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Barriers to Using Cloud Computing in Sustainable Construction in Nigeria: A Fuzzy Synthetic Evaluation

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Abstract: This study aims to assess the barriers impeding cloud computing (CC) applicability in sustainable construction. A total of 11 barriers in the use of CC were identified for the literature review. A questionnaire survey was used to collect the data from construction stakeholders. In total, 101 valid responses were obtained and analyzed using mean ranking, normalized value (NV), overlapping analysis, Kruskal–Wallis *H* test, exploratory factor analysis (EFA), and fuzzy synthetic evaluation (FSE). The EFA extracted four interrelated components: social, economic, expertise, and connectivity. These components were exported for mathematical analyzing using the FSE technique. As a result, the FSE indicated that connectivity is the highest-impacted component, while the overall impact level of barriers is inclined to high regarding CC applicability in sustainable construction. This is due to other components having an average to high impact level. In this regard, the findings reflect the actual current status of developing countries in using CC in sustainable construction. These research findings will allow construction stakeholders to take proactive steps toward increasing the use of CC in their current and future sustainable construction. Decision-makers could also make accurate decisions that are well-informed in managing CC barriers. This paper provides stakeholders, researchers, and decision-makers with a list of CC barriers that hinder developing countries.

Keywords: cloud computing; sustainable development; sustainable construction; construction industry; fuzzy synthetic evaluation; Nigeria

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1. Introduction

Reduced energy usage and the creation of a sustainable environment are prerequisites for sustainable building [1]. Bello [2] asserted that the construction industry relies on a variety of individuals and businesses with excellent data processing and sharing demands since it is a highly data-intensive and project-based industry. Construction stakeholders may have great success in sustainable work by spreading and organizing information using technologies such as cloud computing (CC) [3,4]. Many of these stakeholders have very specific requirements for data exchange. The construction sector also requires effective stakeholder collaboration and adequate data storage. Connectivity and coordination are possible with the use of information management systems (such as cloud computing).

By considering the solutions given in the literature, the expansion of CC, and its effects on the building industry, the issue may be resolved. Zainon [5] requires the creation of a strategy to implement the sustainable growth principle (SGP) and enhance "Sustainable Building Strategies" by integrating disparate data. As a result, CC may assist in achieving sustainable growth in construction projects by dispersing current data to achieve sustainability [6]. By offering remote access to computer services via internet communication technology (ICT) platforms, CC would make this possible. Due to its charge-per-use network, scalability, accessibility, and many other advantages, CC infrastructure is presently being utilized to process data for sustainable economic activities around the globe into a multi-sided framework for sustainable management. These are economical and cost performance indicators for construction projects [7]. Additionally, CC makes it possible for users to access materials through the internet from any location, making it a potentially useful technology for the construction sector's transition towards sustainability [8].

The benefits of CC have been highlighted in earlier research [8]. However, there was little effort made to examine its use in developing nations [9]. Several studies have been conducted on reliable models and adoption methods for the cloud. Kim [10] mentioned that users' worries about the usage of cloud services vary, but common concerns include compliance, support, security, and availability. Consequently, it is necessary to conduct detailed research on the crucial aspects driving CC acceptance [11]. Academic studies on the implementation of cloud computing in the construction industry have highlighted potential barriers. Some studies have been conducted on trust models and implementation methods in cloud computing. Additionally, security is becoming a prominent area of focus as the construction industry contemplates adopting cloud computing.

According to Chong [6], there are various issues that users express when it comes to embracing cloud computing. These include availability, security and privacy, support, interoperability, and compliance, with compliance being primarily relevant to businesses. These are similar concerns that users have had in the past with on-premises computers and software, but with cloud computing, users may become more aware of these issues since their data, applications, and computing resources are no longer under their direct control.

Over the past 10 years, many industries have seen substantial improvements in productivity as they have embraced IT practices. IT has brought these industries numerous benefits, including faster operations, standardized data generation, and enhanced accessibility and information exchange [12]. Cloud-based technology provides businesses and users with convenient access to substantial computing power at low costs. By transferring IT functions such as storage, business applications, and services to the cloud, organizations have the potential to lower their overall IT expenses. As a result, cloud computing presents financial advantages that businesses can no longer overlook [12].

Furthermore, through the use of some studies and investigative apparatus that have been used to research critical success factors that influence the adoption cloud computing practices in construction, this research will create a theoretical basis with the help of related studies and give propositions to be adopted or rejected in the Nigerian construction industry.

Therefore, the CC barriers were suggested to be assessed via the use of fuzzy synthetic evaluation (FSE), an assessment tool for decision-making with multiple mathematical criteria [13,14]. Hence, FSE would detect the level of impact of barriers in the use of CC. Decision-makers could also make accurate decisions that are well-informed in managing CC barriers that decrease its use in sustainable construction. Thus, FSE can facilitate detecting the most impacted CC barriers.

By resolving problems related to its implementation in the Nigerian construction industry, the current study has the potential to promote the work of CC as an emerging field. Despite the evident challenges facing the construction sector, it is crucial to discover the consensus among its major actors. In this regard, the present work's goal is to evaluate the obstacles to the use of CC services for environmentally friendly buildings in the Nigerian construction sector. The research issue for the current study is, then, to determine the major obstacles to and overall consequences of the use of CC services in sustainable building in the Nigerian construction sector.

This work is organized into several sections. Section 1 is the introduction to the research, while Section 2 comprises an overview of the previous literature on CC and its barriers in sustainable construction. Section 3 presents the steps of the research methodology adopted in the present work. Section 4 provides the results of the data analysis techniques that were used to achieve the research objective. The findings of the research are discussed in Section 5. The summary and the implications of the research are presented in Section 6.

2. Cloud Computing Services: An Overview of Its Application Barriers in Sustainable Construction

There must be collaboration to control success in the building sector and some obstacles must be removed [7]. Maximizing productivity requires constant communication and easy access to organizational resources [15]. Due to their high availability and improved functionality, dependability is a key component of cloud-based systems [16]. However, potential adopters have voiced uncertainty due to the expensive cost of CC or the inability of their service providers to fully convey all of the advantages of embracing CC [16]. Content analysis of the most important CC studies also demonstrate widespread worries about catastrophic failures, such as broad service interruptions and sudden virtual machine shutdowns [17]. As a result, concerns regarding service delivery may discourage users from utilizing cloud services.

Establishing a hybrid service model is necessary due to several organizational characteristics, such as the requirement to mix workflows conducted partially online and partially via a business network [17]. Data integration can be difficult because of issues such as making sure there is enough interoperability and having standard governance and accessibility across all services [16]. Integration calls for partners to work together effectively and consistently to integrate subsystems or data at the very least. Ineffective integration leads to several data repositories and multiple system records in different forms [18]. Although there are techniques for integrating systems, it is still a major challenge. Breiter [19] used various implementation approaches to identify three integration patterns.

In general, implementing cloud technology initiatives can take major businesses and governments many years [20]. For instance, larger businesses might select trial versions or trial packages when subscribing to SaaS subscriptions to assess the service quality and investigate its advantages in business operations [21]. Model-based integration is challenging and there may be delays due to a lack of employees or funding for new initiatives or feasibility studies. As a result, employing cloud services may be discouraged for a corporation due to the sheer complexity of the transfer procedure. An enterprise gains complete control over data kept in the cloud across the course of its life cycle after data and workloads are preserved and analyzed on the platform. After moving these operations to the cloud, a business must make sure the cloud host complies with security and compliance regulations [16]. In addition, scholars and researchers have identified major concerns about the adoption of cloud computing, such as security and connectivity. Data security has been recognized as a major concern in the adoption of cloud computing services. Participants are apprehensive about the ease of hacking into data and the issue of spoofing, and they are not confident in how cloud service providers will address these concerns. Privacy and trust are also important elements in this category. It is crucial to distinguish between security and privacy, as security pertains to the vulnerability of data in the cloud and the risk of attacks from third parties, while privacy refers to a breach of trust by the cloud service provider with regard to official or personal information. In the Nigerian construction sector, workers on site may have limited internet access as well as poor signal reception on their mobile devices [22]. As stated by Kunz [23], the availability of reliable internet connection is a crucial issue that needs to be addressed to effectively utilize cloud computing in developing economies, particularly in Nigeria. Currently, internet broadband and Ethernet infrastructure have limited development in Africa, leading enterprises to switch between internet service providers in search of a more suitable connection. This can result in a data inconsistency if operations and data transmission are disrupted due to connection problems. However, with advancements in web technologies and satellite coverage, it is hoped that web connection availability and stability will improve in the future, even in challenging environments, such as construction sites. The high cost of mobile data for uploading and retrieving data from cloud services is also a concern raised by [22]. On the contrary, trust is an integral aspect of daily human life and is essential in our decision making. The level of trust is influenced by how the cloud service provider addresses the security risks and other challenges of cloud adoption and how they appeal to the needs and expectations of potential clients. In other words, those who adopt cloud services will subscribe to providers they consider trustworthy [24]. Ensuring the confidentiality of personal information is a pressing concern for both cloud computing and traditional on-premises systems. Completely guaranteeing 100% security and privacy against all possible sources of the breach, including software flaws, advanced hacking techniques, inadequate protocols, human wrongdoing, and human mistakes, is nearly unattainable [6]. In addition, users worry that cloud service providers will constantly have access to their data and may intentionally reveal them to third parties or use them for unauthorized purposes without their permission [25]. The various security issues, weaknesses, and dangers associated with cloud computing increase the concerns of potential users, leading to distrust in cloud computing and slowing down its adoption [24]. Chong [6] suggested that many cloud service providers currently lack the ability to ensure the precise location of a user's data on designated servers. This increases the risk of data loss or theft, as servers may be located in areas beyond the user's control. Security remains one of the most significant hurdles in the widespread adoption of cloud computing. Cloud computing is plagued by various security issues, including data access control, data distribution across a dispersed infrastructure, data integrity, service availability, and secure communication. Additionally, the mobility aspect of cloud computing adds an extra layer of security challenges, making mobile cloud security more complex [26]. Cloud computing requires a certain level of IT expertise, specifically among employees and IT specialists within the organization. To effectively implement and utilize cloud computing services, it is important for IT managers to provide training for their staff. With the proper training and support from the organization, employees can better understand the benefits of cloud computing and improve their work performance through its use.

Research Gap

The concentration of prior works is on the perception of various stakeholders in identifying the barriers to CC services. In contrast, it Mundfrom is unknown how conscious they are of the possible barriers that can impact the application of CC in sustainable construction in Nigeria. Therefore, the stakeholders in the construction sector need to assess the barriers to the adoption of CC practices for sustainable construction in the Nigerian industry. In this regard, several statistical techniques were used to assess CC service applicability. The barriers in CC adoption are obtained and retained from prior literature, as provided in Table 1.

Table 1. Barriers to the application of CC.

Code	Barriers	Sources										
		[22]	[27]	[10]	[28]	[12]	[29]	[25]	[27]	[6]	[30]	[31]
B01	Privacy	•	•	•	•			•	•	•		
B02	Security	•	•	•	•		•	•	•	•		
B03	Trust	•	•	•				•	•	•		
B04	Awareness							•	•			
B05	Lack of technical knowledge		•				•					
B06	Lack of financial strength											•
B07	Economic situation of the nation		•									
B08	Human resources				•	•						
B09	Cost of operation								•			•
B10	Connectivity problem	•	•			•			•		•	
B11	Limited internet access	•	•			•					•	

3. Methodology

This work seeks to evaluate the barriers hindering CC adoption in sustainable Nigerian construction. The research workflow started with reviewing the literature and ended with a discussion and conclusion, as introduced in Figure 1. Firstly, a comprehensive review of the literature for survey development was undertaken, followed by data collection from construction professionals in related fields to the research objective, including quantity surveyors, builders, engineers, architects, and contractors. Data analysis with various statistical techniques, including reliability analysis, mean ranking, normalization value, agreement analysis, EFA, and FSE was completed. The last step discusses the finding, followed by the conclusion, and provides research implications. The following subsections describe the whole research methodology in detail. Figure 1 shows the research workflow.

3.1. Survey Development

A quantitative approach was used through a questionnaire survey as a data collection tool to achieve the research objective. As shown in Table 1, the barriers in CC were provided in questionnaire format to gather the data from respondents. The survey was structured into 2 sections: respondents' profiles and rating the impact of the barriers to adopting CC using a 5-point Likert grading scale, where 1 = very low, 2 = low, 3 = average, 4 = high, and 5 = very high. A 5-point Likert grading scale has the power to reduce the central tendency obstacles usually connected under ordinal data.

Through carrying out a stratified sampling tool, 1 participant was invited from each group (builder, quantity surveyor, engineer, and architect) involved in sustainable construction projects. Those participants who have perceptions of the subject matter that stems from their experience participating in sustainable construction activities related were asked to pre-test the questionnaire survey. The pilot test process indicated that the survey was understandable. However, some comments were used to raise the clarity of the latest version of the survey. The survey could found at Appendix A in Table A1.

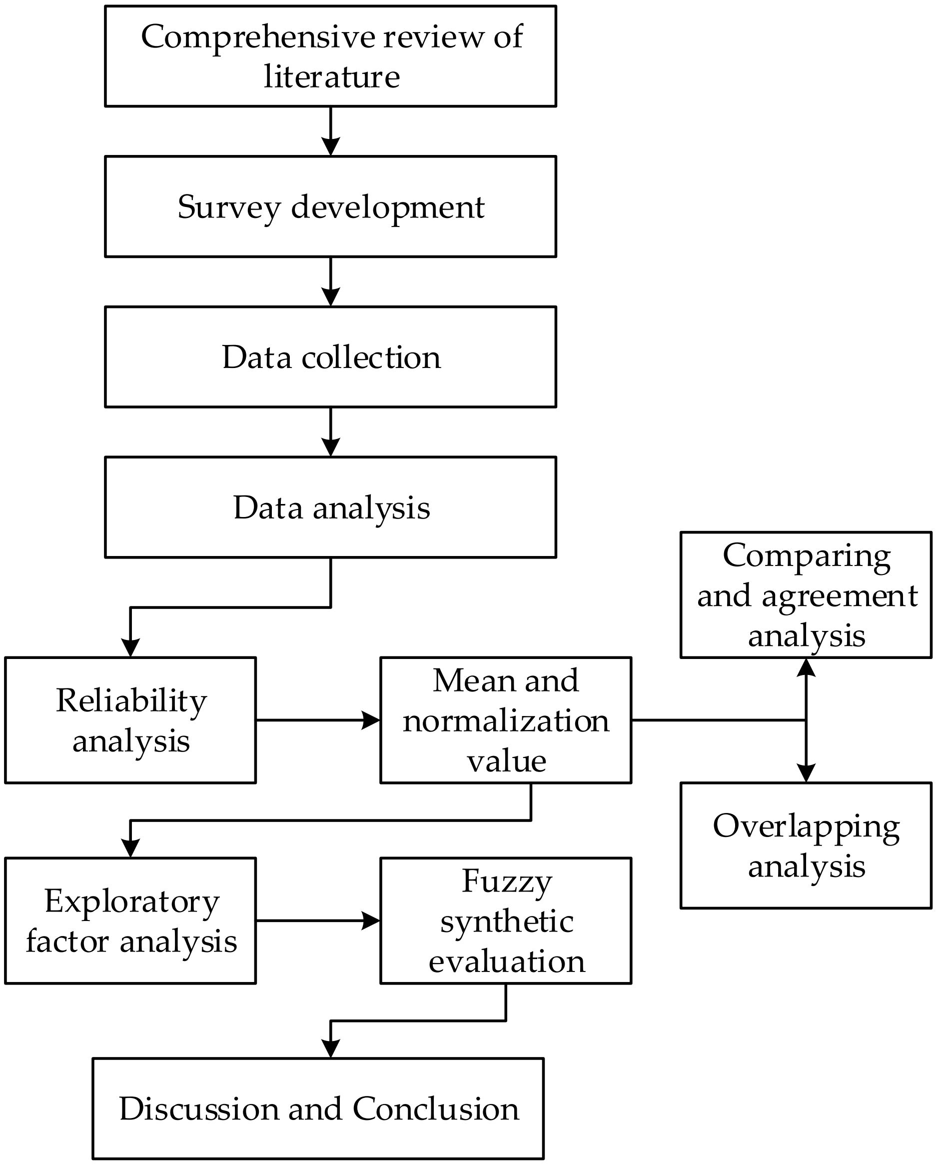

Figure 1. The adopted research workflow.

3.2. Data Collection

The targeted population to respond to the survey included different stakeholders in construction projects, including quantity surveyors, builders, engineers, architects, and contractors. In addition, general contractors, experts in management, exceptional subcontractors or contractors, heavy-duty contractors, and construction managers, staff, users, and operators were considered for the data collection process. In addition, the sample is a set of data collected from a defined population by defined systematic procedures. In obtaining data on Nigerian construction, due to the size as well as the involvement of many stakeholders in relation to the population of the country, a convenient sampling technique was adopted that is suitable to get the available information from the targeted population. Since the focus of this research is on the adoption of cloud computing practices in the effective execution of construction work in the Nigerian construction industry, the sampling technique adopted for this study was the simple random sampling technique due to the large population of samples available. The distribution of data collection instruments was undertaken by random sampling as subjects will be selected at random at the proposed locations for the data so that the population is given an equal and independent chance of being selected. Furthermore, the sample that was used for administering the questionnaire was made up of 173 individuals. Therefore, a total of 173 participants were selected to participate and fill out the survey in the study. Table 2 shows a total of 101 were returned. The sample size refers to the number of items to be chosen from the population to form the sample.

N
n ——————-
1 + N (e2)
where;
n = sample size
N = sample frame
e = level of precision (15%)
n = 173

Table 2. Sampling size.

No	Professional	Population	Sample Size
1	Architect	1700	43
2	Builder	765	42
3	Engineers	2350	44
4	Quantity Surveyors	1035	44
Total	–	5850	173

The data gathering was accomplished via a self-administration of the survey to the targeted population in the construction projects. A total of 101 valid responses were gathered and the total collected number was considered acceptable to undertake further analysis. For example, the minimum number of responses to perform EFA is 100 [32]. The distribution of the participants in the survey was based on their position, highest qualification, and total year of experience. Most respondents were quantity surveyors (39.9%), while other responses were divided among architects (24.8%), engineers (21.8%), and builders (13.8%). With regards to qualifications, a Bachelor of Science and Technology degree comprised the highest number of responses at 43.6%, while MSc/MTech comprised 37.6%, 12.9% held a PhD, and 5.9% had a higher diploma. Similarly, for total years of experience, 6 to 10 years was most common (53.5%), followed by 11 to 15 years (29.7%), while others are distributed over 0 to 5 (12.8%), 16 to 20 (2.0%), and above 21 years (2.0%), respectively. In this regard, most of the participants have adequate experience in sustainable construction, which refers to the credence of the gathered data.

4. Results and Data Analysis

The study used several statistical techniques to analyze the study data. This analysis includes a reliability test using Cronbach's alpha coefficient as the first step for checking the consistency of the dataset [33]. Mean ranking, standard deviation, and normalization value (NV) rank the barriers toward implementing CC. We compared the ranking of the barriers using NV among the survey participants followed by the Kruskal–Wallis *H* test to define whether there were significant differences in the means for each category [34]. The overlapping analysis was also performed to check the overlaps among the categories using the findings for normalized values for each category [35–37]. Exploratory factor analysis (EFA) was performed to determine the underlying relationships between the barriers [38]. The last statistical technique, a fuzzy synthetic evaluation (FSE), was conducted to evaluate the extracted findings from EFA.

4.1. Reliability Analysis

As a critical step before analyzing the collected data, the internal consistency and reliability of the data should be conducted. In this regard, a reliability test was performed using Cronbach's alpha coefficient. A Cronbach's alpha value greater than 0.70 indicates a high internal consistency [39]. The obtained value of this study was 0.857, which indicates the work has high reliability and internal consistency among the barriers in the survey.

4.2. Ranking the Barriers to Implementing Cloud Computing

Mean ranking, standard deviation, and the normalization technique were computed to rank the barriers to adopting CC in sustainable construction. The NV indicates adjusting the survey items to standardized values between zero and one. For example, the item that has the greatest mean value converts to one while the lowest mean value is converted to zero. The NV can be computed using Equation (1). The latest prior works related to construction management used this equation to rank their findings. An NV ≥ 0.60 was used to detect the crucial item [35,40]. This value also indicates the third level in a five-point Likert scale. In this regard, a total of 3 out of 11 items were considered crucial. However, all items were used for further analysis. Table 3 shows the results of the mean ranking, standard deviation, and NV.

$$NV = \frac{(\text{Mean value-Min mean value})}{(\text{Max mean value-Min mean value})} \quad (1)$$

Table 3. Results for the mean ranking and normalization technique.

Code	Barriers	Mean	Standard Deviation	Normalized Value	Rank
B10	Connectivity problems	4.119	0.532	1.000 *	1
B11	Limited internet access	4.010	0.605	0.857 *	2
B05	Lack of technical knowledge	3.822	0.763	0.610 *	3
B09	Operational cost	3.753	0.737	0.519	4
B06	Lack of financial strength	3.743	0.726	0.506	5
B04	Awareness	3.733	0.831	0.494	6
B07	Economic situation of the nation	3.663	0.761	0.403	7
B08	Human resources	3.653	0.750	0.390	8
B03	Trust	3.564	0.916	0.273	9
B02	Security	3.554	0.980	0.260	10
B01	Privacy	3.356	1.001	0.000	11

Notes: NV = (mean–mini mean value)/(maxi mean value–mini mean value); * represents NVs ≥ 0.60 is critical.

4.3. Comparing and Agreement Analysis

The study used the outputs of the normalized technique to proceed with a comparison of the barriers to implementing CC among the respondents based on their qualifications, experience, and position. The latest works in construction management used NV to rank the criticalities of a set of variables [36]. To proceed with the normalized technique, the mean values of various barriers were first calculated and then used to compute their particular NVs. In this regard, only barriers with an NV equal to or higher than 0.60 is critical [40].

Moreover, the Kruskal–Wallis H test was performed to determine whether there are significant differences in the means of the barriers among the survey participants based on their position, experience, and qualification. The Kruskal–Wallis H test is a non-parameter technique that allows us to analyze variations in the responses of various groups [34]. The study used a threshold for the Kruskal–Wallis H test within differences that exist as significant at the level of 0.05. The test produced a p-value higher than 0.05 for all barriers, thereby referring that there are no significant responses from the various participants. Table 4 shows the summary of the comparison and agreement analysis.

Table 4. Results of the summary of comparison and agreement analysis.

Qualification										
Code	**B.Sc/B.Tech**			**MSc/MTech**			**PhD**			**KW *p*-Value**
	Mean	**SD**	**NV**	**Mean**	**SD**	**NV**	**Mean**	**SD**	**NV**	
B10	4.136	0.509	1.000 *	4.026	0.544	1.000 *	4.153	0.554	1.000 *	0.595
B11	4.022	0.549	0.868 *	4.000	0.615	0.948 *	3.769	0.725	0.376	0.566
B05	3.727	0.817	0.527	3.894	0.727	0.736 *	3.923	0.640	0.626 *	0.583
B09	3.727	0.727	0.527	3.894	0.605	0.736 *	3.692	0.630	0.250	0.428
B06	3.795	0.593	0.605 *	3.684	0.774	0.316	3.923	0.640	0.626 *	0.609
B04	3.500	0.876	0.264	3.842	0.754	0.632 *	4.000	0.707	0.751 *	0.083
B07	3.659	0.713	0.448	3.736	0.685	0.420	3.769	0.599	0.376	0.846
B08	3.613	0.722	0.395	3.684	0.701	0.316	3.769	0.599	0.376	0.867
B02	3.409	1.041	0.159	3.526	0.922	0.000	4.076	0.493	0.875 *	0.089
B03	3.454	1.021	0.211	3.552	0.860	0.052	3.923	0.640	0.626 *	0.367
B01	3.272	0.973	0.000	3.552	0.921	0.052	3.538	0.967	0.000	0.413

Experience										
Code	Below 5 years			6–10 years			11–15 years			KW *p*-value
	Mean	SD	NV	Mean	SD	NV	Mean	SD	NV	
B10	4.076	0.640	1.000 *	4.148	0.491	1.000 *	4.033	0.556	1.000 *	0.144
B11	3.923	0.640	0.858 *	4.074	0.557	0.917 *	3.900	0.661	0.806 *	0.456
B05	3.692	1.031	0.643 *	3.759	0.725	0.562	3.866	0.861	0.757 *	0.140
B09	3.769	0.926	0.715 *	3.814	0.728	0.624 *	3.633	0.668	0.417	0.736
B06	3.361	0.776	0.336	3.814	0.728	0.624 *	3.700	0.702	0.515	0.607
B04	3.307	1.250	0.285	3.759	0.799	0.562	3.733	0.583	0.563	0.086
B07	3.153	0.987	0.142	3.796	0.655	0.604 *	3.347	0.764	0.000	0.204
B08	3.615	1.043	0.572	3.703	0.662	0.499	3.500	0.776	0.223	0.271
B02	3.307	1.109	0.285	3.381	1.004	0.137	3.766	0.858	0.611 *	0.650
B03	3.153	1.143	0.142	3.518	0.926	0.291	3.833	0.698	0.708 *	0.432
B01	3.000	1.224	0.000	3.259	0.994	0.000	3.633	0.850	0.417	0.289

Position													
Code	Architect			Builder			Quantity surveyor			Engineer			KW *p*-value
	Mean	SD	NV	Mean	SD	NV	Mean	SD	NV	Mean	SD	NV	
B10	4.080	0.493	1.000 *	4.142	0.662	1.000 *	4.100	0.590	1.000 *	4.181	0.394	1.000 *	0.928
B11	3.920	0.571	0.750 *	3.857	0.864	0.715 *	4.050	0.638	0.944 *	4.136	0.351	0.917 *	0.556
B05	3.960	0.675	0.813 *	3.857	0.864	0.715 *	3.775	0.831	0.639 *	3.727	0.702	0.167	0.675
B09	3.960	0.538	0.813 *	3.428	0.513	0.286	3.675	0.916	0.528	3.863	0.639	0.417	0.874
B06	3.840	0.687	0.625 *	3.785	0.578	0.643 *	3.675	0.828	0.528	3.727	0.702	0.167	0.875
B04	3.960	0.734	0.813 *	3.785	0.699	0.643 *	3.600	0.981	0.444	3.681	0.716	0.083	0.425
B07	3.880	0.600	0.688 *	3.500	0.759	0.358	3.525	0.905	0.361	3.772	0.611	0.250	0.288
B08	3.880	0.600	0.688 *	3.428	0.646	0.286	3.525	0.905	0.361	3.772	0.611	0.250	0.186
B02	3.640	0.907	0.313	3.285	1.138	0.143	3.550	1.036	0.389	3.636	0.902	0.000	0.794
B03	3.680	0.900	0.375	3.357	0.928	0.215	3.475	1.012	0.306	3.727	0.767	0.167	0.520
B01	3.440	1.003	0.000	3.142	0.949	0.000	3.200	1.090	0.000	3.681	0.838	0.083	0.252

Notes: SD is standard deviation; NV is normalized value; * refers NVs $\geq$ 0.60 is critical; KW = Kruskal–Wallis H test is significant at 0.05.

4.4. Overlapping Analysis

The overlapping analysis used the critical barriers toward adopting CC within NV equal to or greater than 0.60 from the comparison findings. This analysis is known as a decision-making tool that compares two groups or more to determine differences and similarities using mean or normalized values [36]. Therefore, this work compares the differences and similarities among respondents' positions, experiences, and qualifications.

Based on the findings of Figure 2, one barrier to adopting CC is overlapped among all survey participant groups. This barrier is 'connectivity problems (B10)'. Another barrier overlapped between respondents' groups from experience and position, while participants from qualification backgrounds between B.Sc/B.Tech and MSc/MTech only, which is 'limited internet access (B11)'. The barrier 'lack of technical knowledge (B05)' has overlapped among all the respondents in the years of experience, except 6 to 10 years, while the academic background is B.Sc/B Tech and PhD only. The barrier that did not overlap among the survey participants is 'economic situation of the nation (B07)'. The remaining barriers overlapped between the two groups in each category of survey participants.

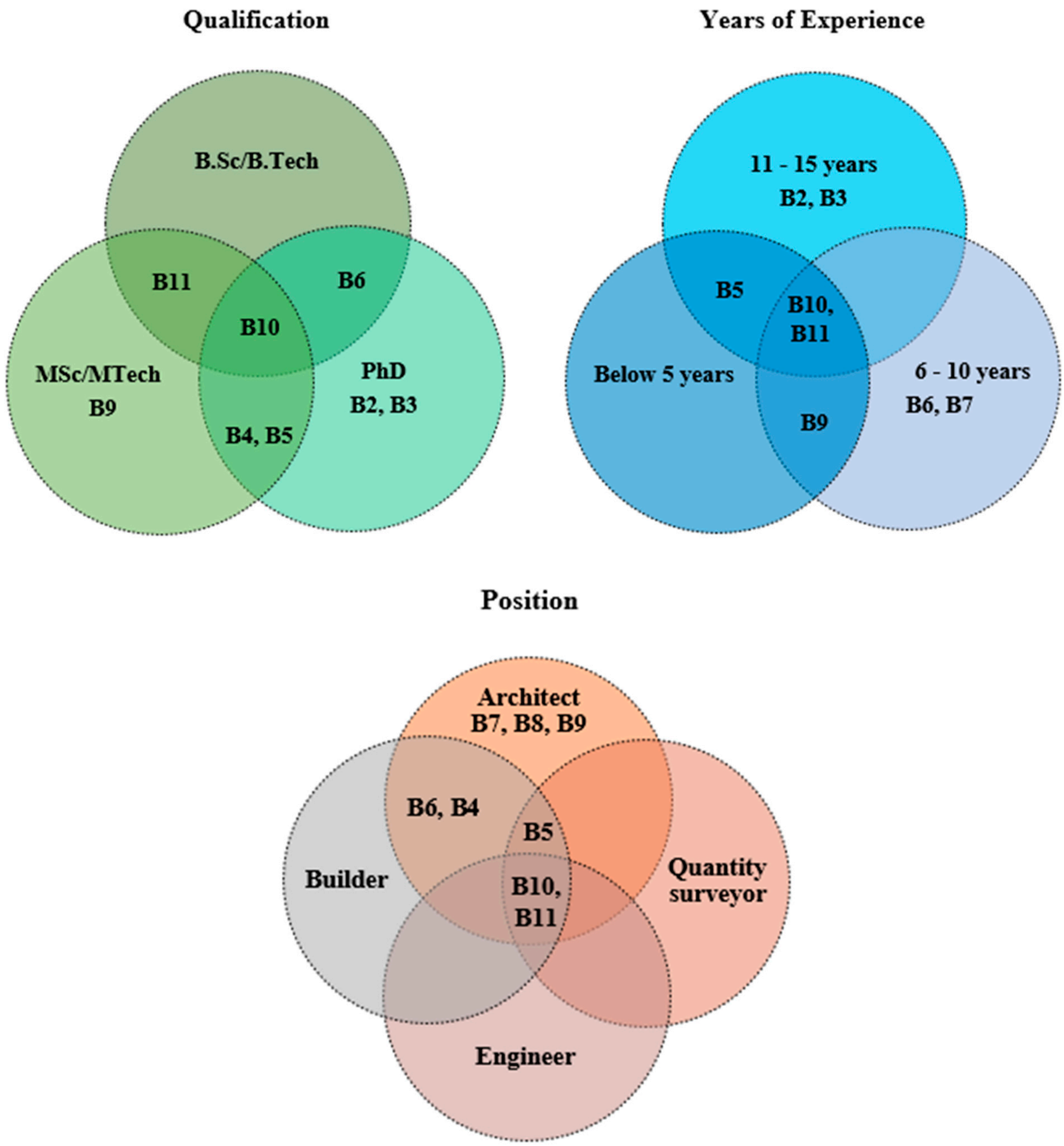

Figure 2. Findings of the overlapping analysis. Notes: B2 = security; B3 = trust; B04 = awareness; B05 = lack of technical knowledge; B06 = lack of financial strength; B09 = operational cost; B10 = connectivity problems; B11 = limited internet access.

Identifying the overlap from different perspectives in barriers to applying CC will assist practitioners in determining the most critical barriers that hinder all parties in sustainable construction, allowing practitioners to provide solutions in advance to avoid facing the barriers. For example, raising the awareness of CC in sustainable construction among practitioners in the construction industry is important [9,41]. Furthermore, remove the limitation and raise the implementation of CC by adopting the internet of things for all facilities [42]. The findings of this analysis will contribute to greater adoption of CC in sustainable construction among practitioners.

4.5. Grouping Analysis

The EFA was used to determine the underlying factors contributing to the barriers to adopting CC. EFA is a statistical reduction technique adopted to reduce data to a more manageable size while keeping as much information as feasible [43]. This statistical technique examines the underlying base of relations or correlations among several sets of items. The EFA uses all items to be included in the analysis, and 11 items were adopted. A principal component analysis (PCA) was chosen as the extraction approach to determine the underlying grouped constructs since it produces more stable loadings than other EFA factor extraction methods. In this study, PCA was selected because it is accurate with lower complexity. Therefore, for the examination of data suitability, a Kaiser–Meyer–Olkin (KMO) test was conducted. The KMO value was 0.733, representing that the data are adequate to perform factor analysis [44]. In addition, the value of Bartlett's test of sphericity examines whether the population correlation matrix is an identity matrix. The result of Bartlett's test of sphericity was 595.967, and the p-value was 0.000, which indicates that the p-value was less than 0.05, which is not an identity matrix [45]. Varimax and the Kaiser normalization rotation was used to extract underlying factors from 11 items [46]. Recently, this analysis has been used widely in the field of construction management [47–50].

According to Kline [51], items with a factor loading of $\geq$0.45 are recommended to be included due to their contribution to the interpretation of the factor. The rotation converged in four iterations and extracted three factors with eigenvalues higher than 1.00, explaining 69.53% of the total variance, which is higher than the 60% required for factor validity [52]. In addition, the commonality values for the items were greater than the recommended cut-off value of 0.400 for keeping the item. The lowest commonality value was 0.643 and the highest value was 0.879. Therefore, all items have been kept for further analysis [43]. Moreover, Figure 1 shows the findings of the screen plot test, indicating eigenvalues for each component. Furthermore, there is a line at eigenvalue 1.000 to clarify the components that are higher than the required value. The decisive point at a visible curve clearly shows the four factors provided. Four constructs were obtained and named social, economic, expertise, and connectivity. Table 4 and Figure 3 summarize the EFA findings.

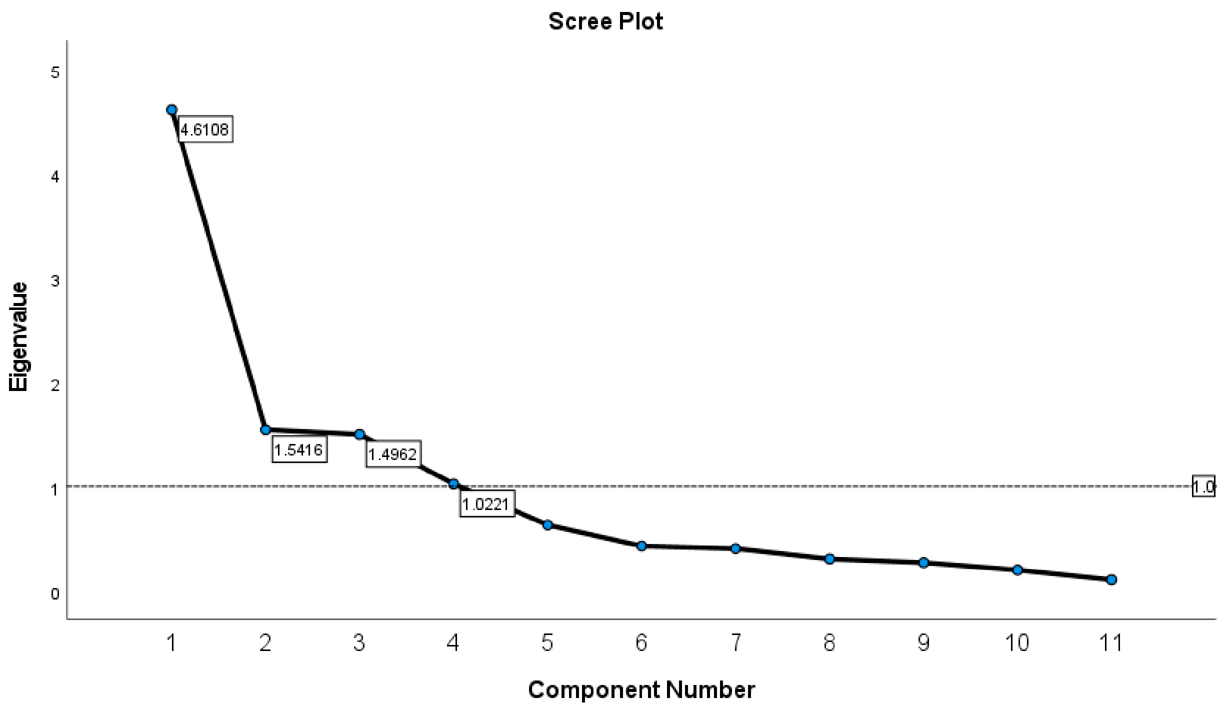

Figure 3. The findings of the screen plot test.

4.6. Evaluating the Barriers to Implementing CC

Fuzzy synthetic evaluation (FSE) is a fuzzy logic technique that aims to evaluate multi-criteria decision-making processes in multiple disciplines. Due to the importance of adopting CC in sustainable construction, the FSE was adopted to remove the unpredictability and inaccuracy of data related to decision making among the stakeholders. This technique has popularity among scholars due to its ease of application and it is also in recent works that have been used widely in construction management studies [1,13,53]. The extracted three components from EFA were used to evaluate the barriers to adopting CC, and thereby, the components serve as the base of FSE. Therefore, the evaluation of the barriers using FSE can be conducted within three steps as follows:

- Computing the weightings for the barriers and components.
- Computing membership function levels for the barriers and three components.
- Computing the overall level index for all components.

In this regard, the following sub-sections also describe the FSE steps and results.

4.6.1. Computing the Weightings of the Barriers to Implementing CC

The first step of FSE is computing the weightings of the components and the 11 barriers for adopting CC for sustainable construction. The weightings can be computed via Equation (2). The accuracy of the FSE results is dependent on the weighting of each item in the component as well as the sub-components. Equation (2) is outlined as:

$$\mathrm{Wi} = \frac{\mathrm{Mi}}{\sum_{i=1}^{5} \mathrm{Mi}} \tag{2}$$

Where W_i is the weighting; M_i is the mean value; and $\sum M_i$ is the sum of the mean value of all barriers for adopting cloud computing. Therefore, the weighting function set is as follows:

$$W_i = (W_1, W_2, W_3, \ldots\ldots\ldots\ldots\ldots, W_n)$$

As in Table 5, the social factor contains three barriers, including B01, B02, and B03. Considering that B03 has a mean value of 3.56, the weighting of B03 is computed using Equation (2) as follows:

$$W_{B03} = \frac{3.564}{3.564 + 3.554 + 3.356} = \frac{3.564}{10.475} = 0.340$$

Through the same equation process, the weightings of the following barriers were calculated and presented in Table 5. The mean values of the barriers within each component were used to obtain the total mean value for a particular component. Therefore, the total mean values for social, economic, expertise, and connectivity are 10.475, 14.812, 7.554, and 8.129, respectively. In addition, using the same approach, the weighting for each component can be computed. For example, the weighting for the social component was computed using Equation (2) as follows:

$$W_{Social} = \frac{10.475}{10.475 + 14.812 + 7.554 + 8.129} = \frac{10.475}{40.970} = 0.256 \tag{3}$$

The weighting for other components was computed by following the same equation process. Thus, the weightings for the 11 barriers and four components are presented in Table 5.

Table 5. Results for the summary of EFA.

Code	Barriers	Components			
		1 Social	2 Economic	3 Expertise	4 Connectivity
B02	Security	0.867	–	–	–
B01	Privacy	0.860	–	–	–
B03	Trust	0.835	–	–	–
B09	Cost of operational	–	0.900	–	–
B07	Economic situation of the nation	–	0.807	–	–
B08	Human resources	–	0.679	–	–
B06	Lack of financial strength	–	0.546	–	–
B04	Awareness	–	–	0.855	–
B05	Lack of technical knowledge	–	–	0.837	–
B10	Connectivity problems	–	–	–	0.893
B11	Limited internet access	–	–	–	0.873
	Eigenvalues	4.611	1.542	1.496	1.022
	% of variance	41.916	14.015	13.602	9.292
	Cumulative %	41.916	55.931	69.533	78.825
	Cronbach's alpha	0.893	0.810	0.815	0.755
Kaiser–Meyer–Olkin measure of sampling adequacy					0.733
Bartlett's test of sphericity			Approx. Chi-square		595.967
			Df		55
			Sig.		0.000

Notes: extraction method: principal component analysis; rotation method: varimax with Kaiser normalization; rotation converged in four iterations.

4.6.2. Computing the Membership Function Levels of the Barriers and Components

The membership functions (MFs) for the barriers and their components to adopting CC for sustainable construction can be obtained by using grading alternatives. The formula for computing MFs can be completed using Equation (4). The five-Likert scales were referred as A_1 = very low, A_2 = low, A_3 = average, A_4 = high, and A_5 = very high.

$$MFu_{in} = \frac{X_{1u_{in}}}{A_1} + \frac{X_{2u_{in}}}{A_2} + \frac{X_{3u_{in}}}{A_3} + \frac{X_{4u_{in}}}{A_4} + \frac{X_{5u_{in}}}{A_5} \quad (4)$$

Furthermore, u_{in} is the barrier to adopting CC, MFu_{in} is the MF of given barriers; $X_{1u_{in}}$(j = 1,2,3,4,5) is the percentage of the participants who rated j for the significance of a particular barrier, which measures the grade of MF; $\frac{X_{ju_{in}}}{A_i}$ is the connection between $X_{ju_{in}}$ and its degree alternative; and symbol '+' indicates the fuzzy set notation. Therefore, the MFs of a particular barrier toward adopting CC can be computed using Equation (4).

$$MFu_{in} = (X_{1u_{in}} + X_{2u_{in}} + X_{3u_{in}} + X_{4u_{in}} + X_{5u_{in}}) \quad (5)$$

The MF values were calculated from the collective assessment of the barriers by participants' responses from the survey using Equation (5). For example, 2% of the participants in the survey rated the barrier B03 as very low, 14% rated B03 to be low, 20% rated B03 as average, 54% rated it as high, and 10% rated B03 as very high. Thus, the MF level three for B03 is obtained using Equation (4).

$$MF_{B04} = \frac{0.02}{\text{Very low}} + \frac{0.14}{\text{Low}} + \frac{0.20}{\text{Average}} + \frac{0.54}{\text{High}} + \frac{0.10}{\text{Very high}}$$

Therefore, the MF level three for B03 can be written as: (0.02,0.14,0.20,0.54,0.10), which is also shown in Table 5. Following the equation, the MFs for the other barriers were calculated. The MFs and the weightings for the given component were addressed to arrive at MF level two for the component. The MF level three for all barriers can be found in Table 5. Therefore, the MF level three is the foundation for computing the MF level two of each component. However, the MF level two for each component needs the barriers' weightings. The weighting of each barrier within each component was used to develop the membership functions of each component by using the following equation:

$$D_i = W_i \oplus R_i = (w_1, w_2, w_3, \ldots, w_n) \oplus \begin{vmatrix} X1_{u_{i1}} & X2_{u_{i1}} & X3_{u_{i1}} & X4_{u_{i1}} & X5_{u_{i1}} \\ X1_{u_{i2}} & X2_{u_{i2}} & X3_{u_{i2}} & X4_{u_{i2}} & X5_{u_{i2}} \\ X1_{u_{i3}} & X2_{u_{i3}} & X3_{u_{i3}} & X4_{u_{i3}} & X5_{u_{i3}} \\ \ldots & \ldots & \ldots & \ldots & \ldots \\ X1_{u_{in}} & X2_{u_{in}} & X3_{u_{in}} & X4_{u_{in}} & X5_{u_{in}} \end{vmatrix} = (d_{i1}, d_{i2}, d_{i3}, \ldots, d_{in}) \quad (6)$$

where D_i indicates to the final evaluation matrix; W_i is the weighting of the barriers toward adopting CC in any given component; MFu_{in} is the membership function of each component; $\oplus$ represents the fuzzy composition operator; X_1 to X_5 are the MFs of the barriers under each component, as shown in Table 5; while d_{in} refers to the membership degree of the grade alternative. By way of illustration, the MF level two and weighting function of a social component can be drawn out in Table 6 as follows:

$$W_i = (0.340, 0.339, 0.320) \text{ and } R = \begin{vmatrix} 0.01 & 0.14 & 0.20 & 0.54 & 0.10 \\ 0.02 & 0.17 & 0.18 & 0.50 & 0.13 \\ 0.04 & 0.19 & 0.23 & 0.46 & 0.08 \end{vmatrix}$$

Table 6. Results for FSE of weightings and membership function level three.

Code	Barriers/Components	Mean	NV	OR	CR	W	MF Level 3
Component 1: Social		10.475	–	–	–	0.256	–
B03	Trust	3.564	0.273	9	1	0.340	0.02,0.14,0.20,0.54,0.10
B02	Security	3.554	0.260	10	2	0.339	0.02,0.17,0.18,0.50,0.13
B01	Privacy	3.356	0.000	11	3	0.320	0.04,0.19,0.23,0.44,0.08
Component 2: Economic		14.812	–	–	–	0.362	–
B09	Cost of operational	3.752	0.519	4	1	0.339	0.01,0.02,0.31,0.53,0.13
B06	Lack of financial strength	3.743	0.507	5	2	0.172	0.00,0.06,0.25,0.58,0.11
B07	Economic situation of the nation	3.663	0.402	7	3	0.331	0.01,0.05,0.31,0.53,0.10
B08	Human resources	3.653	0.389	8	4	0.330	0.02,0.02,0.34,0.53,0.09
Component 3: Expertise		7.554	–	–	–	0.184	–
B05	Lack of technical knowledge	3.822	0.611	3	1	0.506	0.00,0.04,0.28,0.50,0.18
B04	Awareness	3.733	0.494	6	2	0.494	0.02,0.04,0.28,0.51,0.15
Component 4: Connectivity		8.129	–	–	–	0.198	–
B10	Connectivity problems	4.119	1.000	1	1	0.507	0.00,0.00,0.09,0.70,0.21
B11	Limited internet access	4.010	0.857	2	2	0.493	0.00,0.01,0.15,0.66,0.18

Notes: NV = normalized value; OR = overall rank; CR = component rank; W = weightings; MF = membership function.

Therefore, the MF of the social component is computed as follows:

$$W_i = (0.340, 0.339, 0.320) \text{ and } R = \begin{vmatrix} 0.01 & 0.14 & 0.20 & 0.54 & 0.10 \\ 0.02 & 0.17 & 0.18 & 0.50 & 0.13 \\ 0.04 & 0.19 & 0.23 & 0.46 & 0.08 \end{vmatrix}$$

In this regard, the MF level two for the social, economic, expertise, and connectivity components is as follows:

$D_{Connectivity} = (0.03, 0.17, 0.20, 0.50, 0.10)$
$D_{Expertise} = (0.01, 0.04, 0.30, 0.54, 0.11)$
$D_{Economic} = (0.01, 0.04, 0.28, 0.50, 0.17)$
$D_{Social} = (0.00, 0.00, 0.12, 0.68, 0.20)$

Hence, using Equation (6) can generate MF level two for each component. In addition, MFs level one for all components of the barriers to implementing CC can be computed using the same approach as follows:

$D_{Overll} = (0.01, 0.07, 0.24, 0.55, 0.14)$

4.6.3. Overall Level for the Components of Barriers to Adopt CC

Using the outputs of the weightings and followed by MFs levels 3, 2, and 1. The overall level of all components of the barriers toward implementing CC for sustainable construction can be computed using Equation (7), as follows:

$$OL = \sum_{i=1}^{n} (W \times R_i) \times L \quad (7)$$

OL indicates the overall level of barriers' components and for all components to implementing CC; W represents the weighting of each component; R represents the value of MF of each component; L refers to the alternative linguistic grade (1 = very low; 2 = low, 3 = average; 4 = high; 5 = very high). In addition, the outputs of the MF level two for each component and MF level one for all components are summarized as follows:

$D_{Connectivity} = (0.03, 0.17, 0.20, 0.50, 0.10)$
$D_{Expertise} = (0.01, 0.04, 0.30, 0.54, 0.11)$
$D_{Economic} = (0.01, 0.04, 0.28, 0.50, 0.17)$
$D_{Social} = (0.00, 0.00, 0.12, 0.68, 0.20)$
$D_{Overll} = (0.01, 0.07, 0.24, 0.55, 0.14)$

Therefore, the overall level for each barrier's component and the overall level of all components was computed as follows:

$D_{Connectivity}$ = [(0.00 × 1) + (0.00 × 2) + (0.12 × 3) + (0.68 × 4) + (0.20 × 5)] = 4.080 (Very high)
$D_{Expertise}$ = [(0.01 × 1) + (0.04 × 2) + (0.28 × 3) + (0.50 × 4) + (0.17 × 5)] = 3.780 (High)
$D_{Economic}$ = [(0.01 × 1) + (0.04 × 2) + (0.30 × 3) + (0.54 × 4) + (0.11 × 5)] = 3.700 (High)
D_{Social} = [(0.03 × 1) + (0.17 × 2) + (0.20 × 3) + (0.50 × 4) + (0.10 × 5)] = 3.470 (Average)
D_{Overll} = [(0.01 × 1) + (0.07 × 2) + (0.24 × 3) + (0.55 × 4) + (0.14 × 5)] = 3.731 (High)

Using Equation (7), the level for each component of connectivity, expertise, economic, and social with their linguistic descriptions are presented in order, respectively. The overall level and description of the barriers to implementing CC for sustainable construction is also calculated.

5. Discussion

Although one of the components is very high, the impact assessment for components of the barriers to CC to application in Nigeria is high. This is due to the three remaining components being between high to average. Once the practitioners adopt the CC, the overall level will bring a way to objectively measure how much of an impact these barrier components have on their pursuit to adopt CC. In addition, to have a better understanding of the barrier components, this study will discuss each component based on their order in level ranking in the following section.

5.1. Component Rank 1: Connectivity

In terms of the total variance, this component accounted for 9.292%. Connectivity had a very high-level description with a value of 4.080. Connectivity problems and limited internet access contributed to component four. The connectivity barriers highly contributed to hindering access to CC services over the internet, which will reduce the benefits of cloud computing services in sustainable construction. Prior works in the field of construction management by [7,22] affirmed this component and confirmed that slow internet connection is a barrier to widespread CC adoption in sustainable construction in Nigeria. At the same time, construction laborers in Nigeria may have sluggish internet connections and weak cell phone signals [22]. Therefore, to overcome this barrier to wider adoption of CC, developing countries should provide a good service and extend the signal coverage of internet access. Thus, connectivity is a critical barrier to the adoption of CC.

5.2. Component Rank 2: Expertise

This component accounted for 13.602% in terms of variance. The expertise had a high-level description with a value of 3.780. The findings of this component highlighted that awareness and lack of technical knowledge are the barriers that restrain the usage of CC in sustainable construction in Nigeria. This component refers to the expertise of construction laborers which is needed to successfully adopt CC. This component was confirmed in previous work by [54], which suggested that laborers' lack of technical knowledge is still a barrier to the adoption of CC. Generally, developing countries suffer from this barrier in hindering the application of CC in sustainable construction [55]. To move forward and address this barrier, stakeholders in the construction sector must raise the awareness and knowledge of construction workers to achieve the successful and easy application of CC in sustainable construction. For example, they might provide training courses to introduce the importance and benefits of CC for all parties in the construction sector. Thus, awareness and knowledge are critical to the adoption of CC.

5.3. Component Rank 3: Economic

The economic component contributed 14.015% in terms of variance. This component ranked third in the high-level description compared with other components, with a value of 3.700. This component has minimal difference from the expertise component on the level values but the same level description. Four barriers are related to this component: 'cost of operation,' 'economic situation of the nation,' 'human resources,' and 'lack of financial strength'. Those barriers have a high impact to limit the usage of CC in Nigeria. The economic component has been encouraged by [55]. The economic barrier indicates the barriers that hinder the stakeholders from adopting CC due to the high expenses that are needed. For example, the cost of internet access and hiring experts to handle CC. To address this, practitioners are required to provide future plans to policymakers toward reducing the internet access charge. Employing novices under expert supervision that aims to train the novices and reduce reliance on experts in the future may also help. Therefore, the economic component plays a significant role in hindering the application of CC.

5.4. Component Rank 4: Social

The social component accounted for 41.916% in terms of variance. This component has an average level description impact to restrict CC in sustainable construction in Nigeria. In addition, the social component has been ranked as the lowest impact component in the application of CC with a value of 3.470. This component's barriers included 'security,' 'privacy,' and 'trust'. Table 2 shows these three barriers with the lowest impact versus the other eight barriers to the adoption of CC. Although these have a low-level impact, they must be addressed to speed up the adoption of CC among the stakeholders in sustainable construction. For example, a solution may be to develop the infrastructure that is needed to raise the social requirement (security, trust, and privacy). Therefore, social barriers have a low impact but must be addressed.

6. Conclusions

This work has assessed the current extent of CC application in sustainable construction in the Nigerian construction industry using several statistical techniques. Firstly, we performed a reliability analysis to check the data reliability and constancy, while mean ranking and NV were used to detect the critical barriers. Then, we compared the barriers among the participants based on their academic background, years of experience, and their position. We followed this by checking if there were significant differences among those categories using the Kruskal–Wallis H test. The overlapping analysis was performed to check the overlapped barriers among the survey participants. The overlapping analysis uses the critical barriers with NV ≥ 0.60. The EFA has paved the way to conduct an FSE to assess the impact of the barriers' components. The significant findings include:

- 'Connectivity problems,' 'limited internet access,' and 'lack of technical knowledge' are the most critical barriers to the application of CC.
- The most overlapped barrier among the survey participants is 'connectivity problems'. In comparison, the non-overlapped barrier is the 'economic situation of the nation'.
- The EFA extracts four components, which are: 'social', 'economic', 'expertise', and 'connectivity'.
- The FSE identified that 'connectivity' is the highest critical impacted component (very high), while the remaining 'expertise', 'economic,' and 'social' are high, high, and average, respectively.
- The FSE indicates that the overall level of barriers to adopting CC is high.

Therefore, these findings contribute to the understanding of the barriers that curb the application of CC in sustainable construction in the Nigerian industry. The possible benefits found in this work can be used to impose the mitigation measures suggested for the smooth application of CC. This work contributed to a better understanding of the current barriers to CC. The current work will introduce effective training for novices and other construction parties to manage CC. Furthermore, the findings will encourage construction stakeholders to obtain sustainable construction successfully. Lastly, the findings will assist policymakers in generating new policies that promote the application of CC in the Nigerian construction industry. Although the present work was conducted in Nigeria, it could be used as a model for other developing countries that suffer from the same issues. However, it is recommended to research other developing countries for a better understanding and successful application of CC. Future works can assess the barriers of CC in different types of sustainable construction projects.

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Appendix A

Table A1. The survey questions regarding the barriers to using CC in sustainable construction.

No	CC Barriers	Scale				
		Very Low	Low	Average	High	Very High
1	Privacy	○	○	○	○	○
2	Security	○	○	○	○	○
3	Trust	○	○	○	○	○
4	Awareness	○	○	○	○	○
5	Lack of technical knowledge	○	○	○	○	○
6	Lack of financial strength	○	○	○	○	○
7	Economic situation of the nation	○	○	○	○	○
8	Human resources	○	○	○	○	○
9	Cost of operation	○	○	○	○	○
10	Connectivity problem	○	○	○	○	○
11	Limited internet access	○	○	○	○	○

References

1. Beach, T.H.; Rana, O.F.; Rezgui, Y.Y.; Parashar, M. Cloud Computing for the Architecture, Engineering & Construction Sector: Requirements, Prototype & Experience. *J. Cloud Comput.* **2013**, *2*, 1–16. [CrossRef]
2. Bello, S.A.; Oyedele, L.O.; Akinade, O.O.; Bilal, M.; Delgado, J.M.D.; Akanbi, L.A.; Ajayi, A.O.; Owolabi, H.A. Cloud Computing in Construction Industry: Use Cases, Benefits and Challenges. *Autom. Constr.* **2021**, *122*, 103441. [CrossRef]
3. Kineber, A.F.; Oke, A.E.; Alyanbaawi, A.; Abubakar, A.S.; Hamed, M.M. Exploring the Cloud Computing Implementation Drivers for Sustainable Construction Projects—A Structural Equation Modeling Approach. *Sustainability* **2022**, *14*, 14789. [CrossRef]
4. Aghimien, D.; Aigbavboa, C.O.; Chan, D.W.M.; Aghimien, E.I. Determinants of Cloud Computing Deployment in South African Construction Organisations Using Structural Equation Modelling and Machine Learning Technique. *Eng. Constr. Archit. Manag.* **2022**, *12*. [CrossRef]
5. Zainon, N.; Rahim, F.A.; Salleh, H. The Information Technology Application Change Trend: Its Implications for the Construction Industry. *J. Surv. Constr. Prop.* **2011**, *2*, 30. [CrossRef]
6. Chong, H.-Y.; Wong, J.S.; Wang, X. An Explanatory Case Study on Cloud Computing Applications in the Built Environment. *Autom. Constr.* **2014**, *44*, 152–162. [CrossRef]
7. Dahiru, A.A.; Abubakar, H. Cloud Computing Adoption: A Cross-Continent Overview of Challenges. *Niger. J. Basic Appl. Sci.* **2018**, *25*, 23–31. [CrossRef]
8. Oke, A.E.; Kineber, A.F.; Al-Bukhari, I.; Famakin, I.; Kingsley, C. Exploring the Benefits of Cloud Computing for Sustainable Construction in Nigeria. *J. Eng. Des. Technol.* **2021**, *41*. [CrossRef]
9. Oke, A.E.; Kineber, A.F.; Albukhari, I.; Othman, I.; Kingsley, C. Assessment of Cloud Computing Success Factors for Sustainable Construction Industry: The Case of Nigeria. *Buildings* **2021**, *11*, 36. [CrossRef]
10. Kim, W. Cloud Computing: Today and Tomorrow. *J. Object Technol.* **2009**, *8*, 65–72. [CrossRef]
11. Priyadarshinee, P.; Jha, M.K.; Raut, R.D.; Kharat, M.G.; Kamble, S.S. To Identify the Critical Success Factors for Cloud Computing Adoption by MCDM Technique. *Int. J. Bus. Inf. Syst.* **2017**, *24*, 469–510. [CrossRef]
12. Oliveira, T.; Thomas, M.; Espadanal, M. Assessing the Determinants of Cloud Computing Adoption: An Analysis of the Manufacturing and Services Sectors. *Inf. Manag.* **2014**, *51*, 497–510. [CrossRef]
13. Zamani, S.H.; Rahman, R.A.; Fauzi, M.A.; Yusof, L.M. Government Pandemic Response Strategies for AEC Enterprises: Lessons from COVID-19. *J. Eng. Des. Technol.* **2022**, *25*, 12. [CrossRef]
14. Oni, O.Z.; Olanrewaju, A.; Khor, S.C. Fuzzy Synthetic Evaluation of the Factors Affecting Health and Safety Practices in Malaysia Construction Industry. *J. Eng. Des. Technol.* **2023**, *42*, 14. [CrossRef]
15. Othman, I.; Kineber, A.F.; Oke, A.E.; Khalil, N.; Buniya, M.K. Drivers of Value Management Implementation in Building Projects in Developing Countries. *J. Phys. Conf. Ser.* **2020**, *1529*, 42083. [CrossRef]
16. Phaphoom, N.; Wang, X.; Samuel, S.; Helmer, S.; Abrahamsson, P. A Survey Study on Major Technical Barriers Affecting the Decision to Adopt Cloud Services. *J. Syst. Softw.* **2015**, *103*, 167–181. [CrossRef]
17. Phaphoom, N.; Oza, N.; Wang, X.; Abrahamsson, P. Does Cloud Computing Deliver the Promised Benefits for IT Industry? In Proceedings of the WICSA/ECSA 2012 Companion Volume, Helsinki, Finland, 20–24 August 2012; pp. 45–52.

18. Curbera, F. Integrating the Business Cloud. In Proceedings of the 2013 17th IEEE International Enterprise Distributed Object Computing Conference, Vancouver, BC, Canada, 9–13 September 2013; p. 103.
19. Breiter, G.; Naik, V.K. A Framework for Controlling and Managing Hybrid Cloud Service Integration. In Proceedings of the 2013 IEEE International Conference on Cloud Engineering, San Francisco, CA, USA, 25–27 March 2013; pp. 217–224.
20. Trivedi, H. Cloud Computing Adoption Model for Governments and Large Enterprises. Ph.D. Thesis, Massachusetts Institute of Technology, Cambridge, MA, USA, 2013.
21. Conboy, K.; Morgan, L. Assimilation of the Cloud: Challenges to Acceptance, Routinisation and Infusion of Cloud Computing. In Proceedings of the Information Systems (ICIS), 2012 33rd International Conference on Association for Information Systems, Orlando, FL, USA, 16–19 December 2012.
22. Adedeji, A.; Rapheal, O.; Olabosipo, F.; Timothy, M. The Economics of Cloud-Based Computing Technologies in Construction Project Delivery. *Int. J. Civ. Eng. Technol.* **2017**, *8*, 233–242.
23. Kunz, A. Everybody Here Is Like a Therapist: A Qualitative Case Study of School Based Mental Health Integration Within a Multi-Tiered System of Support in One Urban Alternative High School. Master's Thesis, Bethel University, St Paul, MN, USA, 2022.
24. Shimba, F. Cloud Computing: Strategies for Cloud Computing Adoption. Master's Thesis, Technological University Dublin, Dublin, Ireland, 2010.
25. Otuka, R.; Preston, D.; Pimenidis, E. The Use and Challenges of Cloud Computing Services in SMEs in Nigeria. *Proc. Eur. Conf. Inf. Manag. Eval.* **2014**, *43*, 47–55.
26. Shuja, J.; Bilal, K.; Madani, S.A.; Othman, M.; Ranjan, R.; Balaji, P.; Khan, S.U. Survey of Techniques and Architectures for Designing Energy-Efficient Data Centers. *IEEE Syst. J.* **2014**, *10*, 507–519. [CrossRef]
27. Dahiru, A.A.; Bass, J.M.; Allison, I.K. Cloud Computing Adoption in Sub-Saharan Africa: An Analysis Using Institutions and Capabilities. In Proceedings of the International Conference on Information Society (i-Society 2014), London, UK, 10–12 November 2014; pp. 98–103.
28. Ahuja, V.; Yang, J.; Shankar, R. Study of ICT Adoption for Building Project Management in the Indian Construction Industry. *Autom. Constr.* **2009**, *18*, 415–423. [CrossRef]
29. Tehrani, S.R.; Shirazi, F. Factors Influencing the Adoption of Cloud Computing by Small and Medium Size Enterprises (SMEs). In Proceedings of the International Conference on Human Interface and the Management of Information, Heraklion, Greece, 22–27 June 2014; 2014; pp. 631–642.
30. Tabish, S.Z.S.; Jha, K.N. Success Traits for a Construction Project. *J. Constr. Eng. Manag.* **2012**, *138*, 1131–1138. [CrossRef]
31. Ali, M.; Miraz, M.H. Cloud Computing Applications. In Proceedings of the International Conference on Cloud Computing and eGovernance, Dubai, United Arab Emirates, 19–21 June 2013; Volume 1.
32. Mundfrom, D.J.; Shaw, D.G.; Ke, T.L. Minimum Sample Size Recommendations for Conducting Factor Analyses. *Int. J. Test.* **2005**, *5*, 159–168. [CrossRef]
33. Tavakol, M.; Dennick, R. Making Sense of Cronbach's Alpha. *Int. J. Med. Educ.* **2011**, *2*, 53. [CrossRef] [PubMed]
34. Kruskal, W.H.; Wallis, W.A. Use of Ranks in One-Criterion Variance Analysis. *J. Am. Stat. Assoc.* **1952**, *47*, 583–621. [CrossRef]
35. Omer, M.M.; Rahman, R.A.; Almutairi, S. Construction Waste Recycling: Enhancement Strategies and Organization Size. *Phys. Chem. Earth* **2022**, *126*, 103114. [CrossRef]
36. Al-Mohammad, M.S.; Haron, A.T.; Esa, M.; Aloko, M.N.; Alhammadi, Y.; Anandh, K.S.; Rahman, R.A. Factors Affecting BIM Implementation: Evidence from Countries with Different Income Levels. *Constr. Innov.* **2022**. [CrossRef]
37. Farouk, A.M.; Rahman, R.A.; Romali, N.S. Economic Analysis of Rehabilitation Approaches for Water Distribution Networks: Comparative Study between Egypt and Malaysia. *J. Eng. Des. Technol.* **2021**, *21*, 130–149. [CrossRef]
38. Thompson, B. Exploratory and Confirmatory Factor Analysis: Understanding Concepts and Applications. *Appl. Psychol. Meas.* **2007**, *31*, 245–248.
39. DeVellis, R.F. *Scale Development: Theory and Applications*; Sage Publications: Thousand Oaks, CA, USA, 2016; Volume 26, ISBN 1506341551.
40. Omer, M.M.; Rahman, R.A.; Almutairi, S. Strategies for Enhancing Construction Waste Recycling: A Usability Analysis. *Sustainability* **2022**, *14*, 5907. [CrossRef]
41. Mohsen Alawag, A.; Salah Alaloul, W.; Liew, M.S.; Ali Musarat, M.; Baarimah, A.O.; Saad, S.; Ammad, S. Critical Success Factors Influencing Total Quality Management in Industrialised Building System: A Case of Malaysian Construction Industry. *Ain Shams Eng. J.* **2022**, *9*, 101877. [CrossRef]
42. Jiang, D. The Construction of Smart City Information System Based on the Internet of Things and Cloud Computing. *Comput. Commun.* **2020**, *150*, 158–166. [CrossRef]
43. Field, A. *Discovering Statistics Using IBM SPSS Statistics*; Sage: Thousand Oaks, CA, USA, 2013.
44. Kaiser, H.F. An Index of Factorial Simplicity. *Psychometrika* **1974**, *39*, 31–36. [CrossRef]
45. Pallant, J. *SPSS Survival Manual: A Step by Step Guide to Data Analysis Using*; Routledge: Abingdon, UK, 2020; ISBN 1000256235.
46. Kaiser, H.F. An Analytic Rotational Criterion for Factor Analysis. *Amer. Psychol.* **1955**, *10*, 438.
47. Al-Aidrous, A.M.H.; Shafiq, N.; Rahmawati, Y.; Mohammed, B.S.; Al-Ashmori, Y.Y.; Baarimah, A.O.; Alawag, A.M. Major Blocking Factors Affecting the Application of Industrialized Building System. *Ain Shams Eng. J.* **2023**, 102151. [CrossRef]
48. Moyo, T.; Chigara, B. Barriers to Lean Construction Implementation in Zimbabwe. *J. Eng. Des. Technol.* **2021**, *14*, 36. [CrossRef]

49. Aliu, J.; Aghimien, D.; Aigbavboa, C.; Ebekozien, A.; Oke, A.E.; Adekunle, S.A.; Akinradewo, O.; Akinshipe, O. Developing Emotionally Competent Engineers for the Ever-Changing Built Environment. *Eng. Constr. Archit. Manag.* **2022**, *14*, 36.
50. Akinradewo, O.; Aigbavboa, C.; Oke, A.; Edwards, D.; Kasongo, N. Key Requirements for Effective Implementation of Building Information Modelling for Maintenance Management. *Int. J. Constr. Manag.* **2021**, *15*, 1–9. [CrossRef]
51. Kline, P. *An Easy Guide to Factor Analysis*; Routledge: Abingdon, UK, 2014; ISBN 1315788136.
52. Malhotra, N.; Hall, J.; Shaw, M.; Oppenheim, P. *Marketing Research: An Applied Orientation*; Pearson Education Australia: Sydney, Australia, 2006; ISBN 0733970044.
53. Wuni, I.Y.; Shen, G.Q.; Osei-Kyei, R. Quantitative Evaluation and Ranking of the Critical Success Factors for Modular Integrated Construction Projects. *Int. J. Constr. Manag.* **2020**, *22*, 1–13. [CrossRef]
54. Morais, D.; Pinto, F.G.; Pires, I.M.; Garcia, N.M.; Gouveia, A.J. The Influence of Cloud Computing on the Healthcare Industry: A Review of Applications, Opportunities, and Challenges for the CIO. *Procedia Comput. Sci.* **2022**, *203*, 714–720. [CrossRef]
55. Oke, A.E.; Farouk Kineber, A.; Abdel-Tawab, M.; Abubakar, A.S.; Albukhari, I.; Kingsley, C. Barriers to the Implementation of Cloud Computing for Sustainable Construction in a Developing Economy. *Int. J. Build. Pathol. Adapt.* **2021**, *14*, 28. [CrossRef]