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Risk Assessment and Mitigation Strategies in Green Building Construction Projects: A Global Empirical Study

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Abstract

The construction industry significantly impacts environmental degradation, making sustainable practices like green building construction projects (GBCPs) essential. Although GBCPs offer substantial benefits, they also come with unique risks related to their sustainable nature and common construction challenges. Research on GBCP risks is often fragmented, lacks proper classification, and misses a global perspective, with insufficient focus on empirical assessment and risk mitigation strategies. This study addresses these gaps by systematically identifying risks associated with GBCPs, empirically assessing them using data from global experts, and proposing mitigation strategies. Utilising reliability tests, descriptive statistics, one-sample *t*-tests, hypothesis testing, and correlation analysis, 42 risk factors were determined and assigned to nine groups: legal and regulatory, technical, financial, material-related, design, schedule and planning, communication and awareness, performance and operational, and environmental. Green product certification and re-evaluation charges, client finance difficulties, the high cost of green materials and equipment, the absence of qualified project teams, and additional expenditures for green building design and construction are the top five concerns. The study also identifies 45 mitigation strategies, enhancing understanding of GBCP risks and guiding stakeholders in effective risk management and sustainable construction practices.

Keywords: green buildings; risk factors; sustainability; construction projects; descriptive statistics; green construction

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1. Introduction

Huge-scale infrastructure projects and residential constructions are both included in the construction industry [1] and are essential to a nation's growth since they provide a number of benefits [2]. They help the economy grow, create jobs, and build new roads and bridges, among other things. The construction industry is also a big reason why the environment is getting worse. It changes the weather, uses much energy, and pollutes the air [3]. Construction activities significantly contribute to greenhouse gas emissions, particularly carbon dioxide (CO_2), which is a primary driver of global climate change [4]. Also, earlier studies show that the construction industry is responsible for about 35% of all CO_2 emissions and almost 50% of all landfill waste [5]. The construction industry also has a significant effect on how non-renewable energy sources are used, which makes the environment worse and uses up more resources. Tröger et al. [6] say that the construction industry uses 40% of raw materials, 32% of both renewable and non-renewable resources, more than 15% of water resources, and almost half of the world's energy production. The dust and other things that come from construction work can also make the air quality worse for people who live and work near the sites.

People all over the world are becoming more worried about the building industry's big environmental problems. To be better for the environment and more focused on sustainability, we need to change how we do things [7]. The construction industry can be better for the environment if it uses building technologies that use less energy and release fewer greenhouse gases. People are starting to think that green buildings are a good way to lessen the damage that building does to the environment [6,8]. In the last few years, there have been a lot more projects to build green buildings. People are paying more attention to buildings that are good for the environment, as this shows [9]. There are three main benefits of green building construction projects (GBCPs): they are suitable for people, the economy, and the environment. Ferrante et al. [4] and Li et al. [10] say that GBCPs are about using less energy, making less waste, and using materials that are good for the environment. He et al. [11] also noted that people are healthier and feel better when they live or work in green buildings instead of regular ones. This supports what the US Green Building Council (USGBC, 2007) said about GBCPs making people happier and healthier. GBCPs also help people save money by making it cheaper to run and maintain a building [12]. Despite the clear environmental, social, and economic benefits of GBCPs, the complexity of implementing these projects introduces numerous risks that are not yet fully understood. Existing studies have identified various risk factors, but they are often fragmented, limited to specific locations, or focused on particular project types, making it difficult to gain a comprehensive global understanding.

There are many benefits to green building construction projects (GBCPs) over regular construction projects, but there are also more problems and risks [9]. The main reason is that we need to meet our usual goals of building high-quality buildings on time and within budget while also meeting our sustainability goals [13]. GBCPs are also more dangerous now because they use new technologies, eco-friendly materials, and more advanced designs [10,14]. In the construction business, problems like bad quality, missed deadlines, and spending too much money are always happening. But GBCPs are also in danger because they are suitable for the environment [15]. For example, using eco-friendly technology in GBCPs could make building harder, which could cause delays and higher costs [16]. Eco-friendly materials can be harder to buy and cost more because they cost more up front, the supply chain is limited, and it is hard to make sure the quality is good [17]. Also, the need for experts might mean that there are not enough qualified professionals and project teams, which could lead to problems with the project and lower quality. Not knowing or not following some rules and laws about sustainability can make things even more dangerous. This can lead to not following the rules and a bad reputation or legal status [18].

Several risk factors linked to GBCPs have been found in earlier research. Table 1 displays the quantity of green building (GB) risks identified in each study, along with the study's location, subject matter, and methodology. This fragmentation and lack of systematic classification across geographic contexts highlight the need for a comprehensive review and empirical assessment of GBCP risks from a global perspective, which forms the focus of the current study.

Table 1. Summary of studies identifying GB risk factors.

Research Focus	Methodology	Study Location	No. of GB Risks Identified	Reference
Risk identification and evaluation for green residential construction projects	Literature review and survey	Singapore	42	[19]
Risk assessment and identification in commercial green building projects	Literature review, interviews, and survey	Singapore	29	[19]
Risk identification and provision of mitigation measures for green retrofit projects	Survey and interview	Singapore	20	[20]
Creation of a Model for Risk Assessment in Green Building Initiatives	Survey	Singapore	28	[21]
Risk assessment in green building initiatives from a sustainability perspective	Literature review and survey	China	19	[22]
Identification and assessment of risks in environmentally friendly construction projects	Literature review and survey	United Arab Emirates	30	[23]
Conducting risk assessment for green retrofit projects and developing a system to address potential hazards	Survey	Sri Lanka	10	[24]
Determining the financial incentives and risk factors associated with green building construction	Survey	Malaysia	10	[25]
Risk assessment in the supply chain for green buildings and creation of management plans	Survey	Australia	40	[10]
Analysing the interconnections between risks in green construction projects, considering the various stages of the project, and the different risk factors involved	Literature Review and Survey	-	22	[26]
They are identifying construction dangers and their impact on costs in LEED-certified projects.	Survey	-	13	[27]
Recognising material-related hazards in environmentally friendly structures	Literature review and survey	-	25	[28]
Analysing stakeholder-related risks through the development of a Social Network Analysis (SNA) model	Case study	-	42	[29]

But more closely, to see that there are some problems with the current set of materials. Because the risk factors are not grouped or put in the correct order, it is hard to understand the risks that come with GBCPs fully. Moreover, many of the existing studies are limited to specific geographic locations, failing to address the global context and the potential variations in risks across different regions. Therefore, by carefully examining the dangers connected to GBCPs from a worldwide viewpoint, this work seeks to close these gaps. The following are the study's particular goals:

1. To identify a thorough list of risk variables linked to GBCP by conducting a systematic literature review.
2. To empirically assess the identified risk factors by collecting data from GBCP stakeholders worldwide, enabling a global perspective on the significance and impact of these risks.
3. To offer strategies for GBCP risk reduction, ultimately aiming to promote the successful worldwide implementation of sustainable building practices.

2. Research Methodology

There are four primary phases in the study's framework, shown in Figure 1. Finding pertinent articles and defining research objectives are the focus of stage 1. Choosing the Scopus database for article retrieval and establishing the research objectives are the first steps in the procedure. Inclusion and exclusion criteria are used to filter the search results once specific GBCP-related keywords are used to search the database. This stage's last step is to evaluate the retrieved articles' complete texts, abstracts, and titles to see if they are pertinent to the research. In stage 2, a questionnaire survey is used to gather empirical data. Potential responders are identified, and the questionnaire is created using the risk factors found in the literature research. To reach a wide range of responses, the questionnaire is then distributed via a number of platforms, such as LinkedIn and ResearchGate.

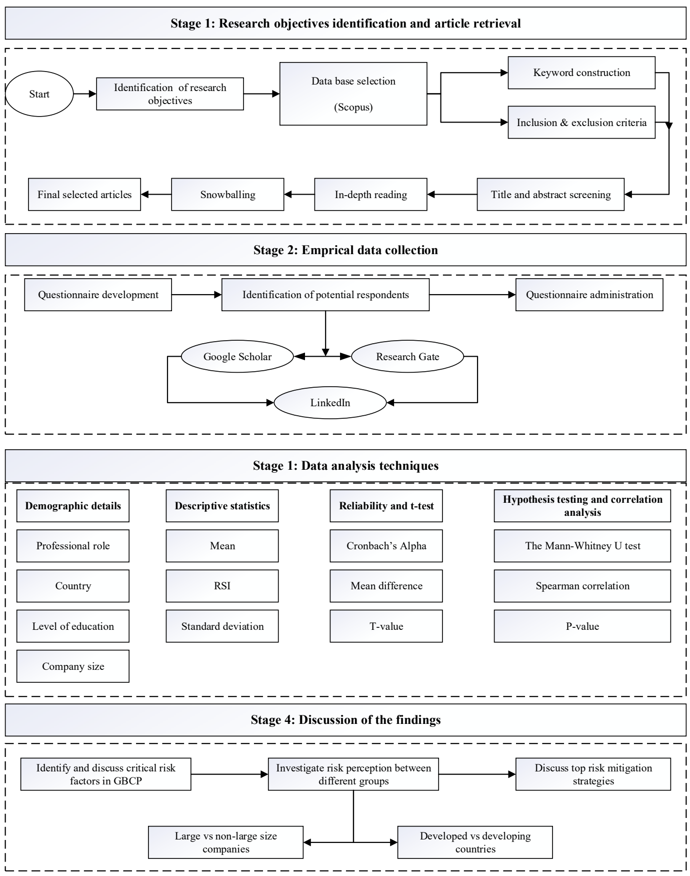

Figure 1. Framework of the study.

Stage 3 involves the analysis of the collected data using various techniques. Demographic details of the respondents are compiled, and descriptive statistics such as mean, relative significance index (RSI), and standard deviation are calculated. Also, tests like

Cronbach's alpha and hypothesis testing are used to make sure the information is strong. People also use correlation analysis to see how different variables are related to each other. The end of stage 4 is when the results are discussed. GBCPs find and talk about important risk factors. The study also looks at how large and small businesses, as well as developed and developing countries, see risk differently. The results are used to figure out the best ways to lower risk, which can help GBCPs handle risk better.

2.1. Stage 1: Identification of Relevant Sources and Risk Factors

2.1.1. PRISMA Protocol for Articles Retrieval

A systematic literature review was performed utilising a PRISMA protocol through Scopus, a database esteemed for its extensive coverage and rigorous indexing criteria, to pinpoint studies concentrating on risk identification in green building construction projects (GBCPs) [30]. The search string used a combination of words, such as "green construction" OR "green building" OR "sustainable construction" AND "risks" OR "barriers" OR "challenges." The first search found 2965 documents. To obtain better results, they were then sorted by language and subject area. This process reduced the number of records to 369, which were then checked for titles and abstracts to find the ones that were most useful. The screening process found 81 documents that were thought to be helpful for the research topic. After that, a careful reading of all 81 articles was carried out, and 35 articles that did not fit the study's goals were left out. This left us with 46 articles to look at in more detail. To perform a comprehensive evaluation, the expanding technique articles required the scrutiny of reference lists from the chosen papers to uncover supplementary relevant studies. This process yielded nine more articles, bringing the total number of relevant articles to 55. These 55 articles formed the basis for the systematic literature review, providing valuable insights into the risks associated with GBCPs and laying the groundwork for the subsequent empirical assessment and risk mitigation strategy development.

2.1.2. GBCP Risk Factors

Forty-two unique risk variables were identified after a careful review of the 55 publications; these are categorised into nine groups and shown in Table 2. The rationale for this grouping was based on the nature and source of each risk factor, aiming to cluster risks with similar origins or impacts to facilitate clearer analysis and management. In cases where a risk could potentially belong to more than one category, it was classified based on the primary aspect it affects. For example, delays caused by the unavailability of eco-friendly materials could be considered both a supply (technical/material) risk and a scheduling risk. In such cases, the risk was classified under technical/material risks, while its impact on scheduling was noted, ensuring overlapping influences were acknowledged without duplicating entries. These groups include risks related to technology, money, materials, equipment, and technical issues; design; scheduling and planning; legal and regulatory issues; communication and awareness; performance and operations; and environmental issues.

Liu et al. [31] said that technical risks in GBCPs can happen when suppliers, project teams, contractors, and subcontractors have technical problems. Maqbool et al. [32] said that building and designing green buildings is risky from a technical point of view. GBCPs are often more expensive than regular buildings because they use green materials and equipment, which could put the company in financial trouble [7,32]. Li et al. [14] say that inflation, not having enough money or resources from clients, and wrong estimates of payback periods or ROI can all make financial risks worse.

GBCPS need to have and be able to choose eco-friendly materials [33]. The same is true for green technology and equipment; if you do not have them, you might worry about technology, equipment, and materials. Abujder Ochoa et al. [34] and Dedasht et al. [35] say that these risks are mainly about the performance, quality, standards, and lack of green technologies, equipment, and materials used in GBCPs. According to Mercogliano et al. [36] and Anagnostopoulos et al. [37], design risk in GBCPs means that there could be problems and unknowns during the design process. These problems could include design data that is wrong or missing, design changes that happen too often, and not properly incorporating sustainability principles into green building designs. Using a schedule and planning risks to find problems and match them with solutions can help the project stay on track. According to Cabral-Ramírez et al. [38], construction projects, even green buildings, often fall behind schedule. There are many reasons why this can happen, such as deadlines that are too strict or not enough supplies and machinery [39].

Regulatory and legal risk includes getting permits that are only for Great Britain, following the right laws and rules, and dealing with any legal problems that may come up [40]. Poor communication, strained relationships with stakeholders, unclear responsibilities for stakeholders, and a lack of public awareness about the importance of green building are all examples of communication and awareness risks that can lead to lower project performance, conflicts, and disputes [41]. According to Fitriawijaya and Taysheng [42], there are risks associated with the operation, maintenance, and productivity of personnel, equipment, and technology in GBCPs. Events that occur during construction and noncompliance with sustainable construction certification standards significantly elevate performance and operational risk [43]. Environmental risks are possible problems that could happen at the GB building site or with the weather, such as unexpected bad site conditions, problems getting land, and the effects of extreme weather events [44]. By explicitly grouping risks and noting overlapping effects, this classification provides a structured framework for analysing GBCP risks while acknowledging the interconnections among different categories.

Table 2. Identified risk factors in GBCP.

No.	Risk Category	Factor	Code	Reference
R1	Technical	Limited availability and dependability of subcontractors for green building	F-01	[42,44]
		Lack of an experienced and competent project crew	F-02	[44,45]
		Reliability and accessibility issues with green building subcontractors	F-03	[46,47]
		Lack of suppliers of environmentally friendly items and materials	F-04	[30,48]
R2	Financial	Lack of resources and funding for the client	F-05	[49]
		Price fluctuations and inflation for labour and green building supplies	F-06	[50,51]
		Additional expenses for green building design and construction	F-07	[52,53]
		Expensive green equipment and materials	F-08	[53,54]
		Extra expenses for reassessing and certifying eco-friendly goods and products	F-09	[55,56]
		Inaccurate payback term or ROI (return on investment) prediction for the project	F-10	[57,58]
		Lack of market demand	F-11	[59,60]

Table 2. *Cont.*

No.	Risk Category	Factor	Code	Reference
R3	Material, Equipment, and Technology	Approved green technology, techniques, and materials are scarce and lacking.	F-12	[61,62]
		Unconfirmed quality of new eco-friendly technology, equipment, materials, and products	F-13	[62,63]
		New green technology, equipment, materials, and products with inadequate or inaccurate green specifications	F-14	[54,58]
		Insufficient utilisation of eco-friendly resources, equipment, and technology	F-15	[32,35]
R4	Design Risks	Insufficient and inaccurate design data	F-16	[64,65]
		Frequent design changes and variations	F-17	[66,67]
		Insufficient incorporation of sustainability into green building design	F-18	[68,69]
R5	Schedule and Planning	The green construction process's delay	F-19	[70,71]
		Unreasonably strict timeline for environmentally friendly building	F-20	[72,73]
		Not obtaining supplies or equipment in the allotted period	F-21	[74,75]
		In sustainable building, a poorly defined scope and an ambiguous role distribution	F-22	[69,70,76,77]
R6	Regulatory and Legal	Complex green building approval processes, codes, and restrictions	F-23	[78,79]
		Modifications to municipal laws and policies	F-24	[80,81]
		Modifying the rules and certification procedure for green buildings	F-25	[82,83]
		The project parties' contractual duties and responsibilities are not adequately defined.	F-26	[84,85]
		Uncertain terms and conditions in green building contracts	F-27	[78,80,86]
		In construction, litigation, court cases, and prosecutions for failing to meet client expectations	F-28	[79,87]
R7	Communication and Awareness	Project team members' poor cooperation, communication, and information sharing	F-29	[88,89]
		Weak collaboration among supply chain partners, the project team, and the client	F-30	[90,91]
		Complex stakeholder composition and requirements	F-31	[92]
		Stakeholders' unclear obligations in obtaining green certification	F-32	[92,93]
		Insufficient public awareness and knowledge	F-33	[94,95]

Table 2. *Cont.*

No.	Risk Category	Factor	Code	Reference
R8	Performance and Operational	Low labour and equipment productivity	F-34	[88]
		Insufficient GB upkeep	F-35	[64–66]
		Difficulties in operating green solutions	F-36	[69,71,74]
		Not fulfilling the certification requirements for sustainable construction	F-37	[77,96]
		Injuries and accidents during construction	F-38	[97,98]
R9	Environmental	Unexpectedly unfavourable site conditions and inadequate construction site investigation	F-39	[99,100]
		There is a strong need to protect the working environment at green construction sites.	F-40	[91,101]
		Uncertainty in purchasing land	F-41	[98,102]
		Changes in the weather	F-42	[103,104]

2.2. Stage 2: Data Collection

2.2.1. Questionnaire Development

After the risk factor list was finished, a questionnaire survey was conducted using the Qualtrics web platform to look at the risk variables found in GBCPs. The survey has two main parts.

The first part is meant to get relevant background information from the people taking part. The questions in this part ask about the respondents' job title, where they work, how long they have been in the building industry, what their highest level of education is, and how big their company is. In numerous studies concerning construction project management, this background information is integrated into the questionnaire development process [101,103].

The second part of the questionnaire has three questions. In the first part, people are asked to rate how important they think 42 risk factors related to GBCPs are on a five-point Likert scale, with 1 being "very low relevance" and 5 being "extremely high importance." This scale allows for a consistent and measurable assessment of the importance of the risk variables. In the second question, respondents can talk about any other GBCP-related issues that were not brought up in the first question. Any potential hazards not included on the established list may still be documented and considered during the investigation of this open-ended question. The last question is open-ended and asks people to suggest ways to make the GBCP risks less harmful. The poll aims to obtain helpful advice and ideas from professionals in academia and business on how to handle and lower the risks that come with GBCPs by asking this question. The combination of open-ended and closed-ended questions allows for the collection of both quantitative and qualitative data, which leads to a better understanding of the risks and possible ways to reduce them in GBCPs.

2.2.2. Questionnaire Administration

A pilot test is required before the final dissemination to ensure the questionnaire's validity and reliability [105]. A group of academics and industry professionals reviewed the instrument to check clarity, consistency, and content validity, after which refinements were made. The survey was aimed at researchers and professionals who were very knowledgeable about the construction industry, since their input was expected to improve the quality and dependability of the data collected.

To make sure the questionnaires were sent out correctly, a multi-pronged approach was used. We made a list of professionals and experts in the construction industry based on what they knew and how helpful they would be to the research question. Everyone on the list received an email invitation that was only for them. The email told them what the study was about, asked them to fill out the questionnaire survey, and stressed how important it was for them to take part. The email had a link to the online survey, and people who hadn't filled out the questionnaire by the deadline received polite reminder emails that stressed how vital their answers were to the study in order to get more people to respond.

Second, the survey was able to reach more people in the construction industry by using professional networks, data from academic journals, and educational platforms. The questionnaire was distributed to authors of papers concerning the research topic and disseminated among 20 LinkedIn groups associated with the construction industry. It was also put on the academic website "ResearchGate. In order to increase the sample size, the snowballing sampling strategy was used, which encouraged survey participants to forward the link to their peers and industry contacts [106]. Consequently, 74 responses were received, of which 55 valid responses were retained after excluding 19 incomplete or inconsistent submissions. This represents a valid response rate of 74.3%. Inclusion criteria required participants to have a minimum of five years of professional or academic experience in construction. Responses were excluded if demographic information or more than 20% of survey items were missing. Given that it satisfies the central limit theorem's minimal requirement of 30, the sample size of 55 is enough [107,108].

2.2.3. Demographics of the Respondents

Figure 2 displays the survey respondents' demographic information. The data shows that more than 42 percent of respondents have 10–15 years of relevant experience. Furthermore, 22% have more than 15 years of expertise, and about 36% have 5 to 10 years. According to the professional role perspective, academicians, which include professors and researchers, make up the largest group of responders (40 percent). This suggests that many people are working in the building industry in academic and research capacities. With 21.8%, 14.6%, and 12.8% of respondents, project managers, architects, and engineers rank second in importance. Smaller percentages of respondents were in other roles that were also recorded by the poll, such as consultants, construction workers, and quantity surveyors. The profile analysis indicates that the construction industry attracts professionals from diverse roles, with a strong representation in managerial, engineering, research, and academic positions.

Geographically, the US (7.28%), the UK (14.54%), and China (30.90%) accounted for the majority of responders. Additionally, some responders are from Saudi Arabia, Malaysia, Australia, India, and other nations. In terms of education, almost half (45.5%) had doctorates. A bachelor's degree was held by 20%, a master's degree by 25.5%, and a college degree by just 7.3%. Regarding company size, the majority (65.5%) worked for large companies with over 250 employees. Approximately 16% were in medium-sized companies, 11% in small companies, and 7% in micro companies. The diverse respondent profile lends credibility to the compiled perspectives.

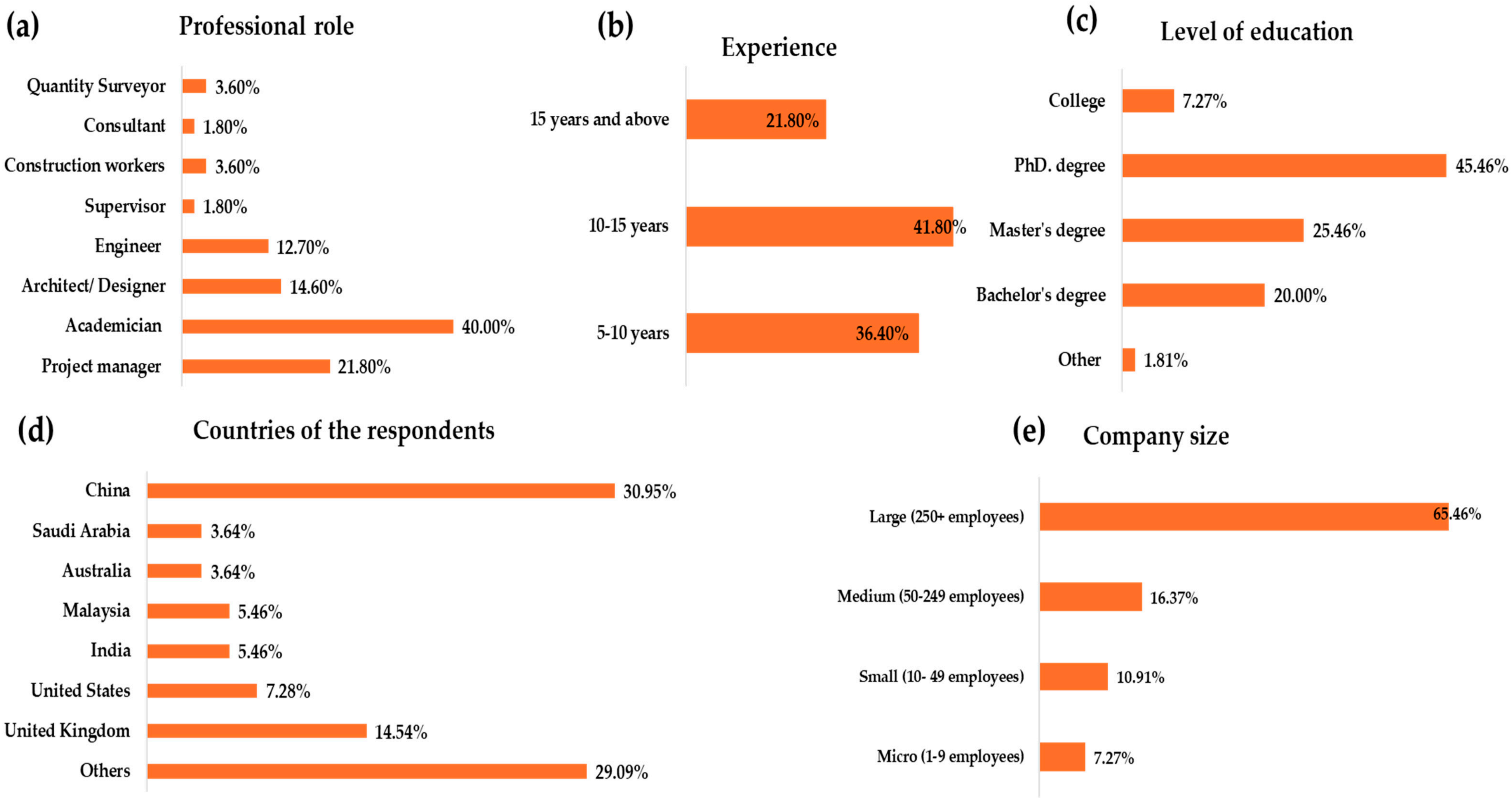

Figure 2. Demographic information of the respondents: (**a**) Professional role; (**b**) Experience; (**c**) Level of education; (**d**) Countries of the respondents; (**e**) Company size.

2.3. Stage 3: Data Analysis Techniques

Data collected from respondents were analysed using IBM SPSS Statistics 26. A reliability analysis was conducted to evaluate data integrity and identify any items that did not significantly contribute to the overall reliability of the dataset [109]. Data reliability was assessed using Cronbach's alpha test, with values greater than 0.7 deemed appropriate for exploratory research [110]. Specifically, $\alpha \geq 0.7$ is acceptable, $\alpha \geq 0.8$ indicates good reliability, and $\alpha \geq 0.9$ is considered excellent [111]. According to [112], descriptive statistical analysis sheds light on data attributes, including mean, standard deviation, median, and mode. The sample mean's departure from the population mean was evaluated using the one-sample *t*-test with a significance level of 0.05 and a test value of 3 [106,113].

The Mann–Whitney U test and Spearman rank correlation were used for hypothesis testing and correlation analysis, respectively. The Mann–Whitney U test, a nonparametric statistical method, is employed to detect significant differences in data distributions [114]. The null hypothesis in hypothesis testing posited no considerable disparity between academicians and project managers concerning the perceived importance of risk factors. The correlation analysis null hypothesis posited that there was no significant relationship between these two professional roles and the perceived relevance ratings of risk factors. The studies focused on academics and project managers due to their considerable representation among the respondents. Finally, we employed the interrater agreement (IRA) method from [115] to determine whether the respondents' assessments of the significance of the risk factors were consistent or divergent. We used average within-group variance (aWG), a common statistic in construction research [116], to find out how much the respondents agreed with each other.

2.4. Stage 4: Discussion of Findings

Stage 4 involves a discussion of the study's findings. We identify and examine the principal risk factors that significantly influence GBCPs. The research investigates the differing perceptions of risk between large and small enterprises, as well as between developed and developing nations. This comparative analysis offers an extensive comprehension of the ways different factors affect the perception of risk. The report also tells you the best ways to lower these risks, which is helpful for making GBCPs stronger. Companies can better prepare for and deal with possible problems if they know these essential things. This will make construction operations more stable.

All methods were carried out following the relevant guidelines and regulations of the University of Manchester. Before data collection, ethical approval for this research was obtained using the University of Manchester's Ethics Decision Tool, which determined the appropriate level of review based on the nature of the study. Also, informed consent was obtained from all participants involved in the study, and, where necessary, from their legal guardians.

3. Research Findings

3.1. Reliability Analysis

Table 3 presents the results of the Cronbach's alpha reliability test conducted on the survey data. The purpose of this analysis is to evaluate the internal consistency and reliability of the responses. As shown, the Cronbach's alpha value for the 42 risk factor importance items is 0.921, which falls into the 'excellent' category ($\alpha \geq 0.9$), demonstrating very strong internal consistency. A high Cronbach's alpha indicates that the 42 risk factors as a set effectively measure a unified underlying construct. In this case, the high alpha suggests that all the risk factor importance ratings reliably measure the same latent concept of "risk factor importance."

Table 3. Results of a data reliability test.

Scale	Cronbach's Alpha	No. of Items
A ranking of 42 risk factors' importance	0.921	42

3.2. Descriptive Statistics

The percentage of participants who responded, the mean, the standard deviation (SD), the rank, and the relative significance index (RSI) are among the descriptive data shown in Table 4. The distribution of participant opinions is recorded and assessed using a five-point Likert scale: 3 indicates medium importance, 4–5 indicates great importance, while 1–2 indicates low relevance. This distribution pattern helps determine how much participants agree or disagree on the significance of risk variables. Remarkably, F-34 (low labour and equipment productivity) exhibits a comparatively consistent view of its significance, with roughly one-third of individuals representing each importance level. However, a significant majority (60%) assign "high importance" to F-08 (high cost of green material and equipment), highlighting its critical role in project considerations. Just 5.45% of those surveyed said it was of "low importance".

Table 4. Analysis using descriptive statistics.

Factors	Percentage of Participants' Respondents			RSI	Mean	SD	Rank
	Minimal Significance (%) (Extremely Low + Low)	Moderately Important (%) (Medium)	Elevated Significance (%) (High + Extremely High)				
F-08	5.45	34.55	60.00	0.85	3.75	0.84	1
F-05	14.55	21.82	63.64	0.84	3.69	1.07	2
F-02	10.91	27.27	61.82	0.84	3.67	0.88	3
F-07	14.55	30.91	54.55	0.83	3.64	1.01	4
F-09	9.09	29.09	61.82	0.81	3.64	0.8	5
F-03	14.55	29.09	56.36	0.80	3.56	1.03	6
F-06	10.91	43.64	45.45	0.79	3.53	1.09	7
F-04	9.09	45.45	45.45	0.78	3.49	0.84	8
F-01	12.73	41.82	45.45	0.78	3.45	0.94	9
F-10	20.00	30.91	49.09	0.77	3.4	1.05	10
F-23	21.82	25.45	52.73	0.77	3.38	0.97	11
F-29	23.64	21.82	54.55	0.76	3.36	1.08	12
F-22	21.82	30.91	47.27	0.75	3.35	1.04	13
F-12	21.82	36.36	41.82	0.73	3.27	1.06	14
F-33	27.27	27.27	45.45	0.73	3.27	1.22	15
F-16	29.09	29.09	41.82	0.73	3.25	1.17	16
F-24	29.09	23.64	47.27	0.72	3.22	1.08	17
F-11	27.27	38.18	34.55	0.72	3.2	1.04	18
F-18	25.45	32.73	41.82	0.71	3.2	1.15	19
F-27	29.09	29.09	41.82	0.71	3.2	1.06	20
F-30	29.09	30.91	40.00	0.70	3.2	1.03	21

Table 4. *Cont.*

Factors	Percentage of Participants' Respondents			RSI	Mean	SD	Rank
	Minimal Significance (%) (Extremely Low + Low)	Moderately Important (%) (Medium)	Elevated Significance (%) (High + Extremely High)				
F-32	29.09	30.91	40.00	0.70	3.18	1	22
F-37	23.64	38.18	38.18	0.70	3.18	1.02	23
F-17	27.27	36.36	36.36	0.70	3.16	1.09	24
F-31	23.64	41.82	34.55	0.70	3.15	0.89	25
F-13	29.09	36.36	34.55	0.69	3.09	1.09	26
F-34	30.91	34.55	34.55	0.68	3.07	1.00	27
F-35	29.09	30.91	40.00	0.68	3.07	0.96	28
F-19	34.55	29.09	36.36	0.68	3.05	1.13	29
F-26	38.18	21.82	40.00	0.68	3.04	1.14	30
F-14	25.45	43.64	30.91	0.67	3.02	1.06	31
F-15	30.91	32.73	36.36	0.67	3.02	1.11	32
F-38	41.82	14.55	43.64	0.67	3.02	1.33	33
F-39	30.91	38.18	30.91	0.67	3.02	1.16	34
F-25	29.09	43.64	27.27	0.67	3.00	0.86	35
F-28	34.55	29.09	36.36	0.66	3.00	1.16	36
F-36	32.73	38.18	29.09	0.65	2.93	0.86	37
F-21	34.55	38.18	27.27	0.64	2.91	1.01	38
F-40	40.00	30.91	29.09	0.63	2.82	1.06	39
F-20	41.82	30.91	27.27	0.62	2.80	1.13	40
F-41	49.09	27.27	23.64	0.61	2.65	1.25	41
F-42	47.27	23.64	29.09	0.58	2.65	1.17	42

RSI is used to rank the risk factors [117]. A higher ranking is the outcome of a higher RSI, which denotes greater relevance. Each factor's ranking can alternatively be ascertained by its mean value. Although global sensitivity analysis has been used in some related research to investigate the robustness of input factors, the RSI approach was selected in this study because it is widely applied in construction risk management research and offers a straightforward, interpretable method for ranking risk factors based on survey data [118,119]. RSI directly translates respondents' Likert-scale assessments into normalised values, facilitating easier comparison across multiple factors. Given the sample size and the exploratory nature of this study, RSI was considered the most suitable and practical method to establish the hierarchy of risk importance. Out of the 42 risk factors, F-08 (high cost of green material and equipment) is by far the most highly scored, with the highest RSI of 0.85 and the highest mean score of 3.75. Participants view this risk factor as the most important, as evidenced by all of these indicators. The standard deviation also varies from 0.80 to 1.33, demonstrating varied levels of agreement or disagreement among individuals about these risk variables. The high RSI value of 0.85 for F-08 (high cost of green materials and equipment) indicates that stakeholders consider cost management a critical challenge in GBCPs. This suggests that project managers should prioritise budgeting and material sourcing strategies to mitigate financial risks in sustainable construction projects. Conversely, factors with lower RSI values (e.g., F-42) were perceived as less critical, implying that they may require less immediate attention in risk mitigation planning.

3.3. One-Sample t-Test

The average importance rating of each of the 42 risk factors was compared to a test value of 3, which is the midpoint of the 1–5 rating scale, using a one-sample *t*-test on the survey data (see Table 5). The objective was to ascertain which risk factors were regarded as considerably more or less significant than a moderate level of importance.

Table 5. Result of one-sample *t*-test.

Factors	*t*	Mean Difference	95% The Difference's Confidence Interval		Significance (2-Tailed)
			Lower	Higher	
F-01	3.589	0.45	0.20	0.71	0.001
F-02	5.650	0.67	0.43	0.91	0.000
F-03	4.050	0.56	0.28	0.84	0.000
F-04	4.355	0.49	0.26	0.72	0.000
F-05	4.792	0.69	0.40	0.98	0.000
F-06	3.600	0.53	0.23	0.82	0.001
F-07	4.688	0.64	0.36	0.91	0.000
F-08	6.553	0.75	0.52	0.97	0.000
F-09	5.885	0.64	0.42	0.85	0.000
F-10	2.833	0.40	0.12	0.68	0.006
F-11	1.421	0.20	−0.08	0.48	0.161
F-12	1.904	0.27	−0.01	0.56	0.062
F-13	0.617	0.09	−0.20	0.39	0.540
F-14	0.127	0.02	−0.27	0.31	0.900
F-15	0.121	0.02	−0.28	0.32	0.904
F-16	1.608	0.26	−0.06	0.57	0.114
F-17	1.119	0.16	−0.13	0.46	0.268
F-18	1.295	0.20	−0.11	0.51	0.201
F-19	0.358	0.06	−0.25	0.36	0.722
F-20	−1.314	−0.20	−0.51	0.11	0.194
F-21	−0.671	−0.09	−0.36	0.18	0.505
F-22	2.463	0.35	0.06	0.63	0.017
F-23	2.914	0.38	0.12	0.64	0.005
F-24	1.494	0.22	−0.07	0.51	0.141
F-25	0.000	0.00	−0.23	0.23	1.000
F-26	0.237	0.04	−0.27	0.34	0.814
F-27	1.398	0.20	−0.09	0.49	0.168
F-28	0.000	0.00	−0.31	0.31	1.000
F-29	2.502	0.36	0.07	0.66	0.015

Table 5. *Cont.*

Factors	*t*	Mean Difference	95% The Difference's Confidence Interval		Significance (2-Tailed)
			Lower	Higher	
F-34	0.541	0.07	−0.20	0.34	0.591
F-35	0.562	0.07	−0.19	0.33	0.576
F-36	−0.629	−0.07	−0.30	0.16	0.532
F-37	1.322	0.18	−0.09	0.46	0.192
F-38	0.102	0.02	−0.34	0.38	0.919
F-39	0.116	0.02	−0.30	0.33	0.908
F-40	−1.277	−0.18	−0.47	0.10	0.207
F-41	−2.049	−0.35	−0.68	−0.01	0.045
F-42	−2.182	−0.35	−0.66	−0.03	0.033
F-30	1.446	0.20	−0.08	0.48	0.154
F-31	1.211	0.15	−0.10	0.39	0.231
F-32	1.346	0.18	−0.09	0.45	0.184
F-33	1.652	0.27	−0.06	0.60	0.104

According to Gan et al. [120] the results showed that 27 risk factors had *p*-values higher than 0.05. This means that their mean ratings were not very different from the test value of 3. The respondents perceived these factors as possessing an average, moderate level of significance. However, 15 factors were found to have *p*-values below 0.05, meaning their mean ratings diverged significantly from the scale midpoint [121]. Among these 15 factors, 13 had mean ratings higher than 3, including F-01 and F-02. This suggests these factors were perceived as significant risks in GBCP. On the other hand, two factors, F-41 and F-42, had means significantly lower than 3, implying respondents viewed them as lower-importance risks. The analysis demonstrates the value of statistical testing, which determines the risk factors that diverge considerably from a neutral level of importance according to the survey ratings. The one-sample *t*-test shows that F-01 and F-02 are significantly above the neutral level ($p < 0.05$), confirming that stakeholders perceive these as high-priority risks. Practically, this indicates that proactive measures, such as enhanced supervision, careful material selection, and risk monitoring, should be implemented to ensure the success of green building initiatives.

3.4. Hypothesis Testing and Correlation Analysis

Similarities and discrepancies in academicians' and project managers' perceptions of the significance of the 42 risk factors were found by hypothesis testing and correlation analysis, as seen in Table 6. For 35 factors, no statistically significant differences or connections were discovered using the Spearman correlation or Mann–Whitney U test. Both groups had similar views on the importance of these risks, as evidenced by *p*-values over 0.05.

Table 6. Result of hypothesis testing and correlation analysis.

Independent Variable	Dependent Variable	Mean Rank	Hypothesis Test Statistic	*p*-Value (2-Sided)	Correlation Coefficient	*p*-Value (2-Sided)
F-01	Academic	15.98	98.50	0.201	0.223	0.206
	Project manager	20.29				
F-02	Academic	16.41	108.00	0.353	0.162	0.36
	Project manager	19.50				
F-03	Academic	20.32	70.00	0.018	−0.412 *	0.015
	Project manager	12.33				
F-04	Academic	18.57	108.50	0.374	−0.155	0.383
	Project manager	15.54				
F-05	Academic	18.48	110.50	0.407	−0.144	0.416
	Project manager	15.71				
F-06	Academic	18.93	100.50	0.224	−0.211	0.23
	Project manager	14.88				
F-07	Academic	19.86	80.00	0.052	−0.339 *	0.05
	Project manager	13.17				
F-08	Academic	20.61	63.50	0.009	−0.455 **	0.007
	Project manager	11.79				
F-09	Academic	19.09	97.00	0.162	−0.243	0.165
	Project manager	14.58				
F-10	Academic	18.27	115.00	0.523	−0.111	0.532
	Project manager	16.08				
F-11	Academic	17.23	126.00	0.823	0.039	0.827
	Project manager	18.00				
F-12	Academic	17.45	131.00	0.97	0.007	0.971
	Project manager	17.58				
F-13	Academic	17.25	126.50	0.838	0.036	0.842
	Project manager	17.96				
F-14	Academic	19.07	97.50	0.196	−0.225	0.201
	Project manager	14.63				
F-15	Academic	17.32	128.00	0.88	0.026	0.883
	Project manager	17.83				
F-16	Academic	20.16	73.50	0.031	−0.376 *	0.028
	Project manager	12.63				
F-17	Academic	17.95	122.00	0.709	−0.065	0.715
	Project manager	16.67				
F-18	Academic	18.20	116.50	0.563	−0.101	0.572
	Project manager	16.21				
F-19	Academic	19.43	89.50	0.113	−0.276	0.115
	Project manager	13.96				
F-20	Academic	20.45	67.00	0.015	−0.425 *	0.012

Table 6. *Cont.*

Independent Variable	Dependent Variable	Mean Rank	Hypothesis Test Statistic	*p*-Value (2-Sided)	Correlation Coefficient	*p*-Value (2-Sided)
	Project manager	12.08				
F-21	Academic	19.30	92.50	0.138	−0.258	0.141
	Project manager	14.21				
F-22	Academic	18.32	114.00	0.499	−0.118	0.507
	Project manager	16.00				
F-23	Academic	17.18	125.00	0.79	0.046	0.794
	Project manager	18.08				
F-24	Academic	17.66	128.50	0.897	−0.023	0.899
	Project manager	17.21				
F-25	Academic	18.55	109.00	0.381	−0.153	0.389
	Project manager	15.58				
F-26	Academic	19.14	96.00	0.179	−0.234	0.183
	Project manager	14.50				
F-27	Academician	19.32	92.00	0.134	−0.261	0.136
	Project manager	14.17				
F-28	Academician	17.68	128.00	0.882	−0.026	0.884
	Project manager	17.17				
F-29	Academician	19.89	79.50	0.046	−0.348 *	0.044
	Project manager	13.13				
F-30	Academician	20.64	63.00	0.009	−0.452 **	0.007
	Project manager	11.75				
F-31	Academician	17.64	129.00	0.909	−0.02	0.911
	Project manager	17.25				
F-32	Academician	20.80	59.50	0.007	−0.474 **	0.005
	Project manager	11.46				
F-33	Academician	17.09	123.00	0.738	0.058	0.744
	Project manager	18.25				
F-34	Academician	18.16	117.50	0.584	−0.095	0.592
	Project manager	16.29				
F-35	Academician	17.34	128.50	0.895	0.023	0.897
	Project manager	17.79				
F-36	Academician	19.09	97.00	0.18	−0.234	0.184
	Project manager	14.58				
F-37	Academician	19.52	87.50	0.09	−0.295	0.091
	Project manager	13.79				
F-38	Academician	19.48	88.50	0.108	−0.28	0.109

Table 6. *Cont.*

Independent Variable	Dependent Variable	Mean Rank	Hypothesis Test Statistic	*p*-Value (2-Sided)	Correlation Coefficient	*p*-Value (2-Sided)
	Project manager	13.88				
F-39	Academician	19.70	83.50	0.071	−0.314	0.071
	Project manager	13.46				
F-40	Academician	18.50	110.00	0.414	−0.142	0.422
	Project manager	15.67				
F-41	Academician	19.41	90.00	0.119	−0.272	0.12
	Project manager	14.00				
F-42	Academician	17.00	121.00	0.683	0.071	0.689
	Project manager	18.42				

Note: Spearman's correlation coefficients marked with * indicates significance at the 0.05 level (two-tailed), and ** indicates significance at the 0.01 level (two-tailed).

However, the remaining seven components (F-03, F-08, F-16, F-20, F-29, F-30, and F-32) exhibited statistically significant differences and associations. *p*-values below 0.05 indicate that respondents in different roles held varying opinions. Academicians and project managers may have differing views on the significance of these seven specific hazards, as indicated by the negative correlation coefficient value, which also demonstrates a negative association between the two professional jobs and the perceived importance of these risk variables. Significant differences observed for F-03, F-08, and F-32 suggest that academicians and project managers perceive certain risks differently. In practice, this highlights the need for alignment sessions or workshops to reconcile perspectives and ensure that critical risks are addressed consistently in GBCP planning and implementation.

3.5. Additional Risk Factors

Participants were invited to rank the significance of the identified risk factors and to suggest any additional risks they considered relevant but were not included in the initial list. This open-ended approach enabled the capture of overlooked or previously unrecognised risks. In total, a further fifty-one criteria were mentioned. However, 32 of these had already been included in the predefined list, demonstrating the extensive coverage of the initial risk identification. After removing the duplicates, 19 unique risk factors emerged from the responses. As shown in Table S1, these encompassed risks related to aspects like safety, technology, training, and project planning.

3.6. Identified Risk Mitigation Strategies

In the last section of the questionnaire survey, participants were asked to describe the mitigation techniques intended to address risk factors in GBCP. Thirteen of the 45 mitigation options that were proposed in light of the findings were brought up frequently. These mitigating techniques are shown in Table 7, along with the frequency and percentage that go with them. Based on the analysis of the survey responses, a framework summarising the top risk mitigation strategies for GBCPs is presented in Figure 3. This flowchart illustrates the hierarchical prioritisation of strategies and links them to the corresponding risk categories, facilitating practical implementation in real-world projects. The parts that follow go over the best mitigating techniques.

Table 7. Risk Mitigation Strategies.

No.	Mitigation Measures	Frequency	Percentage
1	Collaborating with a skilled group of experts who meet certification requirements	5	7.9%
2	Offering project practitioners and stakeholders ongoing education, training, and knowledge-sharing programmes	4	6.3%
3	Choosing naive and untrustworthy designs and construction technical solutions should be avoided in favour of careful project planning and design.	4	6.3%
4	Increasing project stakeholders' and end users' involvement in green building construction projects	4	6.3%
5	Choose sustainable, long-lasting, and environmentally friendly building materials.	3	4.8%
6	Analyse the project's distinctive features, including its location, design, materials, and technologies, as part of a thorough risk assessment to find possible hazards and their possible effects.	3	4.8%
7	Improved oversight and management	2	3.2%
8	Strong Supply Chain Administration	2	3.2%
9	Making certain that the necessary permissions, approvals, and regulatory compliance are carefully examined and accepted	2	3.2%
10	Establish Clear Communication and Enhance Communication by fostering a collaborative workplace with a well-defined goal.	2	3.2%
11	Collaborating with seasoned and reliable individuals, including contractors who have won contracts in the past and have a history of successfully finishing projects	2	3.2%
12	The government ought to offer financial incentives for the construction of green buildings.	2	3.2%
13	Raising awareness of the GBCP culture through formal education and professional associations	2	3.2%
14	Making use of prefabrication methods for materials in a controlled setting	1	1.6%
15	Putting into practice a responsible waste management plan and policy	1	1.6%
16	Integrated Design Process (IDP) and Integrated Project Delivery (IPD) methodologies	1	1.6%
17	Enhancing productivity, driving demand, and ensuring customer security	1	1.6%
18	Enforce stringent quality control procedures	1	1.6%
19	Adopt agile project management practices	1	1.6%
20	Optimise the allocation of tasks and responsibilities	1	1.6%

Table 7. *Cont.*

No.	Mitigation Measures	Frequency	Percentage
21	Conduct thorough technology assessments	1	1.6%
22	Implement approaches that balance social, economic, and environmental factors throughout the entire project lifecycle	1	1.6%
23	Recognise the differences in risks between traditional construction projects and those associated with green building development	1	1.6%
24	Perform Life Cycle Cost Analysis	1	1.6%
25	Conduct safety constructability studies at each phase of the design process to mitigate safety risks	1	1.6%
26	Offer a payment guarantee for the developer's project	1	1.6%
27	Putting in place a system that charges for testing green materials	1	1.6%
28	Improving the construction industry's digital transformation	1	1.6%
29	Sharing, registering, and publicising lessons learned from ongoing initiatives to ensure knowledge management for upcoming ones	1	1.6%
30	knowing the company from the viewpoint of the customer.	1	1.6%
31	The use of BIM	1	1.6%
32	Compile a list of the consequences of identified hazards discussed during field surveys and Focus Group Discussions (FGDs) to obtain more reliable data	1	1.6%
33	Localising the standards for green buildings	1	1.6%
34	Better development of capacity	1	1.6%
35	Including green building practices in routine construction procedures and finished goods	1	1.6%
36	An organised strategy for handling conflicting green building certification programmes	1	1.6%
37	Identify the project's highest-risk areas through vulnerability assessments and implement targeted improvements to mitigate potential negative impacts	1	1.6%
38	Involve specialists or experts with specific expertise in green building	1	1.6%
39	Establish measurable objectives or outcomes for the construction of the project	1	1.6%
40	Efficiently communicating the economic benefits of sustainability in green building initiatives	1	1.6%
41	Increase the amount of required supervision	1	1.6%
42	Make sure that there is adequate fund turnover and sensible fund allocation.	1	1.6%
43	Including clear and binding contractual provisions	1	1.6%
44	Developing strategies or actions that are specifically tailored to address the hazards	1	1.6%
45	Making use of financial resources and regulatory frameworks to advance sustainable behaviours	1	1.6%

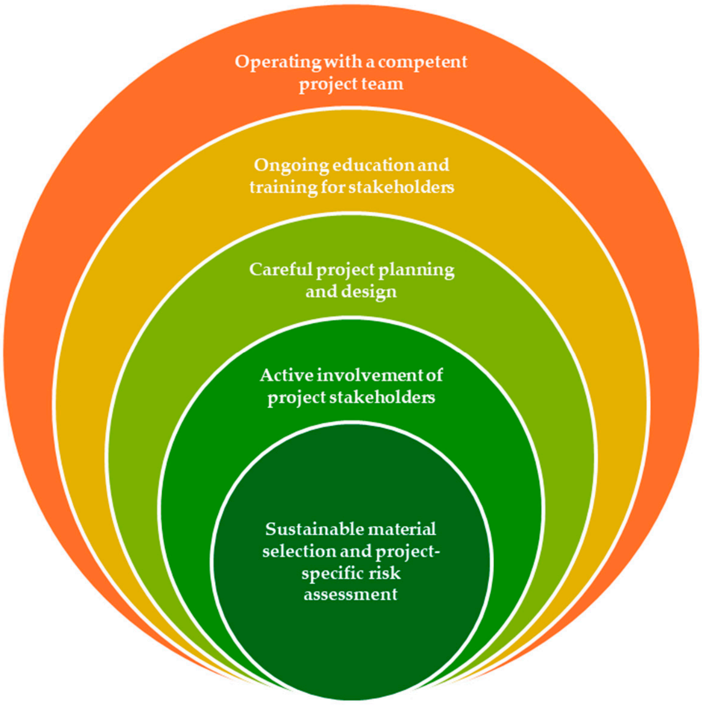

Figure 3. Top Risk Mitigation Strategies and Associated Risk Categories in GBCPs.

4. Discussion of the Result

4.1. Critical Risk Factors

A cut-off point of 65% (i.e., 3.25) is employed in this study to determine the criticality of the factors [122]. Based on this, 16 of the 42 risk factors are considered critical. Figure 4a displays the radar chart, reflecting the assessment visually. The radar chart visually distinguishes critical from non-critical risk factors. The red line represents the mean importance values for each factor, while the blue line indicates the threshold of 3.25 used to determine criticality. Factors F-08, F-05, F-02, F-07, and F-09 exceed the threshold, confirming them as the top five critical risks in green building projects. Factors below the threshold are considered less significant but still relevant for comprehensive risk management.

The most significant risk element is F-08, which is the high price of environmentally friendly supplies and machinery. This element is crucial since it affects a project's financial viability, which could result in a financial burden and long payback periods. According to Xu et al. [123,124], these high costs may make stakeholders less likely to adopt sustainable practices. Next is F-05, which is the client's lack of money and resources. This part is significant because it shows how important it is for customers to have enough money and resources for the project to be successful. Shortages that stop the project lifecycle can cause delays and higher capital costs [125]. Third on the list is F-02, which is the lack of a knowledgeable and experienced project team. This part is important because new or untested green products and technologies need special knowledge. The team's experience is necessary for turning sustainable design into workable solutions. Without it, quality problems, implementation problems, and sustainability goals could be at risk [126]. The fourth most important factor (F-07) pays for the higher costs of designing and building green buildings. Adding green features like renewable energy may make it harder to make money and stick to budgets. F-09, the extra cost of green products and material certification and re-evaluation, comes in fifth. The need to obtain sustainability certifications creates this risk, which could lead to unanticipated costs for retesting non-compliant products. It may result in delays, overspending, problems allocating resources, and maybe unhappy clients [127].

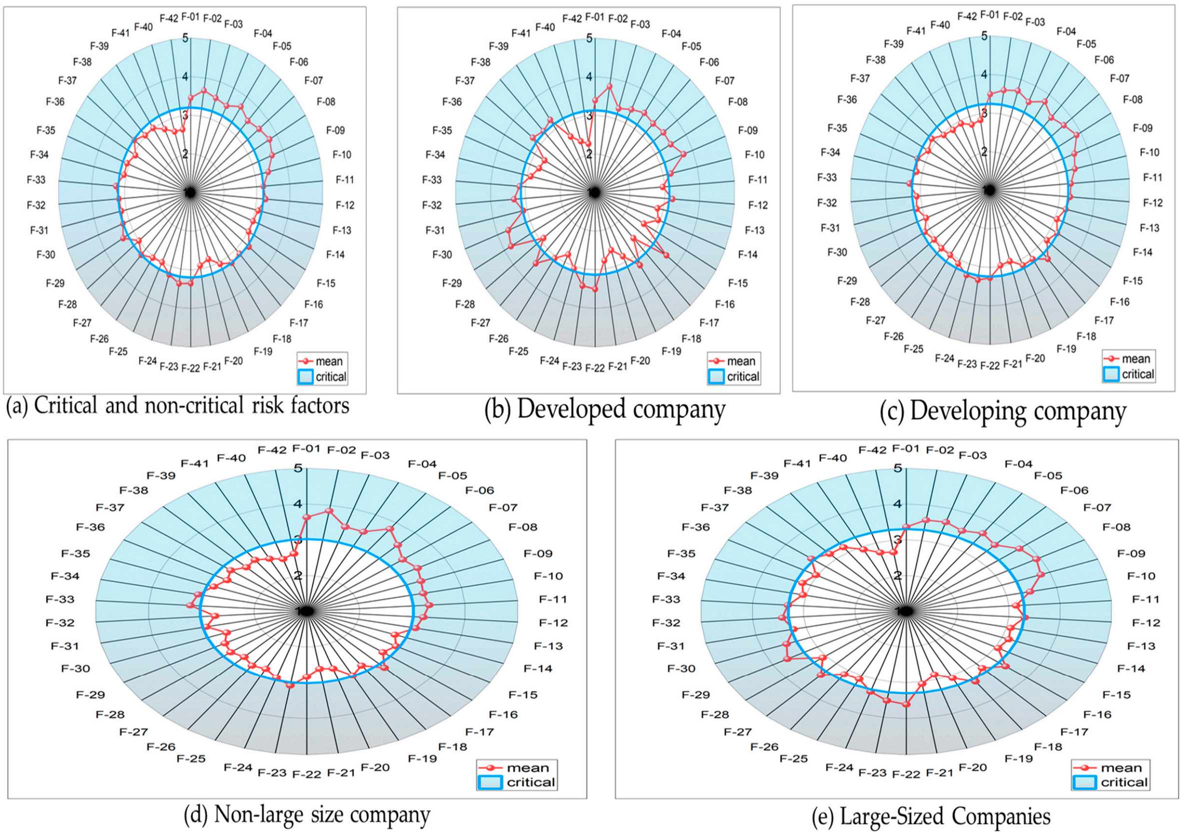

Figure 4. Radar Chart Representing: (**a**) critical and non-critical risk factors; (**b**) developed company; (**c**) developing company; (**d**) Non-large size company; (**e**) Large size company.

4.2. Risk Perception Between Different Groups

4.2.1. Developed and Developing Nations in Comparison

Table 2 presents the mean values, rankings, and importance ratings for each risk factor as evaluated by respondents from both developed and developing countries. The corresponding radar charts are illustrated in Figure 4b,c. Comparison of radar charts between developed and developing countries highlights differences in perceived risk importance. Respondents from developing countries rate F-08 (high cost of green materials and equipment) as the highest-risk factor, whereas developed countries prioritise F-02 (lack of skilled and experienced project teams). The total number of critical risks is slightly higher in developed countries (19) than in developing countries (18), indicating subtle variations in risk perception across regions.

In terms of distinctions, the first one is found in the mean value of the perceived importance overall for respondents from industrialised and developing nations. In particular, the average for the former group is 3.13, but the average for the latter group is marginally higher at 3.24. Second, the group of industrialised countries has somewhat more critical risk factors than the group of developing countries, with 19 and 18, respectively. Furthermore, the two groups differ in the most critical risk factor. In developing countries, F-08, 'High cost of green materials and equipment,' is considered the most significant, while in developed countries, F-02, 'Lack of skilled and experienced project teams,' holds the highest mean value, with values of 3.78 and 3.76, respectively.

Eleven consistent risk variables are found to be crucial in both industrialised and developing nations, based on commonalities. For instance, in both groups, F-23, "Intricate approval procedures, codes, and regulations for green buildings," gets the identical ranking of 12.

4.2.2. Large-Size Versus Non-Large-Size Company

Each risk factor's mean value, rating, and perceived significance among respondents from large and non-large businesses (micro, small, and medium) are shown in Table S3. Figure 4d,e provide a graphic representation of the outcome. Radar charts for large and non-large companies reveal differences in risk prioritisation. Large companies identify more critical risks (22) and rank F-02 as the most significant, reflecting an emphasis on technical expertise. Non-large companies recognise fewer critical risks (11) and consider F-08 as the top concern, highlighting financial constraints as a key risk factor. Shared critical risks, such as F-03 (technical complexity), suggest certain challenges are universally recognised, irrespective of company size.

Regarding differences, large companies had a somewhat higher overall risk importance rating than non-large companies. This suggests that large companies may perceive greater levels of risk in green building projects overall. Additionally, the number of identified critical risks was higher among large companies at 22 versus only 11 for non-large companies. The wider breadth of critical risks perceived by large companies indicates they may take a more holistic risk management approach across diverse factors.

Additionally, the most critical risk differed between the groups—large companies ranked the absence of skilled teams (F-02) as the top priority. In contrast, non-large companies viewed the high cost of green materials (F-08) as the most critical. This points to large companies' greater focus on risk mitigation through expertise, while smaller companies prioritise managing financial risks.

Regarding similarities, 9 risk factors were commonly viewed as critical by both large and non-large companies. For instance, the technical complexity of green construction (F-03) was ranked high by both groups. This suggests that certain risks, like technical challenges, are universally recognised across company sizes.

4.3. Top Risk Mitigation Strategies

As indicated in Table 7, 45 risk mitigation strategies were identified from the questionnaire data. The top 5 strategies, with their frequency of occurrence of at least 3, are discussed in this section. A framework summarising these strategies and linking them to the corresponding risk categories is presented in Figure 3, providing a visual guide for practical implementation in GBCPs.

1. Operating with a competent project team: This strategy, involving qualified professionals who meet certification requirements, was the most frequently discussed mitigation measure. It ensures the effective implementation of sustainable construction [128,129]. However, practical challenges include the limited availability of certified professionals in certain regions and higher recruitment costs, which may hinder implementation.

2. Ongoing education and training for stakeholders: Frequently suggested by respondents, this strategy emphasises continuous learning for project practitioners. Zgheib et al. [130] also highlight the critical importance of education and training facilities. Challenges include the need for sustained investment, scheduling flexibility, and participant engagement, which can be resource-intensive.

3. Careful project planning and design: Suggested four times, meticulous planning helps reduce uncertainty and align project activities. Comparing with prior studies, Cabral-Shan et al. [131] also reported that proactive planning improves project efficiency and minimises risks. Challenges include potential increases in upfront project duration and coordination efforts across multiple teams.

4. Active involvement of project stakeholders: Also mentioned four times, engaging stakeholders throughout the project enhances communication and alignment. This aligns with findings in the literature [131], which emphasise the positive impact of stakeholder

engagement on project success. Implementation challenges may arise from conflicting stakeholder interests, which can lead to delays or disputes.

5. Sustainable material selection and project-specific risk assessment: Reported three times, this strategy involves choosing environmentally friendly materials and integrating project-specific factors into risk assessments. Previous studies, such as Job et al. [132], also highlight the importance of sustainable material selection in enhancing environmental and operational performance. Challenges include high costs, supply chain limitations, and ensuring consistent material quality.

Overall, these top five strategies provide a prioritised roadmap for risk mitigation in GBCPs, while acknowledging real-world implementation constraints.

5. Implications and Significance

The importance of this study lies in its thorough methodology for identifying and evaluating risk factors in GBCPs from a global standpoint. This study consolidates data from GBCP specialists globally, offering a more comprehensive understanding of the associated risks than prior research, which typically focuses on particular regions or types of green building initiatives. This study differs from previous research as it emphasises both risk assessment and mitigation while gathering data globally. It fills in gaps in the current literature and sets the stage for more research and real-world uses in the field of green building construction. The following parts explain what the study means in terms of theory and practice.

5.1. Theoretical Implications

This research contributes to the existing body of knowledge by conducting a comprehensive and methodical examination of the risk factors associated with GBCPs. The identification and categorisation of 42 unique risk factors into nine distinct categories provides a more organised and sophisticated understanding of the risks linked to GBCPs. Future research may enhance this classification, allowing researchers to examine the relationships among various risk categories and create more customised risk management frameworks.

The research fills a void in the literature by employing a global perspective to evaluate the potential disparities in the perceived importance of risk factors across various geographies and occupational roles. The results show that both academics and project managers have a common understanding of the risks associated with GBCPs and do not have very different opinions on the matter. This information can help researchers plan their next steps and get industry and academia to work together more to solve the problems that GBCPs face. The study emphasises the imperative for further context-specific research on GBCPs, as the relevance of particular risk factors may differ according to the project's location, scale, and nature. This necessitates augmented research into the particular challenges and opportunities that GBCPs present in various contexts, thereby enabling the formulation of more customised risk management strategies.

5.2. Practical Implications

This paper is significant for project managers, designers, contractors, and lawmakers, among others, because it talks about GBCPs. The findings provide essential guidance for decision-making and resource allocation in green construction projects by identifying and prioritising the most significant risk factors. Project managers can use this information to make better and more focused plans for managing risks. These plans should deal with substantial problems like the rising costs of design and construction, the high costs of green tools and materials, and the difficulties of getting certified for sustainable building.

The people who took the survey said they were having problems, and the suggested ways to lower risk are good ways to fix them. For instance, GBCPs can be sure that they are financially stable by doing thorough feasibility studies and cost–benefit analyses. Strong relationships with manufacturers and suppliers can also help make green materials and equipment easier to find and less expensive. People who work in this field can change these plans to help GBCPs do better. The study's results also show how important it is to think about sustainability from the beginning of the design process and to give project teams a lot of training and guidance on how to build sustainably and meet certification standards. These insights can help improve training programmes and design standards for GBCPs, which will encourage a more holistic approach to building sustainably.

6. Conclusions

This study systematically reviewed risks in green building construction projects (GBCPs) and identified 42 risk indicators, classified into nine categories: financial, technical, design, schedule and planning, material/equipment/technology, regulatory/legal, communication/awareness, performance/operational, and environmental hazards. Based on a global expert survey, 16 crucial risks were confirmed. The top five risks were as follows: (1) high cost of green materials and equipment (Mean = 3.75, SD = 0.84), (2) lack of client funding and resources (Mean = 3.69, SD = 1.07), (3) lack of knowledgeable and experienced project team (Mean = 3.67, SD = 0.88), (4) additional design and construction costs (Mean = 3.64, SD = 1.01), and (5) certification and re-evaluation costs of green products and materials (Mean = 3.64, SD = 0.80). Respondents also highlighted 19 additional risks, particularly related to safety, technology, training, and project planning.

In terms of mitigation, the analysis emphasised five effective strategies: (1) hiring certified and experienced project teams, (2) providing continuous stakeholder education and training, (3) conducting comprehensive project planning and design, (4) ensuring active stakeholder involvement, and (5) selecting sustainable and eco-friendly materials. These strategies directly address the most critical risks and provide a structured approach for managing challenges in GBCPs.

The study's strengths include its global perspective and comprehensive risk classification. However, its limitations lie in the small sample size and limited data processing techniques, which may affect the generalizability of the findings. In addition, as the survey was disseminated primarily through convenience channels such as LinkedIn and ResearchGate, there is a potential risk of sampling bias, with an overrepresentation of respondents active on academic and professional online platforms. This limitation should be considered when interpreting the results. Future research should focus on expanding the dataset, conducting in-depth regional case studies, and applying advanced statistical techniques such as PLS-SEM to better capture interactions across risk categories. Future studies may extend this analysis using sensitivity analysis techniques to validate and complement RSI-based findings. Overall, this study contributes valuable insights into risk identification, prioritisation, and mitigation in GBCPs. By providing a clear understanding of critical risks and strategies, it supports informed decision-making and fosters the wider adoption of sustainable construction practices worldwide.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/buildings15193485/s1, Table S1: Additional risk factors; Table S2: Risk perception of respondents from developed countries and developing countries and Table S3: Risk perception of respondents from Non-large size company and Large size company.

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