groups, including main and supporting components. Green design, green procurement, and green production in the construction industry were categorized as the main components, and green management and green information in the construction industry were categorized as the supporting components, according to supply chain components depicted in Figure 2.

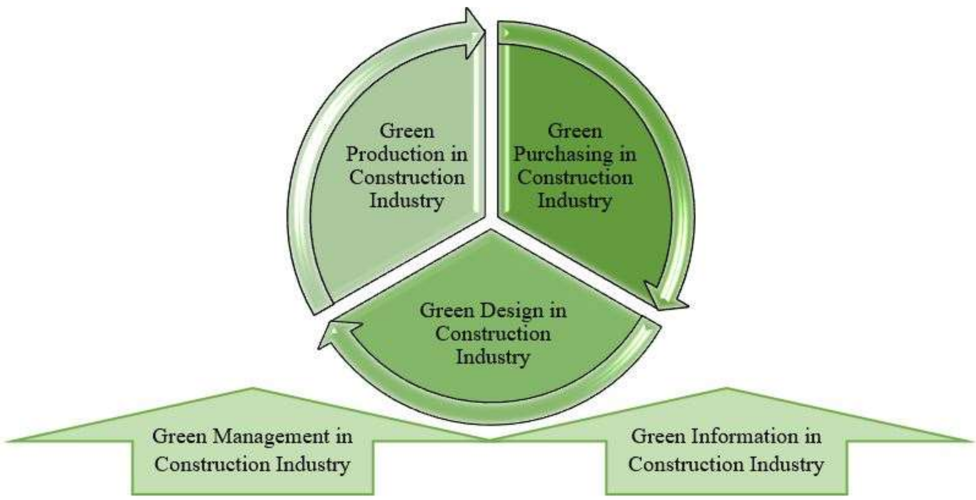

Figure 2. GCSCM based on the experts' opinions.

According to Figure 2, the first step in GCSCM is green procurement. Green procurement refers to materials that consume less resources and energy, are non-toxic, and do not have a detrimental impact on the environment. The second step is green design. Green design includes the use of environmentally friendly methods in the construction industry to reduce the negative effects of construction on the environment. In other words, green design provides opportunities to reduce any potential negative environmental impacts. In green design, the environment and human health should be considered in the process of purchasing materials. The third step is green production, which is known as clean production. Green production emphasizes maximizing the protection of natural resources, reducing negative effects on the environment, and optimizing the consumption of resources. Additionally, the supporting component of green management means the management commitment to considering the concept of green in managing the entire construction supply chain. Moreover, green information, which has the role of information support in GCSCM is introduced as another supporting component.

Subsequently, based on Table 1 and Figure 2, the sub-components of the obstacles of the GCSCM were categorized through another focus group meeting, which are presented in Table 3.

Table 3. The components and sub-components of the obstacles of green construction management (based on supply chain components).

Components	Code	Sub-Components
Green Procurement in Construction Industry	C11	Lack of access to green materials
	C12	Lack of market for recyclable materials
	C13	Lack of proper storage and maintenance of materials
Green Design in Construction Industry	C21	Lack of designers, contractors, and planners in the green construction industry
	C22	Lack of proper training, awareness, and experience of green supply chain
	C23	Absence of environmental controls
Green Production in Construction Industry	C31	Lack of necessary technical skills in the construction industry
	C32	Low efficiency during construction
	C33	Unwillingness to use new methods in construction
	C34	cost increase
	C35	Inappropriate working conditions
	C36	Unrealistic project duration
Green Management in Construction Industry	C41	Lack of complete understanding of project goals and requirements
	C42	Lack of related laws and regulations and government support
	C43	Poor commitment of senior management
Green Information in Construction Industry	C51	Lack of awareness of environmental effects
	C52	Demand shortage
	C53	Failure to share information between construction organizations and suppliers

As shown in Figure 2, five components, including three main components (green procurement, green design, and green production) and two supporting components (green management and green information) were distinguished in GCSCM. Then, 18 sub-components related to the five aforementioned components were identified using the literature review (illustrated in Table 1) and experts' opinions. As an example, three sub-components, including lack of access to green materials and materials (C11), lack of market for recyclable materials (C12), and lack of proper storage and maintenance of materials (C13), which are relevant to the component of green procurement, are among the obstacles and barriers of implementing GCSCM.

In the third step, the fuzzy best–worst method (BWM) was utilized to determine the importance weights of the identified components and sub-components.

In an MCDM problem, a number of alternatives are evaluated with respect to a number of criteria to select the best alternative(s). The best–worst method (BWM) is one of the MCDM methods presented by Rezaei [10]. He also developed this method in 2016. BWM is based on pairwise comparisons between criteria. First, the best criterion and the worst criterion are identified, then the priority of the best criterion, compared to the number of criteria, as well as the degree of superiority of all criteria to the worst criterion, are determined using pairwise comparisons. BWM, as a powerful MCDM technique, has been widely used by several researchers for dealing with a variety of problems related to GSCM around the world [59–61].

Verbal and linguistic judgments made by decision-makers are usually vague and uncertain. Therefore, the fuzzy BWM method, as an extension of BWM, was developed to tackle the ambiguity and uncertainty associated with expert judgment [62].

The implementation steps of the fuzzy BWM method are as follows:

Step 1: Determining the best criterion and the worst criterion: In this step, the most important and the least important criteria are determined using experts' opinions. C_B and C_W denote the best and the worst criteria, respectively.

Step 2: Pairwise comparison of the best criterion with other criteria and other criteria with the worst criterion: In this step, pairwise comparisons can be made using any fuzzy spectrum, but one of the most common spectrums for the fuzzy BWM method is based on the five-point Likert scale comprising the verbal expressions of equal importance (EI), weak importance (WI), moderately important (FI), very important (VI), and absolutely important (AI).

The best vector compared to other criteria is as follows:

$$\tilde{A}_B = (\tilde{a}_{B1}, \tilde{a}_{B2}, \ldots, \tilde{a}_{Bn}) \tag{1}$$

where $\tilde{A}_B$ expresses the fuzzy best vector compared to other criteria and $\tilde{a}_{Bj}$ expresses the fuzzy preference of the best criterion C_B compared to criterion j. It is clear that $\tilde{a}_{BB} = (1,1,1)$.

In addition, the fuzzy preferences of all criteria, with respect to the worst criterion, were determined using the linguistic variables presented in Table 4, as follows:

$$\tilde{A}_W = (\tilde{a}_{W1}, \tilde{a}_{W2}, \ldots, \tilde{a}_{Wn}) \tag{2}$$

where $\tilde{A}_W$ expresses the fuzzy worst vector compared to other criteria and $\tilde{a}_{Wj}$ expresses the fuzzy preference of the criterion i compared to the worst criterion C_W. It is clear that $\tilde{a}_{WW} = (1,1,1)$.

Table 4. Transformation rules of linguistic variables of decision-makers.

Linguistic Variable	Response Scale
Equally important	(1, 1, 1)
Weakly important (WI)	(2/3, 1, 3/2)
Fairly important (FI)	(3/2, 2, 5/2)
Very important (VI)	(5/2, 3, 7/2)
Absolutely important (AI)	(7/2, 4, 9/2)

Step 3: Forming the fuzzy BWM model. In this step, the weights of the criteria can be calculated using the following non-linear mathematical programming model. It is recommended to transform this model into linear mathematical programming model for a number of criteria more than three to obtain better results [62].

$$\min \widetilde{\xi}^* s.t. \begin{cases} \left| \frac{(l_B^W, m_B^W, u_B^W)}{(l_j^W, m_j^W, u_j^W)} - (l_{Bj}, m_{Bj}, u_{Bj}) \right| \leq (k^*, k^*, k^*) \\ \left| \frac{(l_j^W, m_j^W, u_j^W)}{(l_W^W, m_W^W, u_W^W)} - (l_{jW}, m_{jW}, u_{jW}) \right| \leq (k^*, k^*, k^*) \\ \sum_{j=1}^{n} R(\widetilde{W}_j) = 1 \\ l_j^W \leq m_j^W \leq u_j^W \\ l_j^W \geq 0 \\ j = 1, 2, \ldots, n \end{cases} \tag{3}$$

Step 4: Solving the model by one of the optimization software, such as LINGO or GAMS, to obtain the weights of the criteria $\left(\widetilde{W}_1^*, \widetilde{W}_2^*, \ldots, \widetilde{W}_n^*\right)$. In addition, the consistency ratio (CR) is determined using the consistency index (CI) (shown in Table 5) and the obtained optimal value k^*:

$$Consistancy\ Ratio\ (CR) = \frac{k^*}{Consistancy\ Index} \quad (4)$$

Table 5. Consistency Index (CI) for Fuzzy BWM.

Linguistic Terms	$\tilde{a}_{BW}$	CI
Equally importance (EI)	(1, 1, 1)	3.00
Weakly important (WI)	(2/3, 1, 3/2)	3.80
Fairly Important (FI)	(3/2, 2, 5/2)	5.29
Very important (VI)	(5/2, 3, 7/2)	6.69
Absolutely important (AI)	(7/2, 4, 9/2)	8.04

It should be noted that the best and the worst criteria can be determined using each expert's viewpoint individually. Consequently, a fuzzy BWM model is formed for each expert. After solving the model and calculating the weights of the criteria, the weights obtained from each expert are finally merged [62].

4. Results

As aforementioned, for weighing the criteria in BWM, the best criterion and the worst criterion are determined through the experts' opinions. Therefore, five experts in the construction industry were asked to distinguish the most effective component (the best criterion) and the least effective component (the worst criterion). It should be noted that, since the weighting of components (criteria) and sub-components (sub-criteria) requires practical experience in implementation, 5 individuals who were practically involved in implementation (project managers) were selected among 20 research experts.

Then, they were asked to identify the priority of the best criterion (component) over the other criteria, as well as the priority of all criteria over the worst criterion, based on fuzzy numbers. The results are presented in Tables 6 and 7.

Table 6. The priority of the best criterion over the other criteria, according to the expert' opinions.

Expert	Best	C1	C2	C3	C4	C5
Expert 1	C2	WI	EI	FI	WI	AI
Expert 2	C2	AI	EI	VI	WI	AI
Expert 3	C4	FI	WI	VI	EI	VI
Expert 4	C2	WI	EI	FI	FI	VI
Expert 5	C2	WI	EI	FI	FI	VI

Table 7. The priority of the worst criterion over the other criteria, according to the expert' opinions.

Expert	Worst	C1	C2	C3	C4	C5
Expert 1	C5	FI	VI	VI	FI	EI
Expert 2	C5	AI	VI	VI	VI	EI
Expert 3	C5	VI	AI	AI	VI	EI
Expert 4	C5	VI	VI	AI	VI	EI
Expert 5	C5	FI	VI	VI	AI	EI

As can be seen in Table 6, expert 3 selected the C4 criterion as the best and most important criterion; however, the other experts selected the C2 criterion. According to Table 7, all the experts unanimously selected the C5 criterion as the worst and least important criterion.

In accordance with Table 6 and Equation (1), the best-to-others fuzzy vector can be formed based on the opinion of each expert. Additionally, based on Table 7 and Equation (2), the others-to-worst fuzzy vector is formed for each expert's opinion. The following vectors show the results according to the opinion of each expert:

$$E_1 : \begin{cases} \tilde{A}_B^1 = \left(\tilde{a}_{B1}^1, \tilde{a}_{B2}^1, \tilde{a}_{B3}^1, \tilde{a}_{B4}^1, \tilde{a}_{B5}^1\right) = ((0.66, 1, 1.5), (1, 1, 1), (1.5, 2, 2.5), (0.66, 1, 1.5), (3.5, 4, 4.5)) \\ \tilde{A}_W^1 = \left(\tilde{a}_{1W}^1, \tilde{a}_{2W}^1, \tilde{a}_{3W}^1, \tilde{a}_{4W}^1, \tilde{a}_{5W}^1\right) = ((1.5, 2, 2.5), (3.5, 4, 4.5), (2.5, 3, 3.5), (1.5, 2, 2.5), (1, 1, 1)) \end{cases}$$

$$E_2 : \begin{cases} \tilde{A}_B^2 = \left(\tilde{a}_{B1}^2, \tilde{a}_{B2}^2, \tilde{a}_{B3}^2, \tilde{a}_{B4}^2, \tilde{a}_{B5}^2\right) = ((1.5, 2, 2.5), (1, 1, 1), (2.5, 3, 3.5), (0.66, 1, 1.5), (3.5, 4, 4.5)) \\ \tilde{A}_W^2 = \left(\tilde{a}_{1W}^2, \tilde{a}_{2W}^2, \tilde{a}_{3W}^2, \tilde{a}_{4W}^2, \tilde{a}_{5W}^2\right) = ((1.5, 2, 2.5), (3.5, 4, 4.5), (2.5, 3, 3.5), (2.5, 3, 3.5), (1, 1, 1)) \end{cases}$$

$$E_3 : \begin{cases} \tilde{A}_B^3 = \left(\tilde{a}_{B1}^3, \tilde{a}_{B2}^3, \tilde{a}_{B3}^3, \tilde{a}_{B4}^3, \tilde{a}_{B5}^3\right) = ((1.5, 2, 2.5), (0.66, 1, 1.5), (2.5, 3, 3.5), (1, 1, 1), (2.5, 3, 3.5)) \\ \tilde{A}_W^3 = \left(\tilde{a}_{1W}^3, \tilde{a}_{2W}^3, \tilde{a}_{3W}^3, \tilde{a}_{4W}^3, \tilde{a}_{5W}^3\right) = ((2.5, 3, 3.5), (3.5, 4, 4.5), (3.5, 4, 4.5), (2.5, 3, 3.5), (1, 1, 1)) \end{cases}$$

$$E_4 : \begin{cases} \tilde{A}_B^4 = \left(\tilde{a}_{B1}^4, \tilde{a}_{B2}^4, \tilde{a}_{B3}^4, \tilde{a}_{B4}^4, \tilde{a}_{B5}^4\right) = ((0.66, 1, 1.5), (1, 1, 1), (1.5, 2, 2.5), (1.5, 2, 2.5), (2.5, 3, 3.5)) \\ \tilde{A}_W^4 = \left(\tilde{a}_{1W}^4, \tilde{a}_{2W}^4, \tilde{a}_{3W}^4, \tilde{a}_{4W}^4, \tilde{a}_{5W}^4\right) = ((2.5, 3, 3.5), (2.5, 3, 3.5), (3.5, 4, 4.5), (2.5, 3, 3.5), (1, 1, 1)) \end{cases}$$

$$E_5 : \begin{cases} \tilde{A}_B^5 = \left(\tilde{a}_{B1}^5, \tilde{a}_{B2}^5, \tilde{a}_{B3}^5, \tilde{a}_{B4}^5, \tilde{a}_{B5}^5\right) = ((0.66, 1, 1.5), (1, 1, 1), (1.5, 2, 2.5), (1.5, 2, 2.5), (2.5, 3, 3.5)) \\ \tilde{A}_W^5 = \left(\tilde{a}_{1W}^5, \tilde{a}_{2W}^5, \tilde{a}_{3W}^5, \tilde{a}_{4W}^5, \tilde{a}_{5W}^5\right) = ((1.5, 2, 2.5), (2.5, 3, 3.5), (2.5, 3, 3.5), (3.5, 4, 4.5), (1, 1, 1)) \end{cases}$$

According to the vectors $\tilde{A}_B^i$ and $\tilde{A}_W^i$, a linear mathematical programming model is formed using Equation (3) to obtain the optimal fuzzy weights of the main criteria C1 to C5 for experts $i = 1, \ldots, 5$. For instance, the following linear optimization model is presented and solved based on the vectors $\tilde{A}_B^1$ and $\tilde{A}_W^1$ for the first expert.

$$min\ e^* s.t. \begin{cases} l2 - 0.66 * u1 - u1 * e \leq 0; l2 - 0.66 * u1 + u1 * e \geq 0; \\ m2 - 1 * m1 - m1 * e \leq 0; m2 - 1 * m1 + m1 * e \geq 0; \\ u2 - 1.5 * l1 - l1 * e \leq 0; u2 - 1.5 * l1 + l1 * e \geq 0; \\ l2 - 1.5 * u3 - u3 * e \leq 0; l2 - 1.5 * u3 + u3 * e \geq 0; \\ m2 - 2 * m3 - m3 * e \leq 0; m2 - 2 * m3 + m3 * e \geq 0; \\ u2 - 2.5 * l3 - l3 * e \leq 0; u2 - 2.5 * l3 + l3 * e \geq 0; \\ l2 - 0.66 * u4 - u4 * e \leq 0; l2 - 0.66 * u4 + u4 * e \geq 0; \\ m2 - 1 * m4 - m4 * e \leq 0; m2 - 1 * m4 + m4 * e \geq 0; \\ u2 - 1.5 * l4 - l4 * e \leq 0; u2 - 1.5 * l4 + l4 * e \geq 0; \\ l2 - 3.5 * u5 - u5 * e \leq 0; l2 - 3.5 * u5 + u5 * e \geq 0; \\ m2 - 4 * m5 - m5 * e \leq 0; m2 - 4 * m5 + m5 * e \geq 0; \\ u2 - 4.5 * l5 - l5 * e \leq 0; u2 - 4.5 * l5 + l5 * e \geq 0; \\ l1 - 1.5 * u5 - u5 * e \leq 0; l1 - 1.5 * u5 + u5 * e \geq 0; \\ m1 - 2 * m5 - m5 * e \leq 0; m1 - 2 * m5 + m5 * e \geq 0; \\ u1 - 2.5 * l5 - l5 * e \leq 0; u1 - 2.5 * l5 + l5 * e \geq 0; \\ l3 - 2.5 * u5 - u5 * e \leq 0; l3 - 2.5 * u5 + u5 * e \geq 0; \\ m3 - 3 * m5 - m5 * e \leq 0; m3 - 3 * m5 + m5 * e \geq 0; \\ u3 - 3.5 * l5 - l5 * e \leq 0; u3 - 3.5 * l5 + l5 * e \geq 0; \\ l4 - 1.5 * u5 - u5 * e \leq 0; l4 - 1.5 * u5 + u5 * e \geq 0; \\ m4 - 2 * m5 - m5 * e \leq 0; m4 - 2 * m5 + m5 * e \geq 0; \\ u4 - 2.5 * l5 - l5 * e \leq 0; u4 - 2.5 * l5 + l5 * e \geq 0; \\ l1 \leq m1 \leq u1;\ l2 \leq m2 \leq u2;\ l3 \leq m3 \leq u3; \\ l4 \leq m4 \leq u4;\ l5 \leq m5 \leq u5; \\ l1 \geq 0; l2 \geq 0; l3 \geq 0\ l4 \geq 0; l5 \geq 0; \\ e \geq 0; \\ \frac{1}{6} * (l1 + 4 * m1 + u1) + \frac{1}{6} * (l2 + 4 * m2 + u2) \\ + \frac{1}{6} * (l3 + 4 * m3 + u3) + \frac{1}{6} * (l4 + 4 * m4 + u4) \\ + \frac{1}{6} * (l5 + 4 * m5 + u5) = 1; \end{cases}$$

In the following, the consistency ratio (CR) is calculated using Equation (4). The findings are presented in Table 8.

Table 8. The weights of the major criteria (based on the opinion of Expert 1).

Criteria	Fuzzy Weight	Final Weight
C1 (Green Procurement)	(0.185, 0.199, 0.239)	0.203
C2 (Green Design)	(0.277, 0.299, 0.370)	0.307
C3 (Green Production)	(0.185, 0.199, 0.239)	0.203
C4 (Green Management)	(0.185, 0.199, 0.239)	0.203
C5 (Green Information)	(0.079, 0.079, 0.092)	0.081
Objective Value	0.5	
Consistency Ratio	0.06218905	

After calculating the fuzzy weights of the main criteria, the crisp value of the triangular fuzzy number $\tilde{a}_i = (l_i, m_i, u_i)$, called the graded mean integration representation (GMIR), is obtained using Equation (5) [63].

$$R(\tilde{a}_i) = \frac{l_i + 4m_i + u_i}{6}$$

Table 7 shows that the highest value was related to the green design criterion (C2) and the lowest value was related to the green information criterion (C5). Additionally, the value of 0.062 for the consistency ratio indicates the high consistency and accuracy of the findings. Similarly, the weights of the main criteria were obtained based on the other experts' opinions. The findings are presented in Tables 9–12. Additionally, Figure 3 shows the weight of each of the main criteria C1 to C5, regarding the experts' opinions.

Table 9. The weights of the major criteria (based on the opinion of Expert 2).

Criteria	Fuzzy Weight	Final Weight
C1 (Green Procurement)	(0.165, 0.186, 0.196)	0.184
C2 (Green Design)	(0.302, 0.352, 0.352)	0.343
C3 (Green Production)	(0.129, 0.160, 0.179)	0.158
C4 (Green Management)	(0.235, 0.235, 0.258)	0.238
C5 (Green Information)	(0.066, 0.073, 0.073)	0.071
Objective Value	0.8074176	
Consistency Ratio	0.1004250	

Table 10. The weights of the major criteria (based on the opinion of Expert 3).

Criteria	Fuzzy Weight	Final Weight
C1 (Green Procurement)	(0.098, 0.135, 0.168)	0.134
C2 (Green Design)	(0.177, 0.218, 0.246)	0.215
C3 (Green Production)	(0.177, 0.218, 0.246)	0.215
C4 (Green Management)	(0.282, 0.359, 0.380)	0.349
C5 (Green Information)	(0.078, 0.082, 0.082)	0.081
Objective Value	1.354249	
Consistency Ratio	0.1679104	

Table 11. The weights of the major criteria (based on the opinion of Expert 4).

Criteria	Fuzzy Weight	Final Weight
C1 (Green Procurement)	(0.221, 0.249, 0.287)	0.250
C2 (Green Design)	(0.219, 0.240, 0.287)	0.244
C3 (Green Production)	(0.174, 0.207, 0.338)	0.223
C4 (Green Management)	(0.174, 0.206, 0.287)	0.214
C5 (Green Information)	(0.065, 0.065, 0.065)	0.065
Objective Value	0.8542486	
Consistency Ratio	0.1062498	

Table 12. The weights of the major criteria (based on the opinion of Expert 5).

Criteria	Fuzzy Weight	Final Weight
C1 (Green Procurement)	(0.160, 0.194, 0.228)	0.194
C2 (Green Design)	(0.228, 0.262, 0.296)	0.262
C3 (Green Production)	(0.180, 0.229, 0.296)	0.232
C4 (Green Management)	(0.180, 0.229, 0.354)	0.241
C5 (Green Information)	(0.068, 0.068, 0.068)	0.068
Objective Value	0.8542486	
Consistency Ratio	0.1062498	

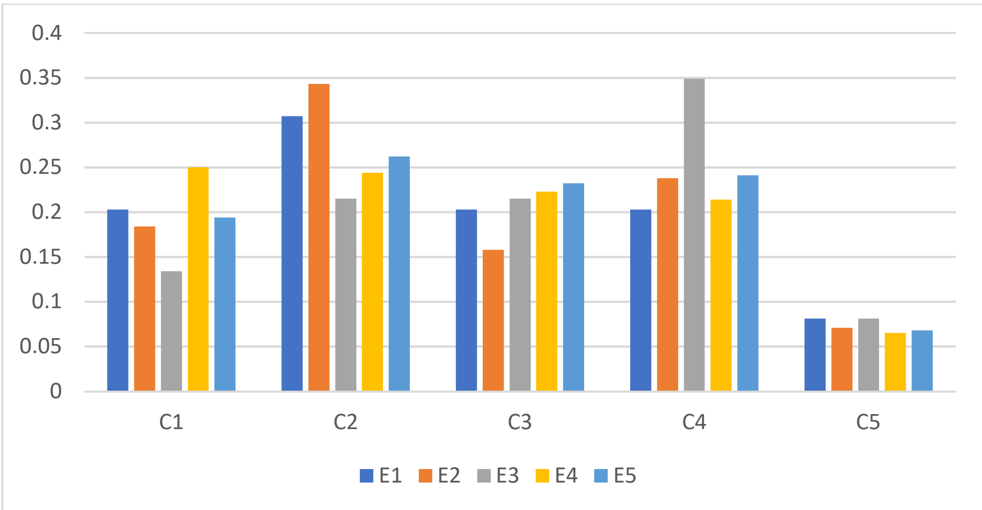

Figure 3. The comparison of the weights of the main criteria of GCSCM from the experts' opinions.

According to the experts' opinions, the order of importance of the main criteria, based on the obtained weights using the fuzzy BWM method, is as follows:

$$E1 : C2 \succ C1 = C3 = C4 \succ C5$$

$$E2 : C2 \succ C4 \succ C1 \succ C3 \succ C5$$

$$E3 : C4 \succ C2 = C3 \succ C1 \succ C5$$

$$E4 : C1 \succ C2 \succ C3 \succ C4 \succ C5$$

$$E5 : C2 \succ C4 \succ C3 \succ C1 \succ C5$$

As can be seen, the C5 (green information) criterion was the least important, based on the opinions of all experts. The C2 (green design) criterion was the most important, based on the opinions of three experts. Subsequently, the geometric mean of each of the main criteria was computed to combine the experts' opinions. Additionally, the importance weights of sub-criteria (sub-components) were calculated using the fuzzy BWM method. The findings are given in Table 13.

Table 13. The final ranking of the obstacles and barriers to the implementation of GCSCM.

Major Criteria	Weight of Major Criteria	Sub-Criteria Code	Local Weight	Global Weight	Final Rank
C1 (Green Procurement)	0.189	C11	0.389	0.0735	4
		C12	0.236	0.0446	9
		C13	0.375	0.0708	5
C2 (Green Design)	0.270	C21	0.378	0.1020	2
		C22	0.369	0.0996	3
		C23	0.253	0.0683	7
C3 (Green Production)	0.204	C31	0.173	0.0352	12
		C32	0.106	0.0216	17
		C33	0.189	0.0385	11
		C34	0.209	0.0426	10
		C35	0.165	0.0336	13
		C36	0.158	0.0322	14
C4 (Green Management)	0.244	C41	0.230	0.0561	8
		C42	0.481	0.1173	1
		C43	0.289	0.0705	6
C5 (Green Information)	0.072	C51	0.349	0.0251	16
		C52	0.285	0.0205	18
		C53	0.366	0.0263	15

As stated in the above table, among the main obstacles and challenges of GCSCM, the C2 (green design) criterion was ranked first, with an importance weight of 0.270. The C4 (green management) criterion, with an importance weight of 0.244, was ranked second, the C3 (green production) criterion, with an importance weight of 0.204, was ranked third, the C1 (green procurement) criterion was ranked the fourth, with an importance weight of 0.189, and finally, the C5 (green information) criterion, with an importance weight of 0.072, was ranked the fifth.

According to "Local Weight" column in Table 12, the sub-criteria C11 (lack of access to green materials and materials), the sub-criterion C21 (lack of designers, contractors, and planners in the green construction industry), the sub-criterion C34 (cost increase), the sub-criterion C42 (lack of related laws and regulations and government support), and the sub-criterion C53 (non-sharing of information between construction companies and suppliers) were the most important sub-criteria of the C1 to C5 main criteria, respectively. Figure 4 shows the weights of the sub-criteria of each of the main criteria, based on local weight.

According to the weights of the main criteria and the local weights of the sub-criteria obtained by the fuzzy BWM method, the final weights of the sub-criteria were calculated, as shown in Table 12. Among the 18 sub-criteria, three sub-criteria C42 (lack of relevant laws and regulations and government support), C21 (lack of designers, contractors, and planners in the green construction industry), and C22 (lack of training, awareness, and appropriate experiences of green supply chain) are ranked the first to third with the importance weights of 0.1173, 0.1020, and 0.0996, respectively. Figure 5 illustrates the final weights of 18 sub-criteria.

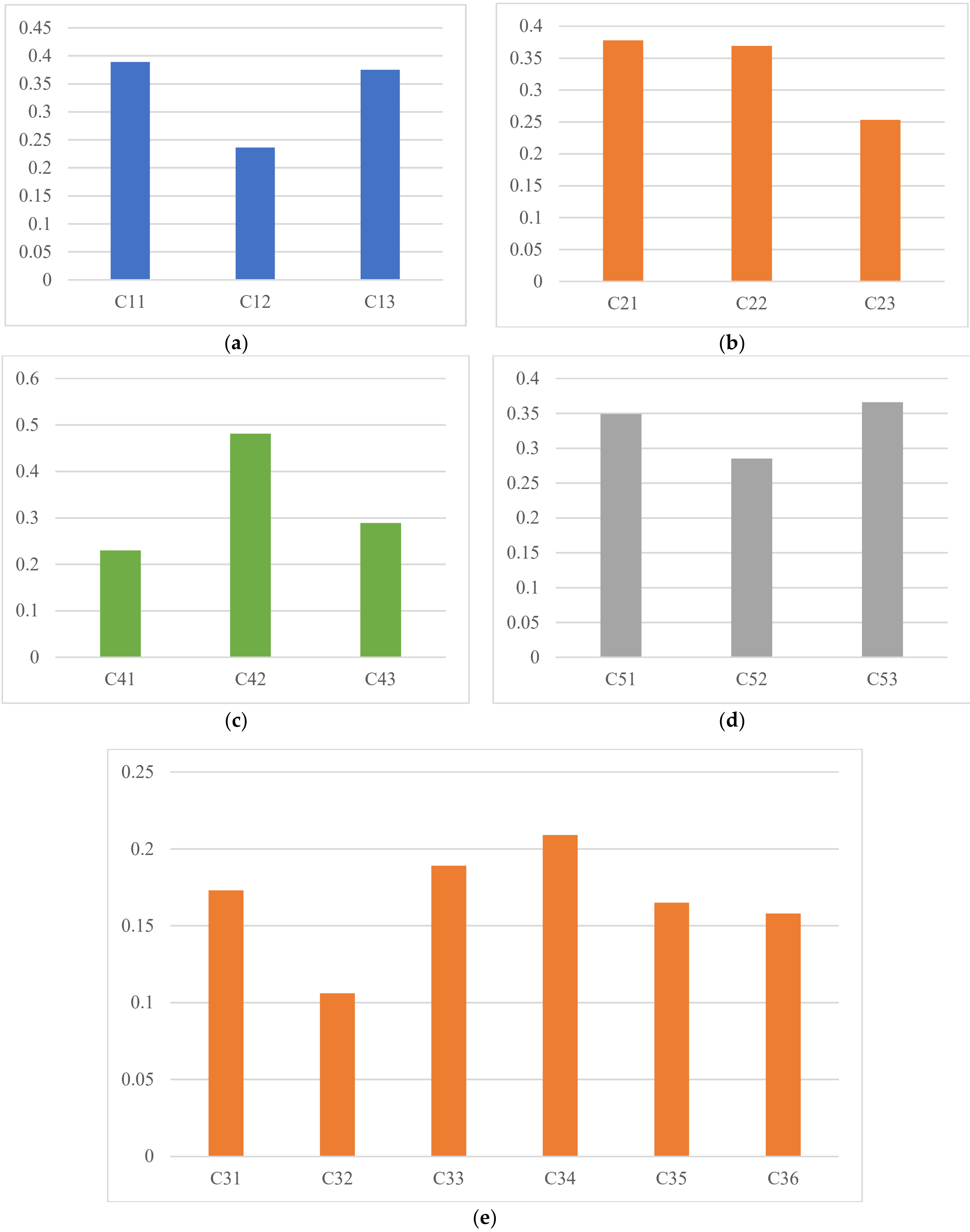

Figure 4. The weights of the sub-criteria of GCSCM: (**a**) the sub-criteria of green procurement (C1), (**b**) sub-criteria of green design (C2), (**c**) sub-criteria of green production (C3), (**d**) sub-criteria of green management (C4), (**e**) sub-criteria of green information (C5).

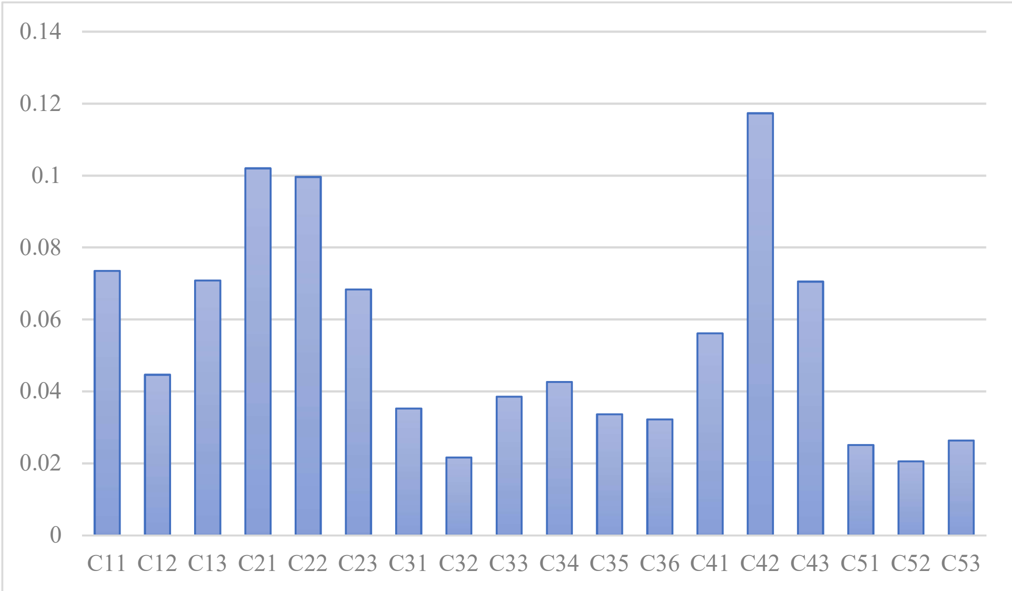

Figure 5. The Global weights of the sub-criteria of GCSCM.

5. Discussion and Conclusions

Considering the share of the construction industry in polluting the environment and increasing the attention of governments, non-governmental organizations, and environmentalists to the requisite of reducing environmental pollution [2,64,65], one of the most important issues is how construction organizations overcome the various obstacles and challenges in GCSCM. The usage of the concept of GSCM in the construction industry means creating environmental thinking at all stages of the construction supply chain, including the design, implementation, and delivery of the bult asset to the final consumers and beneficiaries. The main goal of implementing GCSCM is to minimize the environmental consequences and impacts caused by the activities of construction projects on air, water, soil, animal species, plants, and natural resources [38].

The current research was conducted with the aim of identifying the obstacles and barriers of implementing GSCM in the construction industry. Reviewing the related literature to obstacles and barriers affecting the implementation of GCSCM, as well as soliciting the opinions of the experts in the construction industry, revealed that five components influence the successful implementation of GCSCM. These five components were considered according to the concept of supply chain management, green management, and the construction industry. The conceptual model of this study contains five components, three of which are main components, including "Green Procurement", "Green Design", and "Green Production". Two other components have the supporting role for this cycle, which are "Green Management" and "Green Information". Then, the sub-components of each component were identified through the literature review and expert judgment. The weighting and prioritization of components showed that most challenges and obstacles in GCSCM are related to "Green Design" in the construction industry.

Based on the obtained weights of the main criteria using the fuzzy BWM method, "Green Design", with a score of 0.270, is the most important component. The weight of this component has a significant difference with the weights of the other components that are placed in the second to fifth places. The importance weight of "Green Design" (the first ranked component), compared to "Green Management" (the second ranked component), is more than 10%, compared to "Green Production" (the third ranked component) is more than 32%, compared to "Green Procurement" (the fourth ranked component) is more than 42%, and finally, compared to "Green Information" (the fifth ranked component), is more than 2.75 times. This matter indicates that the main focus should be on proper design, considering all principles of the green concept in construction projects. Compliance with these principles, along with the principles of green management in the construction industry, is responsible for more than half of the challenges and obstacles.

In addition, among all the sub-components related to the environmental challenges, the sub-component of "lack of related laws and regulations and government support" was recognized as the most important barrier. Although many countries have laws and regulations about the environment and several national and international efforts have been made to protect the environment, environmental challenges have significantly increased in many areas, particularly the construction industry. Therefore, governments should pay more attention to the necessity of implementing GSCM and supporting it. GSCM is the integration of supply chain management with environmental requirements. This integration includes all stages of product design, the selection and supply of raw materials, manufacturing, and transportation. Hence, the goal of GSCM in the construction industry is to optimize the allocation and consumption of resources, increase benefits, and achieve environmental compatibility through the promotion of environmentally friendly activities. Taking environmental considerations into account and providing appropriate executive frameworks can lead to the development of the entire supply chain, along with environmental protection. Environmental protection not only has a vital role in sustainable development, but also has direct and indirect effects on economic activities, quality of life, social welfare and satisfaction, and the level of real incomes.

5.1. Practical Implications

The present study was conducted with the aim of determining and ranking the significant barriers and obstacles affecting GCSCM. Since the construction industry is one of the main sectors in the development of countries and known as one of the environmentally polluting industries, the implementation of GSCM in this industry is very important and challenging. Previous studies regarding green supply chain management in the construction industry investigated and identified the influential factors, in order to reduce and resolve conflicts between supply chain components and increase cooperation. As an example, Xie et al. [38] examined the issue of strengthening public and private partnerships in green construction management. However, due to the complexity of the construction supply chain, only 1.39% of research works have addressed the application of green supply chain management in the construction industry [66]. Therefore, the present research added value and contributed to the extant knowledge through collecting, identifying, and categorizing the implementation obstacles and challenges of GCSCM. In addition, the novel fuzzy BWM, as a novel MCDM method, was employed to rank the identified barriers and obstacles. Among the MCDM methods, BWM has received more attention from researchers and scholars because of the less pairwise comparisons and higher accuracy. In this paper, the importance weight of each of the main criteria and sub-criteria was evaluated and obtained through the opinions of the construction experts. Inevitably, it is crucial to managers, contractors, and decision-makers in the construction industry to distinguish these challenges and obstacles.

5.2. Academic Implications

Due to the importance of environment and green management in the construction industry, the role of researchers in developing theoretical grounds becomes more prominent. For this purpose, some suggestions are provided, as follows:

- Training and informing planners and decision-makers on the topic of green management,
- Reviewing and modifying the relevant laws and regulations,
- Proposing novel scientific methods for different phases of the construction supply chain management can develop some of these theoretical foundations and be scientific for universities and researchers.

5.3. Suggestions for Further Research

In this research, 18 obstacles and barriers of implementing green supply chain management in the construction industry have been identified. As a suggestion for future research, more challenges and obstacles may be identified. Additionally, it is suggested to evaluate the interrelationship and impact of the identified obstacles on each other.

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

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data are available upon request.

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

References

1. Badi, S.; Murtagh, N. Green supply chain management in the construction: A systematic literature review and future agenda. *J. Clean. Prod.* **2019**, *223*, 312–322. [CrossRef]
2. Banihashemi, S.A.; Khalilzadeh, M.; Zavadskas, E.K.; Antucheviciene, J. Investigating the Environmental Impacts of Construction Projects in Time-Cost Trade-Off Project Scheduling Problems with CoCoSo Multi-Criteria Decision-Making Method. *Sustainability* **2021**, *13*, 10922. [CrossRef]
3. Balasubramanian, S.; Shukla, V. Green supply chain management: An empirical investigation on the construction sector. *Supply Chain Manag.* **2017**, *22*, 58–81. [CrossRef]
4. Banihashemi, S.A.; Khalilzadeh, M. Evaluating Efficiency in Construction Projects with the TOPSIS Model and NDEA Method Considering Environmental Effects and Undesirable Data. *Iran. J. Sci. Technol. Trans. Civ. Eng.* **2021**, *46*, 1589–1605. [CrossRef]
5. Naghizadeh Vardin, A.; Ansari, R.; Khalilzadeh, M.; Antucheviciene, J.; Bausys, R. An Integrated Decision Support Model Based on BWM and Fuzzy-VIKOR Techniques for Contractor Selection in Construction Projects. *Sustainability* **2021**, *13*, 6933. [CrossRef]
6. Irizarry, J.; Karan, E.; Jalaei, F. Integrating BIM and GIS to improve the visual monitoring of construction supply chain management. *Autom. Constr.* **2013**, *31*, 241–254. [CrossRef]
7. Fulford, R.; Standing, C. Construction industry productivity and the potential for collaborative practice. *Int. J. Proj. Manag.* **2014**, *32*, 315–326. [CrossRef]
8. Pryke, S. *Construction Supply Chain Management: Concepts and Case Studies*; Blackwell Publishing, John Wiley & Sons: Chichester, UK, 2009.
9. Sarkis, J.; Zhu, Q.; Lai, K. An organizational theoretic review of green supply chain management literature. *Int. J. Prod. Econ.* **2011**, *130*, 1–15. [CrossRef]
10. Rezaei, J. Best-worst multi-criteria decision-making method. *Omega* **2015**, *53*, 49–57. [CrossRef]
11. Segerstedt, A.; Olofsson, T. Supply chains in the construction industry. *Supply Chain Manag.* **2010**, *15*, 347–353. [CrossRef]
12. Behera, P.; Mohanty, R.P.; Prakash, A. Understanding Construction Supply Chain Management. *Prod. Plan. Control* **2015**, *26*, 1332–1350. [CrossRef]
13. Hao, C.; Du, Q.; Huang, Y.; Shao, L.; Yan, Y. Evolutionary Game Analysis on Knowledge-Sharing Behavior in the Construction Supply Chain. *Sustainability* **2019**, *11*, 5319. [CrossRef]
14. Battula, V.R.; Namburu, S.K.; Kone, V. A study on factors involved in implementation of supply chain management in construction industry. *Mater. Today Proc.* **2020**, *33*, 446–449. [CrossRef]
15. Koc, K.; Gurgun, A.P. Stakeholder-Associated Life Cycle Risks in Construction Supply Chain. *J. Manag. Eng.* **2021**, *37*, 04020107. [CrossRef]
16. Liu, Y.; Dong, J.; Shen, L. A Conceptual Development Framework for Prefabricated Construction Supply Chain Management: An Integrated Overview. *Sustainability* **2020**, *12*, 1878. [CrossRef]
17. Studer, W.P.; De Brito Mello, L.C.B. Core Elements Underlying Supply Chain Management in the Construction Industry: A Systematic Literature Review. *Buildings* **2021**, *11*, 569. [CrossRef]
18. Hussein, M.; Eltoukhy, A.E.E.; Karam, A.; Shaban, I.; Zayed, T. Modelling in off-site construction supply chain management: A review and future directions for sustainable modular integrated construction. *J. Clean. Prod.* **2021**, *310*, 127503. [CrossRef]
19. Masood, R.; Lim, J.B.P.; González, V.A.; Roy, K.; Khan, K.I.A. A Systematic Review on Supply Chain Management in Prefabricated House-Building Research. *Buildings* **2022**, *12*, 40. [CrossRef]

20. Cigolini, R.; Gosling, J.; Iyer, A.; Senicheva, O. Supply chain management in construction and engineer-to-order industries. *Prod. Plan. Control* **2022**, *33*, 803–810. [CrossRef]
21. Salari, S.A.-S.; Mahmoudi, H.; Aghsami, A.; Jolai, F.; Jolai, S.; Yazdani, M. Off-Site Construction Three-Echelon Supply Chain Management with Stochastic Constraints: A Modelling Approach. *Buildings* **2022**, *12*, 119. [CrossRef]
22. Gurgun, A.P.; Genc, M.I.; Koc, K.; Arditi, D. Exploring the Barriers against Using Cryptocurrencies in Managing Construction Supply Chain Processes. *Buildings* **2022**, *12*, 357. [CrossRef]
23. Dallasega, P.; Rauch, E. Sustainable Construction Supply Chains through Synchronized Production Planning and Control in Engineer-to-Order Enterprises. *Sustainability* **2017**, *9*, 1888. [CrossRef]
24. Zeng, N.; Liu, Y.; Mao, C.; König, M. Investigating the Relationship between Construction Supply Chain Integration and Sustainable Use of Material: Evidence from China. *Sustainability* **2018**, *10*, 3581. [CrossRef]
25. Mee-ngoen, B.; Nualkaw, S.; Sirariyakul, T.; Tomcharoen, N.; Jermsittiparsert, K. Green training, green project and green construction as antecedents of customer satisfaction: Examining the mediating role of green supply chain management. *Int. J. Supply Chain Manag.* **2020**, *9*, 393–402.
26. Ali, Y.; Saad, T.B.; Sabir, M.; Muhammad, N.; Salman, A.; Zeb, K. Integration of green supply chain management practices in construction supply chain of CPEC. *Manag. Environ. Qual.* **2020**, *31*, 185–200. [CrossRef]
27. Hussain, M.; Malik, M. Organizational enablers for circular economy in the context of sustainable supply chain management. *J. Clean. Prod.* **2020**, *256*, 120375. [CrossRef]
28. Liao, H.; Ren, R.; Antucheviciene, J.; Šaparauskas, J.; Al-Barakati, A. Sustainable construction supplier selection by a Multiple Criteria Decision-making Method with hesitant linguistic information. *Econ. Manag.* **2020**, *23*, 119–136. [CrossRef]
29. Farnam, M.; Darehmiraki, M. Supply chain management problem modelling in hesitant fuzzy environment. *J. Fuzzy Ext. Appl.* **2022**, *3*, 317–336. [CrossRef]
30. Lin, Y.; Guo, C.; Tan, Y. The incentive and coordination strategy of sustainable construction supply chain based on robust optimization. *J. Control Decis.* **2020**, *7*, 126–159. [CrossRef]
31. Marandi Alamdari, A.; Jabarzadeh, Y.; Samson, D.; Sanoubar, N. Supply chain risk factors in green construction of residential mega projects—Interactions and categorization. *Eng. Constr. Archit. Manag.* **2021**, *in press*. [CrossRef]
32. Mojumder, A.; Singh, A. An exploratory study of the adaptation of green supply chain management in construction industry: The case of Indian Construction Companies. *J. Clean. Prod.* **2021**, *295*, 126400. [CrossRef]
33. Kosanoglu, F.; Kus, H.T. Sustainable supply chain management in construction industry: A Turkish case. *Clean Technol. Environ. Policy* **2023**, *23*, 2589–2613. [CrossRef]
34. RezaHoseini, A.; Noori, S.; Ghannadpour, S.F. Integrated scheduling of suppliers and multi-project activities for green construction supply chains under uncertainty. *Autom. Constr.* **2021**, *122*, 103485. [CrossRef]
35. Cataldo, L.; Banaitis, A.; Samadyia, A.; Banaitienė, N.; Kumar, A.; Luthra, S. Sustainable supply chain management in construction: An exploratory review for future research. *J. Civ. Eng. Manag.* **2022**, *28*, 536–553. [CrossRef]
36. Mohammadnazari, Z.; Ghannadpour, S.F. Sustainable construction supply chain management with the spotlight of inventory optimization under uncertainty. *Environ. Dev. Sustain.* **2021**, *23*, 10937–10972. [CrossRef]
37. Alavi, S.; Zeinalnezhad, M.; Mousavi, E. Prioritisation of GPM activities from lean-agile resilience perspective using fuzzy analytic hierarchy process. *J. Fuzzy Ext. Appl.* **2022**, *3*, 263–278. [CrossRef]
38. Xie, Y.; Zhao, Y.; Chen, Y.; Allen, C. Green construction supply chain management: Integrating governmental intervention and public–private partnerships through ecological modernization. *J. Clean. Prod.* **2022**, *331*, 129986. [CrossRef]
39. Sun, H.; Mao, W.; Dang, Y.; Xu, Y. Optimum path for overcoming barriers of green construction supply chain management: A grey possibility DEMATEL-NK approach. *Comput. Ind. Eng.* **2022**, *164*, 107833. [CrossRef]
40. Amoozad Mahdiraji, H.; Arzaghi, S.; Stauskis, G.; Zavadskas, E.K. A hybrid fuzzy BWM-COPRAS method for analyzing key factors of sustainable architecture. *Sustainability* **2018**, *10*, 1626. [CrossRef]
41. Mathiyazhagan, K.; Gnanavelbabu, A.; Lokesh Prabhuraj, B. A sustainable assessment model for material selection in construction industries perspective using hybrid MCDM approaches. *J. Adv. Manag. Res.* **2019**, *16*, 234–259. [CrossRef]
42. Alkan, R.; Yucesan, M.; Gul, M. Alkan, R.; Yucesan, M.; Gul, M. A Multi-attribute decision-making to sustainable construction material selection: A Bayesian BWM-SAW hybrid model. In *Advances in Best-Worst Method*; Rezaei, J., Brunelli, M., Mohammadi, M., Eds.; Lecture Notes in Operations Research; Springer: Cham, Switzerland, 2022. [CrossRef]
43. Singh, A.; Kumar, V.; Verma, P.; Ramtiyal, B. Can suppliers be sustainable in construction supply chains? Evidence from a construction company using best worst approach. *Manag. Environ. Qual.* **2022**, *in press*. [CrossRef]
44. Ayarkwa, J.; Acheampong, A.; Wiafe, F.; Boateng, B.E. Factors affecting the implementation of sustainable construction in Ghana: The architect's perspective. In Proceedings of the ICIDA 2017-6th International Conference on Infrastructure Development in Africa, Kumasi, Ghana, 12–14 April 2017.
45. Aigbavboa, C.; Ohiomah, I.; Zwane, T. Sustainable construction practices: "a lazy view" of construction professionals in the South Africa construction industry. *Energy Procedia* **2017**, *105*, 3003–3010. [CrossRef]
46. Baron, N.; Donath, D. Learning from Ethiopia—A discussion on sustainable building. In Proceedings of the SBE16 Hamburg International Conference on Sustainable Built Environment Strategies-Stakeholders-Success Factors 2016, Hamburg, Germany, 8–11 March 2016.

47. Shrestha, S. *Comparison of Energy Efficient and Green Buildings: Technological and Policy Aspects with Case Studies from Europe, the USA, India and Nepal*; Universitätsverlag der TU Berlin: Berlin, Germany, 2016; p. 49.
48. AlSanad, S. Awareness, drivers, actions, and barriers of sustainable construction in Kuwait. *Procedia Eng.* **2015**, *118*, 969–983. [CrossRef]
49. Babalola, I.H.; Oluwatuyi, O.E.; Lawal, A.; Aiyewalehinmi, E. Factors influencing the performance of construction projects in Akure, Nigeria. *Int. J. Civ. Eng. Constr. Estate Manag.* **2015**, *3*, 57–67.
50. Wei, W.; Ramalho, O.; Mandin, C. Indoor air quality requirements in green building certifications. *Build. Environ.* **2015**, *92*, 10–19. [CrossRef]
51. Govindan, K.; Kaliyan, M.; Kannan, D.; Haq, A.N. Barriers analysis for green supply chain management implementation in Indian industries using analytic hierarchy process. *Int. J. Prod. Econ.* **2014**, *147*, 555–568. [CrossRef]
52. Djokoto, S.D.; Dadzie, J.; Ohemeng-Ababio, E. Barriers to sustainable construction in the Ghanaian construction industry: Consultant's perspectives. *J. Sustain. Dev.* **2014**, *7*, 134. [CrossRef]
53. Opoku, A.; Fortune, C. Implementation of sustainable practices in UK construction organizations: Drivers and challenges. *Int. J. Sustain. Policy Pract.* **2013**, *8*, 121–132. [CrossRef]
54. Ojo, E.; Mbowa, C.; Akinlabi, E.T. Barriers in implementing green supply chain management in construction industry. In Proceedings of the International Conference on Industrial Engineering and Operations Management 2014, Bali, Indonesia, 7–9 January 2014.
55. Liu, X.; Yang, J.; Qu, S.; Wang, L.; Shishime, T.; Bao, C. Sustainable production: Practices and determinant factors of green supply chain management of Chinese companies. *Bus. Strategy Environ.* **2012**, *21*, 1–16. [CrossRef]
56. Holt, D.; Ghobadian, A. An empirical study of green supply chain management practices amongst UK manufacturers. *J. Manuf. Technol. Manag.* **2009**, *20*, 933–956. [CrossRef]
57. Sharfman, M.P.; Shaft, T.M.; Anex, R.P., Jr. The road to cooperative supply-chain environmental management: Trust and uncertainty among pro-active firms. *Bus. Strategy Environ.* **2009**, *18*, 1–13. [CrossRef]
58. Dashore, K.; Sohani, N. Green supply chain management: A hierarchical framework for barriers. *J. Sustain. Dev.* **2008**, *5*, 2011.
59. Rezaei, J.; Nispeling, T.; Sarkis, J.; Tavasszy, L. A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method. *J. Clean. Prod.* **2016**, *135*, 577–588. [CrossRef]
60. Gupta, H.; Barua, M.K. Supplier selection among SMEs on the basis of their green innovation ability using BWM and fuzzy TOPSIS. *J. Clean. Prod.* **2017**, *152*, 242–258. [CrossRef]
61. Amiri, M.; Hashemi-Tabatabaei, M.; Ghahremanloo, M.; Keshavarz-Ghorabaee, M.; Zavadskas, E.K.; Banaitis, A. A new fuzzy BWM approach for evaluating and selecting a sustainable supplier in supply chain management. *Int. J. Sustain. Dev. World Ecol.* **2021**, *28*, 125–142. [CrossRef]
62. Guo, S.; Zhao, H. Fuzzy best-worst multi-criteria decision-making method and its applications. *Knowl. Based Syst.* **2017**, *121*, 23–31. [CrossRef]
63. Chen, S.H.; Hsieh, C.H. Representation, ranking, distance, and similarity of LR type fuzzy number and application. *Aust. J. Intell. Process. Syst.* **2000**, *6*, 217–229.
64. Banihashemi, S.A.; Khalilzadeh, M.; Shahraki, A.; Rostami Malkhalifeh, M.; Ahmadizadeh, S.S.R. Optimization of environmental impacts of construction projects: A time-cost-quality trade-off approach. *Int. J. Environ. Sci. Technol.* **2021**, *18*, 631–646. [CrossRef]
65. Banihashemi, S.A.; Khalilzadeh, M. Application of fuzzy BWM-CoCoSo to time-cost-environmental impact trade-off construction project scheduling problem. *Int. J. Environ. Sci. Technol.* **2022**. [CrossRef]
66. Bhatia, M.S.; Gangwani, K.K. Green supply chain management: Scientometric review and analysis of empirical research. *J. Clean. Prod.* **2021**, *284*, 124722. [CrossRef]